Meeting Program

SVP 2019

ANNUAL MEETING

October 9 – 12, 2019

Brisbane Convention & Exhibition Centre

Brisbane, Queensland

AUSTRALIA

Society of Vertebrate Paleontology

79th Annual Meeting

9–12 October, 2019

BRISBANE, AUSTRALIA

SVP

SOCIETY OF VERTEBRATE PALEONTOLOGY

IT'S LIVE! in Queensland

brisbane

australia's new world city

http://vertpaleo.org/annual-meeting/annual-meeting-home.aspx

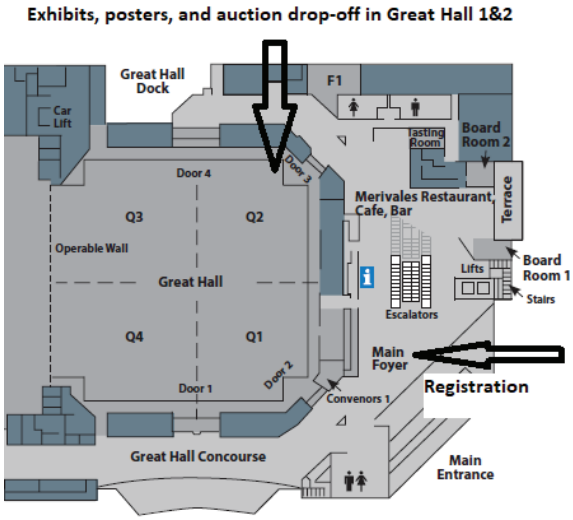
SOCIETY OF VERTEBRATE PALEONTOLOGY
OCTOBER 2019
ASBTRACTS OF PAPERS
79TH ANNUAL MEETING

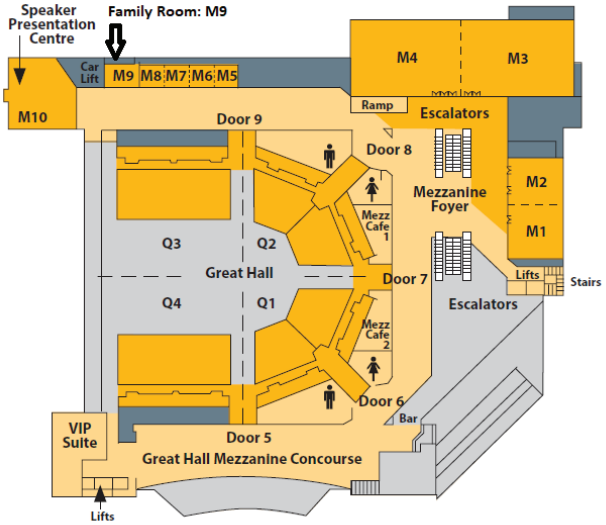
Brisbane Convention and Exhibition Centre
Brisbane, Queensland
Australia

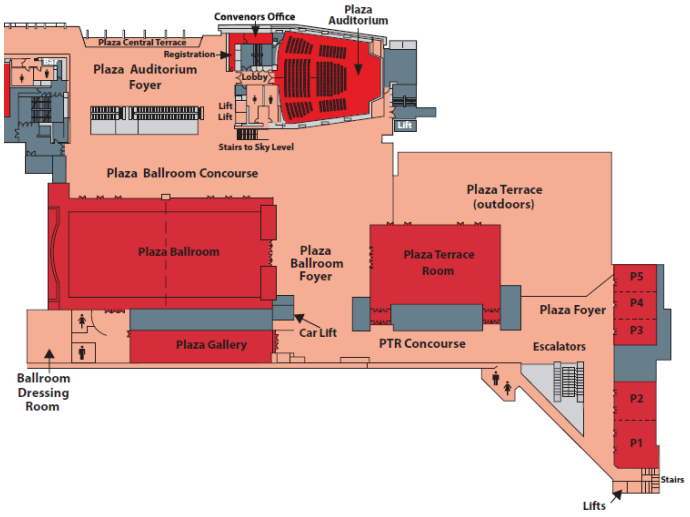
October 9-12, 2019

Brisbane Convention and Exhibition Centre Map

Foyer, Mezzanine, and Plaza Levels







WELCOME TO BRISBANE

G'day!

The Host Committee of the 79th Annual Meeting is delighted to welcome all participants to the Society of Vertebrate Paleontology's 2019 meeting in Brisbane, Queensland, Australia. The meeting will take place at the Brisbane Convention and Exhibition Centre, ideally located in the unique riverside cultural and lifestyle precinct of South Brisbane.

The 79th meeting will be only the third SVP to be hosted outside of North America, and the first one in the Southern Hemisphere. The meeting is co-hosted by The University of Queensland and the Queensland Museum. Although vertebrate fossils were first recognised in Australia by Europeans in the 1830s, global interest in the continent's vertebrate fossil record was invigorated in the 1950s and 1960s following the fieldwork and research of American paleo-mammalogist, Dr. Ruben Stirton, and his team of students including Richard Tedford and Michael Woodburne. Interest in Australian vertebrate paleontology grew considerably after that time, culminating in the inaugural Conference on Australasian Vertebrate Evolution, Paleontology, and Systematics, an informal, voluntarily organised biennial meeting first held in Brisbane in 1987. The 79th SVP meeting represents a coming-of-age for Australian vertebrate paleontology.

Brisbane's location as the capital of Queensland's premier tourist region presents the ideal opportunity for delegates to enjoy a microcosm of Australia's iconic experiences. World Heritage-listed rainforests, amazing beaches, islands, wineries, and the internationally famous Australia Zoo – home of the 'Crocodile Hunter' – are all easily accessible within an hour of the city. It is even possible to do day trips to the Great Barrier Reef from Brisbane. The Queensland Museum's geoscience collection, based in the Brisbane suburb of Hendra, is the largest paleontological collection in Australia and one of the largest in the Southern Hemisphere.

2019 represents the first SVP Annual Meeting held on a Gondwanan continent and provides a gateway to the major regions of global paleontological significance including other cities and regional locations around Australia, New Zealand, Antarctica, and Southeast Asia. Queensland in particular is home to:

- The Riversleigh World Heritage Area, considered by Sir David Attenborough as one of the four most important fossil sites on Earth;
- A new and diverse suite of Cretaceous-aged dinosaur sites critical in the understanding of Gondwanan biogeography;
- The earliest known Carboniferous tetrapods in Gondwana;
- The youngest uncontested Australian Pleistocene megafauna site, Neds Gully, just a stone's throw from Brisbane;
- The earliest known crown-group marsupials along with some of the oldest evidence for echo-locating bats, song birds, and extant genera of frogs; and
- The Chinchilla Fauna, Australia's most extensive Pliocene vertebrate fossil locality and one that contains the forebearers to most modern Australian marsupials.

We invite everyone to attend the Welcome Reception at the Queensland Museum where we will highlight Queensland's rich heritage in vertebrate paleontology. We hope that you will enjoy all that Brisbane, Queensland, and Australia more broadly has to offer during the 79th Annual Meeting of the Society of Vertebrate Paleontology!

Gilbert Price, SVP 79th Annual Meeting Host Committee Co-Chair
Scott Hocknull, SVP 79th Annual Meeting Host Committee Co-Chair

PRESENTATION POLICIES

SVP Abstracts are reviewed by the Program Committee and members of the Education & Outreach, Preparators', and Romer Prize Committees, as appropriate. Authors are responsible for the technical content of their articles.

Unless specified otherwise, coverage of abstracts presented orally at the Annual Meeting is strictly prohibited until the start time of the presentation, and coverage of poster presentations is prohibited until the relevant poster session opens for viewing. As defined here, "coverage" includes all types of electronic and print media; this includes blogging, tweeting, advanced online publication, and other intent to communicate or disseminate results or discussion presented at the SVP Annual Meeting.

Still photography, video and/or audio taping, or any other electronic recording at the SVP Annual Meeting is strictly prohibited, with the exception of the designated SVP press event. The SVP reserves the right to engage professional photographers or audio/videotape professionals to archive sections of the Meeting for the Society's use.

Editorial policies for unpublished work: If you are planning to submit, or have submitted, your work to a journal that has embargo policies, be sure you are familiar with any restrictions they may impose on disseminating it before publication.

Please address any questions about program practices to the Program Committee or to the Executive Committee.

Citing an Abstract in the 2019 SVP Program and Abstracts Book
This Program and Abstracts Book is an official supplement to the online version of the *Journal of Vertebrate Paleontology*. The citation format for an abstract printed in this book is: *Journal of Vertebrate Paleontology*, *Program and Abstracts*, 2019, <insert page number here>.

SVP CODE OF CONDUCT

The Code of Conduct has been updated for 2019. Please familiarize yourself with this updated version. The Society of Vertebrate Paleontology (SVP) is dedicated to providing a courteous, professional, harassment-free conference experience for everyone, regardless of gender, gender identity and expression, sexual orientation, disability, physical appearance, race, or age. Demeaning, abusive, harassing, or threatening behavior towards other attendees, staff or the public is not permitted in either personal or electronic interactions. Personal and electronic interactions should be professional, rational, and mutually respectful at all conference events, both formal and informal. Intellectual property should be respected by not disseminating photographs, recordings, or other reproductions of presentations or artwork without permission of the author. The full policy is available at http://vertpaleo.org/Annual-Meeting/Code-of-Conduct.aspx.

SOCIAL MEDIA GUIDELINES

Please Read Before You Tweet (or Blog, or Facebook, or Instagram…)

The Society of Vertebrate Paleontology encourages open discussion on social media and other outlets at our annual meeting. In order to find a balance between embracing social media and protecting authors' work, we set forth the following guidelines:

- SVP has an embargo in place on discussing presentations until the beginning of the talk or poster session. Please do not discuss presentations until this time if you do not have the authors' permission to do so.
- This embargo exists to protect the authors. As an author, you have permission to break your own embargo or permit someone else to do the same. This includes discussing your own presentation online, posting slides or posters, etc. However, to protect yourself, make sure you are aware of any potential future publisher's policies about early dissemination of work.
- Do not photograph or videotape a talk or poster without the authors' express permission. Never post any images or video without the authors' permission.
- While the default assumption is to allow open discussion of SVP presentations on social media, please respect any request by an author to not disseminate the contents of their talk. The following icon may be downloaded from the SVP website for inclusion on slides or posters to clearly express when an author does not want their results posted:

We want to thank everyone for following these basic guidelines for online posts of all kinds. As a reminder, the official hashtag of the meeting is #2019SVP. We look forward to seeing your thoughts and discussion online!

PHOTOGRAPHY AND RECORDING

Still photography, video and/or audio taping, or any other electronic recording at the SVP Annual Meeting is strictly prohibited, with the exception of the designated SVP press event. The SVP reserves the right to engage professional photographers or audio/videotape professionals to archive sections of the Meeting for the Society's use.

Please check the SVP APP for the latest schedule

2019 SVP Schedule of Events

All events are held at the Brisbane Convention and Exhibition Centre unless otherwise noted with an **

Tuesday, October 8

7:00pm–9:00pm	**Special Lecture by Professor Michael Archer** Life, Sex, Songs, Scrat and the Sponge: Australia's Guinness Book of Evolutionary Records	**UGHD Auditorium, Advanced Engineering Building, The University of Queensland

Wednesday, October 9

8:00am–12:15pm	**Technical Session I: Marine Tetrapods**	M1&2
	Technical Session II: Dinosaurs I	M3
	Symposium: From Molecules to Macroevolution: Paleobiological Applications of Vertebrate Soft Tissue Preservation	M4
9:30am–6:15 pm	**Exhibit and Poster Viewing Hours** **Colbert Prize Competition Posters** (B1–B29) **Colbert Prize posters will be on display Wednesday through Saturday* **Education and Outreach Poster Session** (B30–B51) **Education and Outreach posters will be on display Wednesday through Saturday* **Posters associated with Preparators' Session** (B52–B63) *****Preparators' posters will be on display Wednesday through Saturday* **Regular Session Posters** (B64-B126)	Great Hall 1&2
12:15pm-1:45pm	**Diversity in Paleontology**	P1
1:45pm–4:15pm	**Technical Session III: Mammals I**	M1&2
	Technical Session IV: Evolution of the Dentition	M3
	Technical Session V: Cenozoic Birds	M4
4:15pm–6:15pm	**Exhibit/Poster Mixer** **Poster Session I Regular Session Posters, (**B64-B126) **Poster Session I authors will be present at their posters* **Education and Outreach Poster Session** (B30-B51) **Authors with odd board numbers will be present at their posters*	Great Hall 1&2
7:30pm—10:30pm	**Welcome Reception**	**Queensland Museum

Thursday, October 10

8:00am–12:15pm	**Technical Session VI: Mammals II**	M1&2
	Technical Session VII: Archosaurs	M3
	Romer Prize Session	M4
9:30am–6:15pm	**Exhibit and Poster Viewing Hours** **Colbert Prize Competition Posters** (B1–B29) **Colbert Prize posters will be on display Wednesday through Saturday* **Education and Outreach Poster Session** (B30–B51) **Education and Outreach posters will be on display Wednesday through Saturday* **Posters associated with Preparators' Session** (B52–B63) ******Preparators' posters will be on display Wednesday through Saturday* **Regular Session Posters** (B64-B126)	Great Hall 1&2
12:30pm–1:30pm	**SVP Business Meeting and Open Forum** An opportunity to bring your questions to SVP leadership!	M4
1:45pm–4:15pm	**Technical Session VIII: Mammal Cranial Evolution**	M3
	Preparators' Session	M1&2
	Technical Session IX: Squamates and Herpetofaunas	M4
4:15pm–6:15pm	**Exhibit/Poster Mixer** **Colbert Prize Competition Posters** (B1–B29) **Authors will be present at their posters* **Posters associated with Preparators' Session** (B52–B63) **Authors will be present at their posters* **Poster Session II Regular Session Posters, (**B64–B125) **Poster Session II authors will be present at their posters*	Great Hall 1&2
7:30pm–11:30pm	**Student and Postdoc Roundtable and Reprint Exchange**	M3

Friday, October 11

8:00am–12:15pm	**Technical Session X: Fish**	M1&2
	Technical Session XI: Mammalian Paleoecology and Macroevolution	M3
	Technical Session XII: Dinosaurs II	M4
9:30am–6:15pm	**Exhibit and Poster Viewing Hours** **Colbert Prize Competition Posters** (B1–B29) **Colbert Prize posters will be on display Wednesday through Saturday* **Education and Outreach Poster Session** (B30–B51) **Education and Outreach posters will be on display Wednesday through Saturday* **Posters associated with Preparators' Session** (B52–B63) *****Preparators' posters will be on display Wednesday through Saturday* **Regular Session Posters** (B64-B126)	Great Hall 1&2
1:45pm–4:15pm	**Technical Session XIII: Early Reptiles**	M1&2
	Symposium: Quaternary Extinctions in the Asia-Pacific: Causes and Consequences	M3
	Technical Session XIV: Bird Origin and Evolution	M4
4:15pm–6:15pm	**Exhibit/Poster Mixer** **Poster Session III Regular Session Posters, (**B64-125) **Poster Session III authors will be present at their posters* **Education and Outreach Poster Session** (B30–B51) *****Authors with even board numbers will be present at their posters*	Great Hall 1&2
6:30pm–11:30pm	**Annual Benefit Auction and Social**	Great Hall 3

Saturday, October 12

8:00am–12:15pm	**Technical Session XV: Fins to Limbs**	M1&2
	Symposium: Origin of a Sunburnt Country: Development of the Modern Australian Vertebrate Fauna from the Late Miocene Onwards	M3
	Technical Session XVI: Dinosaurs III	M4
9:30am–6:15pm	**Exhibit and Poster Viewing Hours** **Colbert Prize Competition Posters** (B1–B29) **Colbert Prize posters will be on display Wednesday through Saturday* **Education and Outreach Poster Session** (B30–B51) **Education and Outreach posters will be on display Wednesday through Saturday* **Posters associated with Preparators' Session** (B52–B63) ******Preparators' posters will be on display Wednesday through Saturday* **Regular Session Posters** *(*B64-B126)	Great Hall 1&2
1:45pm–4:15pm	**Technical Session XVII: Mesozoic and Early Paleogene Mammals**	M1&2
	Technical Session XVIII: Evolutionary and Faunal Studies	M3
	Technical Session XIX: Terrestrial and Locomotor Biomechanics	M4
4:15pm–6:15pm	**Exhibit/Poster Mixer** **Poster Session IV Regular Session Posters,** (B64-124) **Poster Session IV authors will be present at their posters*	Great Hall 1&2
7:30pm–10:00pm	**Awards Banquet** **Ticket required for admittance*	Plaza Ballroom
10:30pm–12:00am	**After Hours Party**	Plaza Ballroom

2019 SVP Workshops

**For Pre-registered Attendees*

TUE, October 8 1:00pm–5:00pm	**Women in Paleontology: A Discussion on Promoting Gender Equality**	Brisbane Convention and Exhibition Centre
TUE, October 8 9:00am-12:00pm	**SVP 3D Workshop**	The Edge @ State Library of Queensland
TUE, October 8 10:00am-4:00pm	**Best Practices in Paleontology: Fossil Laws, Global Persectives, and 50 Years of UNESCO 1970**	Brisbane Convention and Exhibition Centre
TUE, October 8 9:00pm–4:30pm	**Neotoma Paleoecology Database: Facilitating Transparent Data Curation in Vertebrate Paleontology**	Brisbane Convention and Exhibition Centre
TUE, October 8 9:00am–4:00pm	**Australasian Paleontology on the World Stage: CAVEPS 2019**	Brisbane Convention and Exhibition Centre
TUE, October 8 9:00am–4:30pm	**Fossil Preparation, Conservation, Replication and Storage Techniques**	Queensland Museum, Hendra Campus
TUE, October 8 9:00am–5:00pm	**Developing Accessible and Inclusive Research-Focused Paleontology Education Plans for K-12 Classrooms**	Brisbane Convention and Exhibition Centre

2019 SVP Field Trips

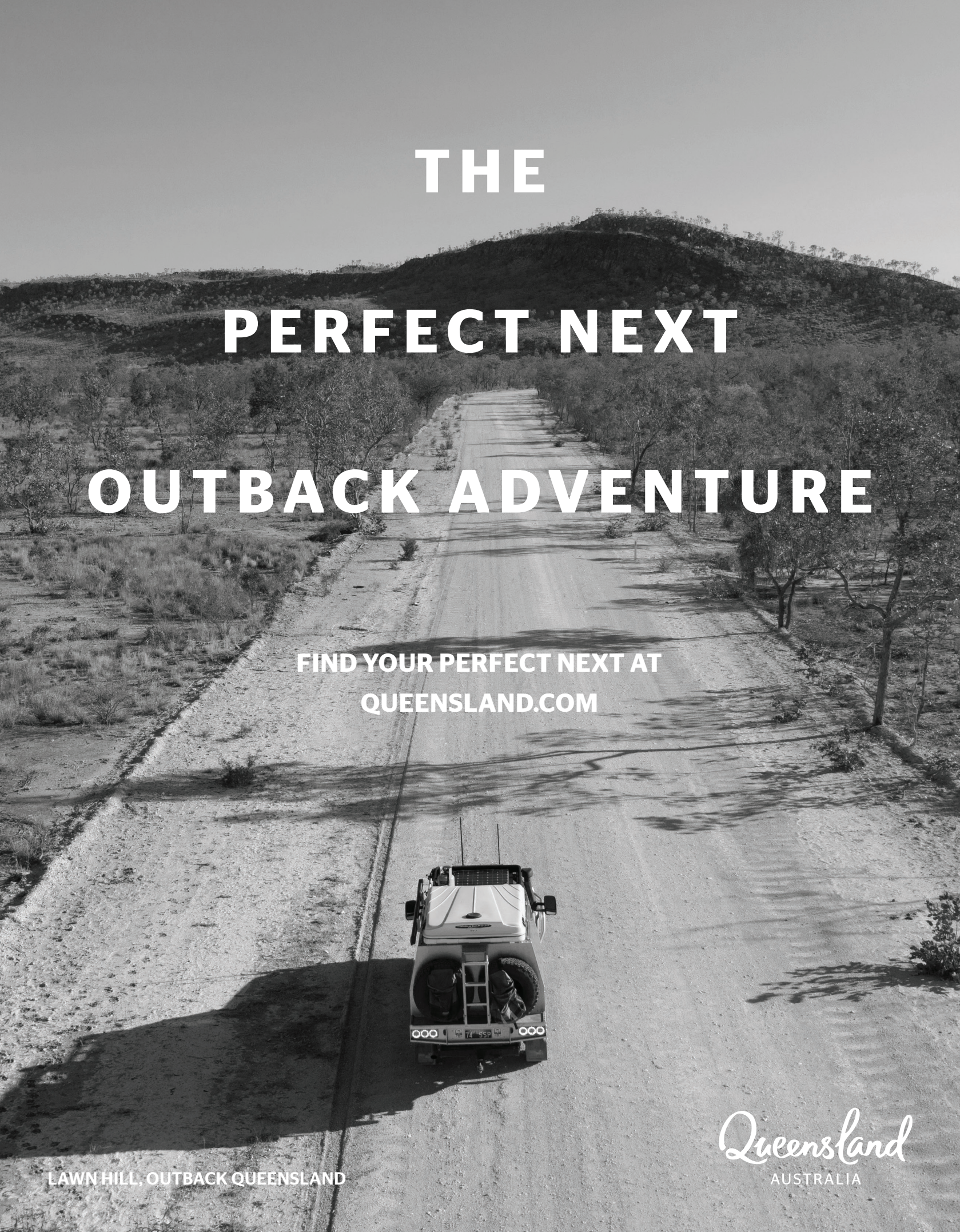
**For Pre-registered Attendees*

For field trip pickup and dropoff locations and times, please check with your field trip leader, check the mobile app, or go to www.vertpaleo.org/Annual-Meeting/Field-Trips.aspx

Day/Time	Title
MON, September 30 – SUN, October 6	**Exploring the Cretaceous of Central Queensland, Australia: Dinosaur Tracks, Bones, and Marine Fossils**
FRI, October 4 – TUES, October 8	**Rocks and Bones from the Red Centre**
SAT, October 5 – MON, October 7	**Australia's Prehistoric Serengeti: Plio-Pleistocene Megafauna of the Darling Downs**
MON, October 7	**Rocks and Fossils of Greater Brisbane**
MON, October 14 – FRI, October 18	**Field Trip to Heron Island, Southern Great Barrier Reef**
MON, October 14 – FRI, October 18	**Walking with Dinosaurs and Swimming with Placoderms in the Kimberley: Dinosaurian Tracks of the Broome Sandstone and the Upper Devonian Gogo Fish Fauna**
MON, October 14 – THU, October 17	**The World Heritage Fossil Deposits of Riversleigh, Queensland**

	M 1&2	M3	M4	M 1&2	M3	M4
	Marine Tetrapods	Dinosaurs I	Soft Tissue Preservation	Mammals II	Archosaurs	Romer Prize Session
	WED	WED	WED	THUR	THUR	THUR
8:00 am	WANG	BEVERIDGE	BRIGGS	REED	SCHWAB	EISLER
8:15 am	HAYASHI	WILKINSON	WIEMANN	LOPEZ-AGUIRRE	POL	FOFFA
8:30 am	WINTRICH	STEWART	MCCOY	ALUMBAUGH	TURNER	JOHNSON
8:45 am	LAMBERT	ENRIQUEZ	TRINAJSTIC	DE VRIES	WHITE	KRAHL
9:00 am	PARK	GATESY	TSCHOPP	HOPKINS	RUBIN	FUNSTON
9:15 am	K. SMITH	POROPAT	NAVALÓN	CRAMB	RISTEVSKI	EVERS
9:30 am	COSTE	MANNION	NORELL	MARCY	SERENO	TERRILL
9:45 am	FORDYCE	GORSCAK	CLARKE	LANG	CLARK	SINGH
10:00 am	COFFEE					
10:15 am	FITZGERALD	AVRAHAMI	KORNEISEL	SANSALONE	SEYMOUR	KLEIN
10:30 am	LOCH	KITCHENER	ROY	MACLATCHY	FORTNER	THORN
10:45 am	MARX	DUNCAN	HASSLER	KINGSTON	PENTLAND	BROCKLEHURST
11:00 am	VELEZ-JUARBE	SALISBURY	J. O'CONNOR	T. SMITH	QVARNSTRÖM	HAUPT
11:15 am	NELSON	HOCKNULL	MEYER	BEGUN	KELLNER	LANZETTI
11:30 am	MORI	KOBAYASHI	CHIN	COTE	MARTIN-SILVERSTONE	ARMAN
11:45 am	RULE	YU	NEDZA	CANTALAPIEDRA	BEHRENSMEYER	TANIS
12:00 pm	POUST	GEE	MITCHELL	SANISIDRO MORANT	ZHANG	KEALY
12:15 pm	BREAK					SVP BUSINESS MEETING
1:30 pm						
	M 1&2	M3	M4	M 1&2	M3	M4
	Mammals I	Evolution of the Dentition	Cenozoic Birds	Preparator's Session	Mammal Cranial Evolution	Squamates & Herpetofaunas
1:45 pm	KORT	CHEN	CHINSAMY-TURAN	M. MILLER	BENOIT	AMSON
2:00 pm	TOMIYA	MCCURRY	CHEN	VAN BEEK	MIYAMAE	PHANTRATANAMONGKO
2:15 pm	WARBURTON	OLROYD	FIELD	GROENKE	MENG	BOLET
2:30 pm	KUHN	BRINK	SCOFIELD	PINSDORF	GOSWAMI	FORMOSO
2:45 pm	MEACHEN	WU	MAREK	BURKE	SCHULTZ	JACISIN
3:00 pm	WITHDRAWN	STILSON	GIOVANARDI	DALLMAN	VIACAVA	SCARPETTA
3:15 pm	VAN HETEREN	COLBERT	MATTS	WILLIAMS	MENNECART	BONNAN
3:30 pm	WITHDRAWN	SELIG	STIDHAM	BADER	HAND	L. ROBERTS
3:45 pm	MEDINA	NASRULLAH	N. SMITH	GORDON	JACQUEMETTON	BLOCH
4:00 pm	CLEVELAND	EVANS	RAWLENCE	FERGUSON	ROESSNER	WEBER
4:15 pm	*Poster Session I*			*Poster Session II*		
6:15 pm						

	M 1&2	M3	M4	M 1&2	M3	M4
	Fish	**Mammalian Paleoecology**	**Dinosaurs II**	**Fins to Limbs**	**Origin of a Sunburnt Country**	**Dinosaurs III**
	FRI	**FRI**	**FRI**	**SAT**	**SAT**	**SAT**
8:00 am	M. ZHU	VITERI	KAMMERER	HU	BECK	KIRMSE
8:15 am	Y. ZHU	ZONNEVELD	FELICE	BARDUA	BREWER	DRUCKENMILLER
8:30 am	LONG	H. SMITH	FABBRI	JONES	NGUYEN	LAMANNA
8:45 am	COATES	SURAPRASIT	BROUGHAM	FABRE	WROE	LANGER
9:00 am	LU	FOX	DUNNE	DEMAR	OLIVER	CARRANO
9:15 am	DOWDING	STEGNER	BUTTON	SANDER	YATES	CARR
9:30 am	ARGYRIOU	FUSCO	IRMIS	SIDOR	TRAVOUILLON	ZANNO
9:45 am	BEAN	P. ROBERTS	SAITTA	SUMIDA	PRIDEAUX	NEENAN
10:00 am	COFFEE					
10:15 am	LISTON	HALLIDAY	STRICKSON	BENDEL	PRIYA	NAPOLI
10:30 am	DAESCHLER	WITHDRAWN	CHAPELLE	MUSSER	MCDOWELL	MA
10:45 am	CLAESON	BADGLEY	KNAPP	GROENEWALD	ARCHER	WANG
11:00 am	CAWLEY	BLANCO	SCANNELLA	WHITNEY	BUTLER	P. O'CONNOR
11:15 am	WU	HOCK	BULLAR	KULIK	KERR	GREEN
11:30 am	BAZZI	CLEMENTZ	LEAHEY	DUHAMEL	RICHARDS	CARROLL
11:45 am	BERNARD	POLLY	ZHENG	FRÖBISCH	CAMENS	LYSON
12:00 pm	MCKEEBY	PARDI	DYER	MILLER-CAMP	WEISBECKER	KUBO
12:15 pm	**BREAK**					
1:30 pm						
	M 1&2	**M3**	**M4**	**M 1&2**	**M3**	**M4**
	Early Reptiles	**Quartenary Extinctions**	**Bird Origin and Evolution**	**Mesozoic and Early Paleogene Animals**	**Evolutionary and Faunal Studies**	**Terrestrial Locomotor Biomechanics**
1:45 pm	SOBRAL	WESTAWAY	GRIFFIN	MAO	SIMOES	LENNIE
2:00 pm	STOCKER	DE PIETRI	PITTMAN	BI	BELL	BLOB
2:15 pm	BRITT	DESANTIS	IMAI	WEAVER	FISCHER	HIRASAWA
2:30 pm	VAKIL	WORTHY	HU	BRANNICK	SULLIVAN	DEMUTH
2:45 pm	KLIGMAN	LOUYS	BENITO	WILLIAMSON	CLOSE	CUFF
3:00 pm	VERRIÈRE	RABI	WANG	CLAYTOR	PHILLIPS	BISHOP
3:15 pm	MACDOUGALL	AMANO	HELLERT	SHELLEY	SCHULP	DRÓZDZ
3:30 pm	CHATTERJI	LUBEEK	BAUMGART	HOVATTER	I.MILLER	STEIN
3:45 pm	SZCZYGIELSKI	GARVEY	CANOVILLE	BERTRAND	WTIHDRAWN	JANNEL
4:00 pm	REISZ	PRICE	THOMAS	GONG	MOORE	HECK
4:15 pm	*Poster Session III*			*Poster Session IV*		
6:15 pm						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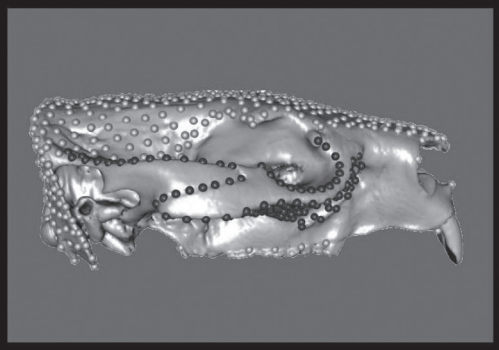
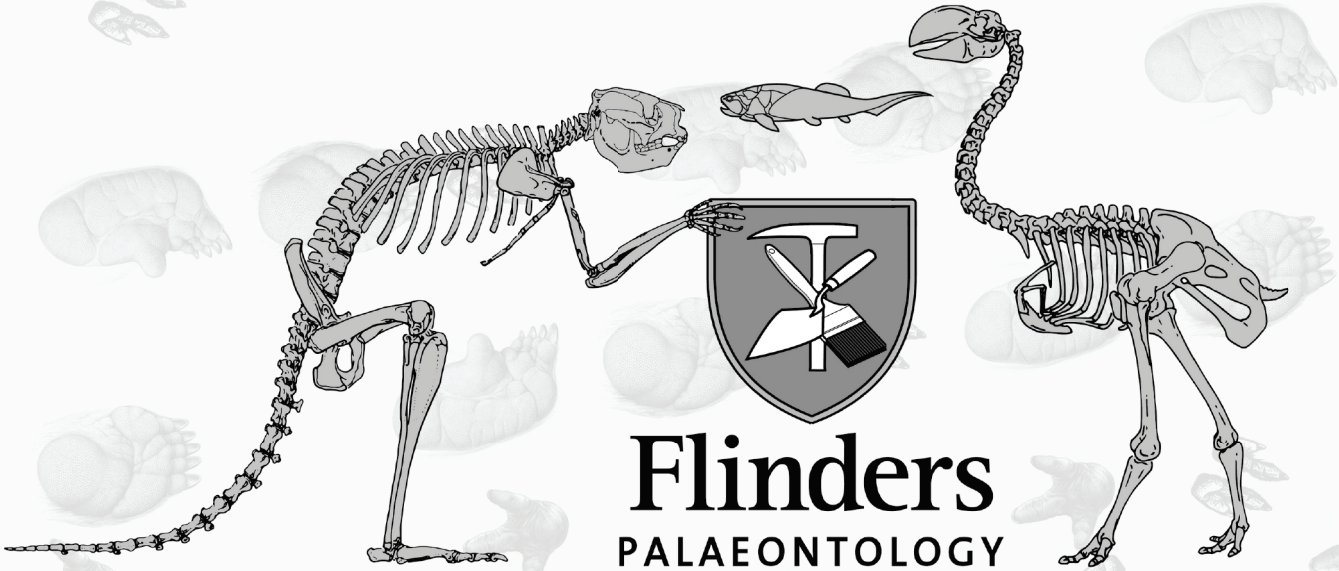


The University Of Queensland

AUSTRALIA

SVP 2019 proudly supported by UQ's School of Earth and Environmental Sciences, School of Biological Sciences, and the Faculty of Science



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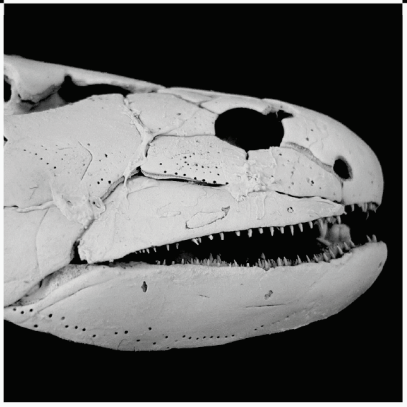

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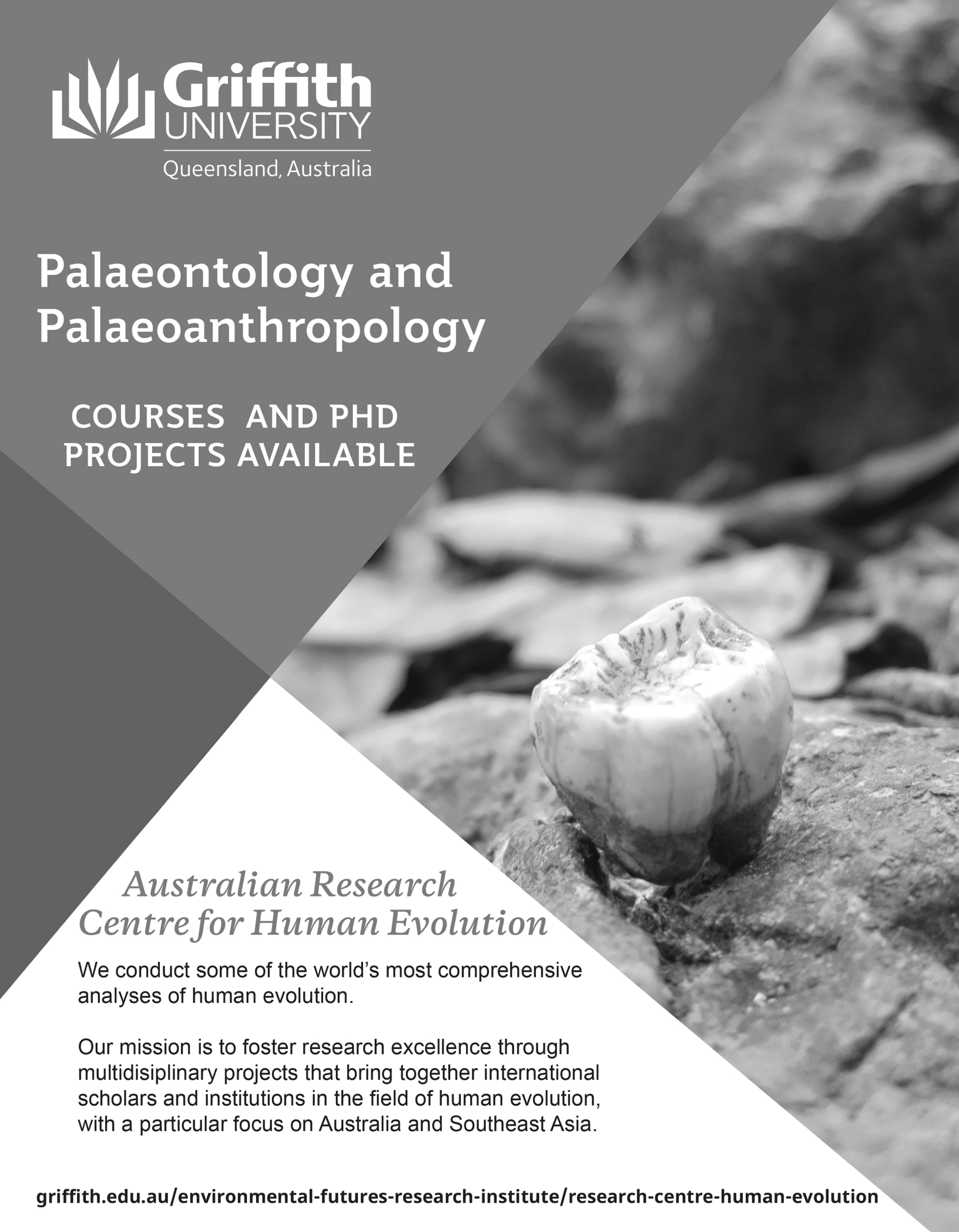

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The Royal Society journal *Biology Letters* regularly publishes research, opinion pieces and reviews in vertebrate palaeontology.

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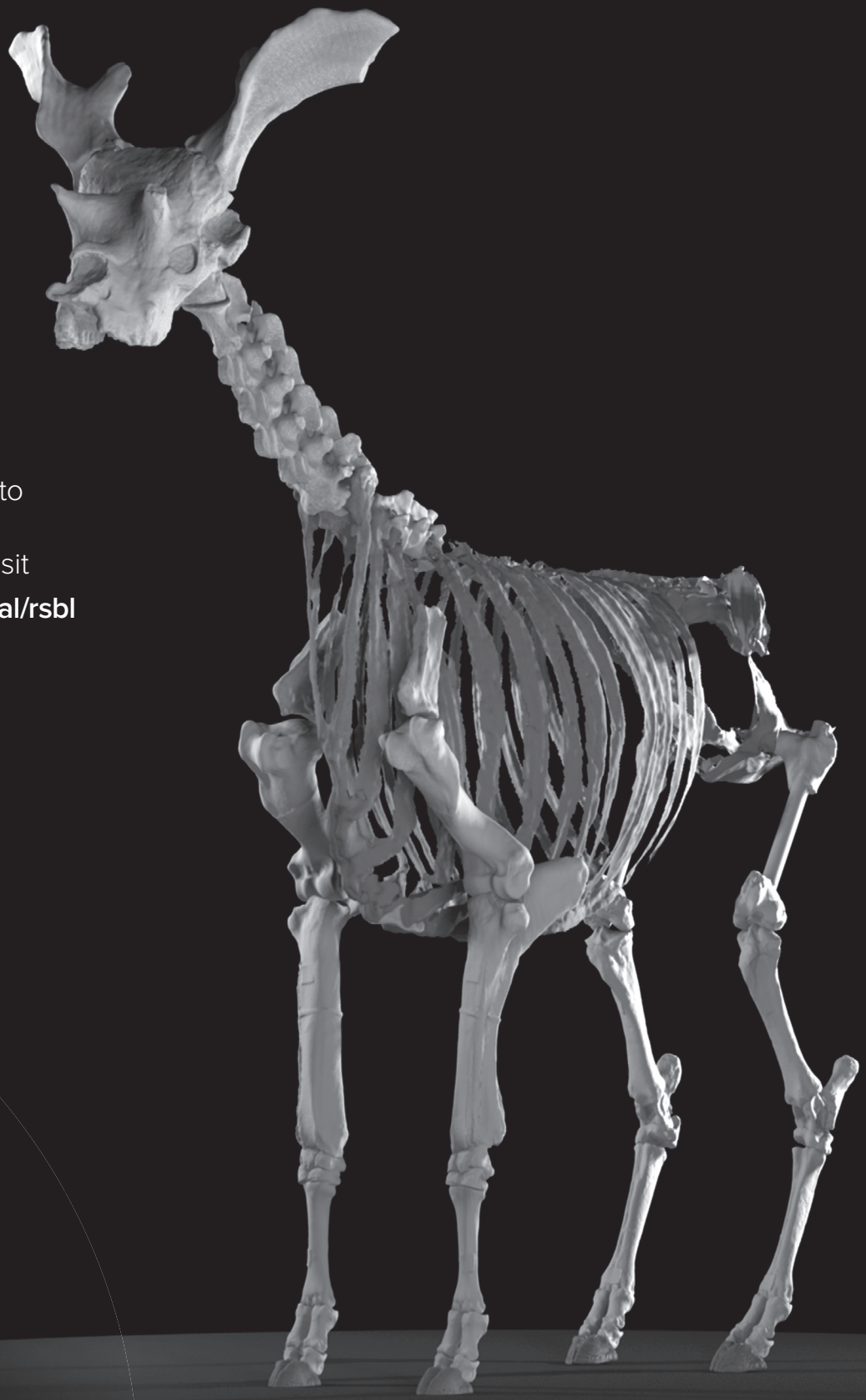

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Image: A composite skeletal reconstruction of *Sivatherium giganteum*. Credit: Chris Basu.

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List of Authors and Abstract Titles in Chronological Session Order

WEDNESDAY MORNING, OCTOBER 9, 2019
SYMPOSIUM: FROM MOLECULES TO MACROEVOLUTION: PALEOBIOLOGICAL APPLICATIONS OF VERTEBRATE SOFT TISSUE PRESERVATION
MEETING ROOM M4
MODERATORS: Jasmina Weisman and Derek Briggs

8:00 **D. E. Briggs, J. Wiemann** TRENDS IN SOFT TISSUE PRESERVATION AND ITS ROLE IN REVEALING THE HISTORY OF LIFE

8:15 **J. Wiemann, D. E. Briggs** FOSSIL SOFT TISSUES RESOLVE THE VERTEBRATE TREE OF LIFE AND RECORD METABOLIC RATES

8:30 **V. E. McCoy, J. Wiemann, J. C. Lamsdell, C. D. Whalen, S. Lidgard, P. Mayer, H. Petermann, D. E. Briggs** NEW EVIDENCE FOR THE AFFINITY OF THE MAZON CREEK PROBLEMATICUM *TULLIMONSTRUM GREGARIUM*

8:45 **K. Trinajstic, J. A. Long, S. Sanchez, C. A. Boisvert, D. Snitting, P. Tafforeau, V. Dupret, P. Currie, B. Roelofs, P. E. Ahlberg** EXCEPTIONAL 3D PRESERVATION OF SOFT TISSUES AND ORGANS IN THE VERTEBRATE FAUNA FROM THE LATE DEVONIAN GOGO FORMATION

9:00 **E. Tschopp, J. Wiemann, F. Dela Pierre, S. Cavagna, M. A. Norell** HOWE QUARRY (UPPER JURASSIC MORRISON FORMATION, WESTERN USA), A HOT SPOT FOR SAUROPOD SOFT TISSUE

9:15 **G. Navalón, J. Marugán-Lobón, L. M. Chiappe, J. L. Sanz, Á. D. Buscalioni** LIMESTONE CHICKEN WINGS: SOFT TISSUES FROM A STEM-BIRD FROM LAS HOYAS (CENTRAL SPAIN) AND THE EARLY EVOLUTION OF FLIGHT IN BIRDS

9:30 **M. A. Norell, J. Wiemann, M. Fabbri, C. Yu, C. A. Marsicano, D. J. Varricchio, D. Pol, D. Zelenitsky** THE FIRST DINOSAUR EGG WAS SOFT

9:45 **J. A. Clarke, C. Eliason** METABOLIC PHYSIOLOGY EXPLAINS MACROEVOLUTIONARY TRENDS IN THE MELANIC COLOUR SYSTEM ACROSS AMNIOTES

10:15 **D. E. Korneisel, S. J. Nesbitt, S. Xiao** WHAT IS AN 'EXCEPTIONAL' FOSSIL? ASSESSMENT OF THE MICROSCOPIC PRESERVATION OF A JEHOL BIOTA FEATHERED DINOSAUR

10:30 **A. Roy, M. Pittman, E. T. Saitta, T. G. Kaye** FOSSIL COLOR RECONSTRUCTION IN DINOSAURS AND CLOSE RELATIVES

10:45 **A. Hassler, J. E. Martin, R. Amiot, T. Tacail, F. Arnaud-Godet, R. Allain, V. Balter** CALCIUM ISOTOPES AND DINOSAUR RESOURCE PARTITIONING

11:00 **J. O'Connor, A. Bailleul, M. Wang, Z. Li, Z. Zhou** INVESTIGATING PROBABLE REPRODUCTIVE TISSUES IN STEM BIRDS USING ADVANCED MICROSCOPIC ANALYTICAL METHODS

11:15 **D. L. Meyer, J. Wiemann** A PHYLOGENETIC SIGNAL RETAINED IN FOSSIL SOFT TISSUES PLACES [STEM] TURTLES IN THE REPTILE TREE OF LIFE

11:30 **K. Chin** THE COMPLEX TAPHONOMIC HISTORY OF ORGANIC TISSUES WITHIN LITHIFIED COPROLITES

11:45 **C. Nedza, M. Purnell, J. Vinther, S. Gabbott** DECAY CHANGES THE DISTRIBUTION AND SHAPE OF MELANOSOMES IN AQUATIC VERTEBRATES: IMPLICATIONS FOR THE INTERPRETATION OF COLOUR PATTERNS IN FOSSIL TAXA

12:00 **K. J. Mitchell, A. R. Perri, A. Mouton, S. Alvarez-Carretero, A. Hulme-Beaman, J. Haile, A. Jamieson, J. Meachen, A. T. Lin, B. W. Schubert, C. Ameen, P. Bover, S. Grace, A. Carmagnini, C. Carøe, J. A. Samaniego Castruita, J. C. Chatters, K. Dobney, M. Do** DIRE WOLVES WERE THE LAST OF AN ANCIENT NEW WORLD CANID LINEAGE

WEDNESDAY MORNING, OCTOBER 9, 2019
TECHNICAL SESSION I: MARINE TETRAPODS
MEETING ROOM M1&2
MODERATORS: Carolina Loch and Erich Fitzgerald

8:00 **W. Wang, C. Li, X. Wu** NEW COMPLETE SKELETON OF *PSEPHOCHELYS POLYOSTEODERMA* (SAUROPTERYGIA, PLACODONTIA) WITH A DEVELOPING CARAPACE

8:15 **S. Hayashi, Y. Nakajima, T. Sato, A. Houssaye, T. Wintrich, Y. Hikida, P. M. Sander** MICROANATOMICAL SHIFT IN PLESIOSAUR VERTEBRA: EVOLUTIONARY AND ECOLOGICAL SIGNIFICANCE

8:30 **T. Wintrich, C. Fleischle, P. Sander** INFERENCES ON PLESIOSAURIAN METABOLIC RATE AND VASCULAR SYSTEM FROM NUTRIENT FORAMINA IN LONG BONES

8:45 **O. Lambert, G. Bianucci, R. Salas-Gismondi, C. Di Celma, E. Steurbaut, M. Urbina, C. De Muizon** EARLY DISPERSAL FOR QUADRUPEDAL CETACEANS: AN AMPHIBIOUS WHALE FROM THE MIDDLE EOCENE OF THE SOUTHEASTERN PACIFIC

9:00 **T. Park, N. Cooper, T. Guillerme** EXAMINING THE EVOLUTION OF ECHOLOCATION IN ODONTOCETES (MAMMALIA, CETACEA) VIA MORPHOLOGICAL DISPARITY OF THE COCHLEA

9:15 **K. Smith, J. Geisler, D. Patel** ENDOCRANIAL MORPHOLOGY AND ENCEPHALIZATION IN THE PROTOCETID CETACEAN *GEORGIACETUS VOGTLENSIS*

9:30 **A. M. Coste, R. E. Fordyce, C. Loch** DAUNTING DENTITIONS: TUSKS AND TEETH IN THREE OLIGOCENE DOLPHINS FROM NEW ZEALAND

9:45 **R. E. Fordyce** A ZIPHIID-LIKE PLATANISTOID DOLPHIN FROM THE OTEKAIKE LIMESTONE (WAITAKIAN STAGE, LATEST OLIGOCENE), HAKATARAMEA VALLEY, NEW ZEALAND

10:15 **E. M. Fitzgerald, N. S. Pledge** NEW MIOCENE SHARK-TOOTHED DOLPHINS FROM AUSTRALIA SHED LIGHT ON THE PHYLOGENY AND BIOGEOGRAPHY OF SQUALODONTIDAE (CETACEA, ODONTOCETI)

10:30 **C. Loch, C. S. Gutstein, N. D. Pyenson, M. T. Clementz** BUT DID IT EAT OTHER WHALES? NEW ENAMEL MICROSTRUCTURE AND ISOTOPIC DATA ON *LIVYATAN*, A LARGE PHYSETEROID FROM THE ATACAMA REGION, NORTHERN CHILE

10:45 **F. G. Marx, A. Collareta, O. Lambert, C. De Muizon, M. Urbina, G. Bianucci** MIOCENE BALEEN WHALES FROM THE PERUVIAN DESERT

11:00 **J. Velez-Juarbe, J. Parham** NEW DATA ON THE NEOGENE MARINE MAMMAL FAUNAS OF THE EASTERN NORTH PACIFIC

11:15 **M. D. Nelson, C. M. Peredo, M. D. Uhen** FIRST KNOWN MYSTICETE FROM THE FAIRHAVEN MEMBER OF THE CALVERT FORMATION

11:30 **H. Mori, K. Miyata, T. Kato** THE OLDEST KNOWN PACIFIC SIRENIAN FROM THE EARLIEST OLIGOCENE, SAIKAI, NAGASAKI PREFECTURE, WESTERN JAPAN

11:45 **J. P. Rule, J. W. Adams, A. R. Evans, A. J. Tennyson, P. R. Scofield, E. M. Fitzgerald** THE EVOLUTION OF SEALS (FAMILY PHOCIDAE) IN THE SOUTHERN OCEAN: NEW FOSSIL EVIDENCE FROM NEW ZEALAND

12:00 **A. W. Poust, R. W. Boessenecker, M. Churchill, S. Boessenecker** NEW WALRUSES FROM THE PURISIMA FORMATION REVEAL PATTERN OF HIGH LOCAL PINNIPED DIVERSITY IN THE MIO–PLIOCENE EASTERN PACIFIC

WEDNESDAY MORNING, OCTOBER 9, 2019
TECHNICAL SESSION II: DINOSAURS I
MEETING ROOM M3
MODERATORS: Congyu Yu and Stephen Poropat

8:00 **T. L. Beveridge, E. M. Roberts, J. Ramezani, A. L. Titus** NEW HIGH-PRECISION U–PB GEOCHRONOLOGY FOR THE WAHWEAP FORMATION, SOUTHERN UTAH AND IMPLICATIONS FOR LATE CRETACEOUS DINOSAUR EVOLUTION IN NORTH AMERICA

8:15 **M. Wilkinson, S. A. Hocknull, R. Mackenzie** WHAT IS AND CAN BE KNOWN ABOUT THE WINTON FORMATION? UNDERSTANDING THE GEOLOGY OF THE WINTON FORMATION AND INTEGRATING NEWLY DISCOVERED FOSSIL FIELDS FROM SOUTH-WEST QUEENSLAND, AUSTRALIA

8:30 **D. G. Stewart, P. S. Druckenmiller, G. M. Erickson, D. Capps, J. Benowitz, K. C. May, P. J. McCarthy** PALEOENVIRONMENTAL ASSOCIATIONS AND VERTEBRATE ICHNOLOGY OF A DIVERSE, MULTI-LAYERED, DINOSAUR TRACK ASSEMBLAGE FROM THE UPPER CRETACEOUS CANTWELL FORMATION (MAASTRICHTIAN), DENALI NATIONAL PARK AND PRESERVE, ALASKA

8:45 **N. J. Enriquez, N. E. Campione, M. White, C. Sullivan, F. Fanti, M. J. Vavrek, R. Sissons, P. Bell** A HIGH-LATITUDE ORNITHOPOD AND THEROPOD ICHNOFAUNA FROM THE LATE CRETACEOUS WAPITI FORMATION OF ALBERTA, CANADA

9:00 **S. M. Gatesy, M. L. Turner, P. L. Falkingham** CT IMAGING OF DINOSAUR FOOTPRINTS: HIDDEN TOPOGRAPHY AND THE ORIGIN OF PENETRATIVE TRACK DIVERSITY

9:15 **S. F. Poropat, P. D. Mannion, P. Upchurch, D. A. Elliott** NEW SAUROPOD DINOSAUR DISCOVERIES IN THE LOWER UPPER CRETACEOUS WINTON FORMATION (CENOMANIAN–LOWER TURONIAN) OF QUEENSLAND, AUSTRALIA: IMPLICATIONS FOR TITANOSAURIAN EVOLUTION

9:30 **P. Mannion, V. Díez Díaz, Z. Csiki-Sava, P. Upchurch, A. Cuff** DWARFS AMONG GIANTS: RESOLVING THE SYSTEMATICS OF THE TITANOSAURIAN SAUROPOD DINOSAURS FROM THE LATEST CRETACEOUS OF ROMANIA

9:45 **E. Gorscak, J. Sertich, F. K. Manthi** TITANOSAURIAN SAUROPOD DINOSAUR FOSSILS FROM THE UPPER CRETACEOUS LAPUR SANDSTONE (TURKANA GRITS), TURKANA BASIN, NORTHWESTERN KENYA

10:15 **H. M. Avrahami, P. Makovicky, L. Zanno** PALEOHISTOLOGY OF A NEW ORODROMINE FROM THE UPPER CRETACEOUS (CENOMANIAN) MUSSENTUCHIT MEMBER OF THE CEDAR MOUNTAIN FORMATION, UTAH: HISTOLOGICAL IMPLICATIONS FOR BURROWING BEHAVIOR

10:30 **J. L. Kitchener, N. E. Campione, E. Smith, P. Bell** HIGH-LATITUDE NEONATE AND PERINATE ORNITHOPODS FROM THE MID-CRETACEOUS OF SOUTHEASTERN AUSTRALIA

10:45 **R. J. Duncan, S. F. Poropat, T. H. Rich** DESCRIPTION OF FIRST NEORNITHISCHIAN DINOSAUR CRANIAL MATERIAL FROM THE ERIC THE RED WEST LOCALITY (EUMERALLA FORMATION: UPPER APTIAN–LOWER ALBIAN), CAPE OTWAY, VICTORIA, AUSTRALIA

11:00 **S. W. Salisbury, M. C. Herne, M. C. Lamanna, J. P. Nair, C. Syme, L. M. Witmer** AN EXCEPTIONALLY PRESERVED SMALL-BODIED ORNITHOPOD DINOSAUR FROM THE LOWER CRETACEOUS (UPPER ALBIAN) WINTON FORMATION OF ISISFORD, CENTRAL-WESTERN QUEENSLAND, AUSTRALIA, AND THE DIVERSIFICATION OF GONDWANAN ORNITHOPODS

11:15 **S. A. Hocknull, M. Wilkinson, R. A. Lawrence, N. Newman, R. Mackenzie** ON THE SHOULDERS OF TITANS: INTRODUCING NEW CRETACEOUS DINOSAUR FOSSIL FIELDS FROM SOUTHWEST QUEENSLAND, AUSTRALIA, AND DEMONSTRATING THE UTILITY OF SCANNING (SURFACE AND CT) IN TAPHONOMIC AND ICHNOFOSSIL INTERPRETATION

11:30 **Y. Kobayashi, T. Nishimura, R. Takasaki, K. Chiba, A. R. Fiorillo, K. Tanaka, C. Tsogtbaatar, T. Sato, K. Sakurai** A NEW CRESTED HADROSAURINE (DINOSAURIA: HADROSAURIDAE) FROM THE MARINE DEPOSITS OF THE LATE CRETACEOUS HAKOBUCHI FORMATION (MAASTRICHTIAN), YEZO GROUP, JAPAN

11:45 **C. Yu** DIFFERENT DEVELOPMENTAL TRAJECTORIES IN TWO GROUPS OF ORNITHISCHIAN DINOSAURS, HADROSAURS AND CERATOPSIANS, REVEALED BY DEEP LEARNING

12:00 **C. T. Gee, M. M. Howell, C. Böttger, K. Südekum** A SUPERFOOD FOR MESOZOIC HERBIVORES? EMERGING DATA ON THE EXTREME DIGESTIBILITY OF *EQUISETUM* AND IMPLICATIONS FOR YOUNG, GROWING HERBIVOROUS SAUROPODS

WEDNESDAY AFTERNOON, OCTOBER 9, 2019
TECHNICAL SESSION III: MAMMALS I
MEETING ROOM M1&2
MODERATOR: Anneke van Heteren

1:45 **A. E. Kort** AN EARLY 'CAT GAP'? AN EVALUATION OF OXYAENIDS AS ECOLOGICAL ANALOGUES OF FELIDS

2:00 **S. Tomiya, S. P. Zack, M. Spaulding, J. J. Flynn** CARNIVOROUS MAMMALS FROM THE MIDDLE EOCENE WASHAKIE FORMATION, WYOMING, U.S.A., AND THEIR DIVERSITY TRAJECTORY IN A POST-WARMING WORLD

2:15 **N. M. Warburton, A. Yates** FUNCTIONAL MORPHOLOGY OF *WAKALEO* POSTCRANIA FROM THE MIDDLE TO LATE MIOCENE OF CENTRAL AUSTRALIA REVEALS NEW INSIGHTS IN THE EVOLUTION OF MARSUPIAL HYPERCARNIVORES

2:30 **B. F. Kuhn, M. J. Salesa, M. Anton, A. Argant, L. Kgasi, D. Gommery** BURIED PRIDE: MULTIPLE PANTHERA INDIVIDUALS RECOVERED FROM SINGLE FOSSIL DEPOSIT, BOLT'S FARM, SOUTH AFRICA

2:45 **J. Meachen, J. Cohen, M. I. Pardi, E. Hall, W. Binder, F. R. O'Keefe, J. Southon, E. Lindsey, B. Fuller, L. R. Desantis** THE LATE QUATERNARY ECOLOGICAL EVOLUTION OF COYOTES AS EVIDENCED FROM RANCHO LA BREA

3:00 **A. Hartstone-Rose, E. Elminowski, D. Flores, E. Burridge** THE SQUADS OF RANCHO LA BREA

3:15 **A. H. Van Heteren, B. Figueirido** DIET RECONSTRUCTION IN CAVE BEARS FROM MANDIBULAR MORPHOLOGY

3:30 **B. Wang, M. Zelditch, C. Badgley** JAW DISPARITY IN RELATION TO DIET IN THE ARTIODACTYLA, WITH IMPLICATIONS FOR PALEOECOLOGY

3:45 **P. Medina, K. Moreno** ON THE FORM, MOVEMENT RANGE, AND FUNCTION: CONSTRUCTING A MORPHOFUNCTIONAL SPACE FOR THE EXCAVATION MOTOR GESTURE FOR THE FORELIMB OF *CARAGUATYPOTHERIUM MUNOZI* (NOTOUNGULATA, MESOTHERIIDAE)

4:00 **C. Cleveland, M. Patzkowsky, R. Graham** OREODONT ADAPTATION AND EXTINCTION IN THE CENTRAL HIGH PLAINS, MIOCENE NORTH AMERICA

WEDNESDAY AFTERNOON, OCTOBER 9, 2019
TECHNICAL SESSION IV: EVOLUTION OF THE DENTITION
MEETING ROOM M3
MODERATORS: Kelsey Stilson and Matthew McCurry

1:45 **D. Chen, V. Vaškaninová, S. Sanchez, P. Tafforeau, Z. Johanson, K. Trinajstic, T. Märss, H. Blom, P. E. Ahlberg** DEVELOPMENT RELATIONSHIPS BETWEEN TEETH AND JAWBONES IN STEM GNATHOSTOMES AND STEM OSTEICHTHYANS REVEALED BY 3D HISTOLOGY: INSIGHTS INTO THE EVOLUTION OF TOOTH REPLACEMENT AND TOOTH ORGANIZATION

2:00 **M. R. McCurry, A. R. Evans, E. M. Fitzgerald, C. R. McHenry, J. Bevitt, N. D. Pyenson** THE REPEATED EVOLUTION OF APICOBASAL RIDGES IN AQUATIC-FEEDING AMNIOTES

2:15 **S. L. Olroyd, A. R. LeBlanc, K. D. Angielczyk** TOOTH MIGRATION, REPLACEMENT, AND THE EVOLUTION OF MULTIPLE TOOTH ROWS IN ENDOTHIODONT DICYNODONTS (THERAPSIDA, ANOMODONTIA)

2:30 **K. Brink, J. Richman** TOOTH REPLACEMENT RATES IN HETERODONT REPTILES

2:45 **Y. Wu, L. M. Chiappe, D. J. Bottjer, W. Nava, A. G. Martinelli** DENTAL MORPHOLOGY AND REPLACEMENT PATTERN OF LATE CRETACEOUS BRAZILIAN ENANTIORNITHINE BIRDS

3:00 **K. T. Stilson, C. F. Ross, Z. Luo, D. A. Reed** IMMUNOHISTOCHEMICAL INSIGHTS INTO DISTRIBUTION AND OSTEOLOGICAL CORRELATES OF PERIODONTAL LIGAMENT INNERVATION IN *DIDELPHIS VIRGINIANA*

3:15 **M. W. Colbert, C. T. Griffin** SAMPLE SIZE ARTIFACTS IN PALEONTOLOGICAL ANALYSES OF ONTOGENETIC SEQUENCES

3:30 **K. R. Selig, W. Khalid, M. T. Silcox** COMPLEXITY OF THE LOWER MOLAR ROW IS EXPLAINED BY THE INHIBITORY CASCADE MODEL AND DIET WITHIN EUARCHONTA

3:45 **Q. Nasrullah, A. R. Evans** TOOTH COMPLEXITY BLUEPRINT AND THE EVOLUTION OF THE ANTEROCONID IN RODENTS

4:00 **A. R. Evans, T. I. Pollock, S. G. Cleuren, W. M. Parker, H. L. Richards, T. E. Wilson, D. P. Hocking, J. W. Adams** A UNIVERSAL POWER LAW FOR THE GROWTH AND FORM OF TEETH, CLAWS, HORNS, THORNS, AND BEAKS

WEDNESDAY AFTERNOON, OCTOBER 9, 2019
TECHNICAL SESSION V: CENOZOIC BIRDS
MEETING ROOM M4
MODERATORS: Thomas Stidham and Anusuya Chinsamy-Turan

1:45 **A. Chinsamy-Turan, T. H. Worthy, W. D. Handley** GROWTH STRATEGIES LINKED TO PREVAILING ENVIRONMENTAL CONDITIONS IN AUSTRALIAN GIANT FLIGHTLESS MIHIRUNG BIRDS (AVES: DROMORNITHIDAE)

2:00 **A. Chen, N. D. White, R. Benson, M. J. Braun, D. Field** TOTAL-EVIDENCE FRAMEWORK REVEALS COMPLEX MORPHOLOGICAL EVOLUTION AND RAPID EVOLUTION IN NIGHTBIRDS (STRISORES)

2:15 **D. J. Field, E. E. Saupe** CLIMATIC SHIFTS DROVE MAJOR CONTRACTIONS IN AVIAN LATITUDINAL DISTRIBUTIONS THROUGHOUT THE CENOZOIC

2:30 **P. Scofield, V. De Pietri, A. Mannering, L. Love, G. Mayr** MEDICAL CT REVEALS THE OLDEST, SMALLEST, AND PHYLOGENETICALLY MOST BASAL PELAGORNITHID (AVES: ODONTOPTERYGIFORMES), FROM THE EARLY PALEOCENE OF NEW ZEALAND.

2:45 **R. D. Marek** THE SURROGATE ARM: FUNCTIONAL AND ECOLOGICAL DRIVERS OF NECK MORPHOLOGY IN EXTANT AVES

3:00 **S. Giovanardi, D. T. Ksepka, D. B. Thomas** A NEW SPHENISCIFORM FOSSIL FROM THE NORTH ISLAND OF NEW ZEALAND FURTHER RESOLVES THE BAUPLAN OF EXTINCT GIANT PENGUINS

3:15 **K. A. Matts, R. E. Fordyce** A NEW LOOK AT THE LATE OLIGOCENE *PLATYDYPTES* PENGUINS OF ZEALANDIA

3:30 **T. Stidham, Z. Li** AVIAN EVOLUTION NEAR THE TIBETAN PLATEAU AND EVIDENCE FOR CENTRAL ASIAN ARIDITY IN THE LATE MIOCENE BASED ON THE FIRST FOSSIL SKELETON OF A SANDGROUSE (AVES: PTEROCLIDAE) FROM THE LINXIA BASIN IN WESTERN CHINA

3:45 **N. Smith, J. Watkins, J. Jay** PHYLOGENETIC RELATIONSHIPS OF SULIDAE (AVES: SULIFORMES) INFERRED FROM EXTERNAL MORPHOLOGICAL CHARACTERS AND CONGRUENCE BETWEEN MORPHOLOGICAL AND MOLECULAR DATASETS

4:00 **N. J. Rawlence** EXTINCT BIRDS OF NEW ZEALAND: HOW ANCIENT DNA AND MORPHOLOGY IS RAPIDLY INCREASING THE NUMBER OF HUMAN DRIVEN EXTINCTIONS

WEDNESDAY - SATURDAY, OCTOBER 9-12, 2019
COLBERT PRIZE POSTER SESSION
GREAT HALL 1&2
Authors must be present from 4:15 - 6:15 p.m. Thursday, October 10

B1 **H. M. Maisch, M. A. Becker, M. L. Griffiths, Z. Rao, E. R. Kast, A. A. Akhtar, D. Sigman, J. A. Higgins** VERTEBRATE LAG DEPOSITS FROM A K/PG BOUNDARY SECTION NEAR MALVERN, ARKANSAS, USA: NON-CATASTROPHIC ACCUMULATIONS IN RESPONSE TO SEA LEVEL CYCLICITY

B2 **S. Kim, Y. Lee, J. Park, S. Lee, H. Lee** THE FIRST DISCOVERY OF REDFIELDIIFORM FISH (ACTINOPTERYGII) FROM THE UPPER TRIASSIC AMISAN FORMATION OF KOREA AND ITS PALEOBIOGEOGRAPHIC IMPLICATIONS

B3 **J. Driebergen, S. Keenan** COSMOPOLITAN OLIGOCENE ANURAN ASSEMBLAGES: PROXIES FOR THE EFFECTS OF CLIMATE CHANGE?

B4 **A. C. Ricker, P. L. Koch, J. Mueller, G. Böhme** RESOURCE PARTITIONING IN AN AMPHIBIAN COMMUNITY DURING THE LATE QUATERNARY

B5 **A. F. Howard, J. J. Head** ALTERNATE PHYLOGENETIC POSITIONS OF FOSSILS EFFECTS BODY SIZE ESTIMATES OF SNAKE ORIGINS

B6 **C. Nicholl, J. P. Rio, P. Mannion** AN EXAMINATION OF MIOCENE EUROPEAN CROCODYLIAN SPECIES DIVERSITY: THE PHYLOGENETIC RELATIONSHIPS OF ITALIAN AND MALTESE TOMISTOMINES

B7 **J. P. Rio, P. D. Mannion, M. Sutton** A REASSESSMENT OF THE PHYLOGENETIC CHARACTERISTICS OF CROCODYLIA USING A SUPER-MATRIX APPROACH

B8 **A. Srinivas, E. J. Rayfield, S. A. Tavares, J. Cunningham** CONSTRAINTS AND ADAPTATIONS IN CROCODILIAN SKULL FORM AND FUNCTION

B9 **W. Ma, S. Lautenschlager, M. Pittman, R. J. Butler** FINITE ELEMENT ANALYSIS OF OVIRAPTOROSAUR JAWS: IMPLICATIONS FOR DIETARY INFERENCE

B10 **M. Zaher, A. G. Sennikov, M. J. Benton, E. J. Rayfield** JAW MUSCULATURE IN PARAREPTILES: DIGITAL RECONSTRUCTION AND ECOLOGICAL IMPLICATIONS OF MUSCLE FORCES FOR PAREIASAURS AND PROCOLOPHONIDS

B11 **S. M. Hamilton, M. Cross, Y. Wang, M. J. Ryan, C. Sullivan** MUSCULAR RECONSTRUCTION AND COMPUTATIONAL MODELLING OF THE PECTORAL GIRDLE IN *LAMBEOSAURUS* (DINOSAURIA, HADROSAURIDAE).

B12 **A. P. McIntosh** PEDAL CLAW MORPHOLOGY OF *CONFUCIUSORNIS SANCTUS* AND ITS IMPLICATIONS FOR DIET AND BEHAVIOR

B13 **T. Sokolskyi, L. Zanno, J. C. Kosch** UNUSUAL TOOTH REPLACEMENT IN A NEW CENOMANIAN IGUANODONTIAN FROM THE MUSSENTUCHIT MEMBER OF THE CEDAR MOUNTAIN FORMATION

B14 **P. Cunningham, M. A. Loewen, J. Sertich** THE UTILITY OF PERIOSTEAL AGING TO ASSESS THE MATURITY OF ISOLATED THEROPOD CRANIAL AND FEMORAL ELEMENTS

B15 **S. Lee, Y. Lee, P. J. Currie, R. Sissons, J. Park, S. Kim, R. Barsbold, K. Tsogtbaatar** A NEW HALSZKARAPTIRINE FROM THE BARUUNGOYOT FORMATION OF MONGOLIA: PRELIMINARY DESCRIPTION AND PHYLOGENETIC ANALYSIS

B16 **E. A. Patellos, S. J. Nesbitt, C. F. Kammerer, A. Wyss, J. J. Flynn, L. Ranivoharimanana** A NEW REPTILE FROM THE ?MIDDLE TRIASSIC OF MADAGASCAR MAY REPRESENT THE EARLIEST-DIVERGING AVEMETATARSALIAN (ARCHOSAURIA)

B17 **S. Holpin, T. E. Williamson, S. L. Shelley, S. Brusatte** SIZE VARIATION IN POPULATIONS OF *TETRACLAENODON* (MAMMALIA, 'CONDYLARTHRA') FROM THE TORREJONIAN NALMA OF THE SAN JUAN BASIN, NEW MEXICO, REVEALS NEW INSIGHTS INTO THEIR EVOLUTION AND PALEO-ENVIRONMENT

B18 **Z. Kynigopoulou, S. L. Shelley, T. E. Williamson, S. L. Brusatte** THE POSTCRANIAL MORPHOLOGY AND PHYLOGENY OF TAENIODONTS (MAMMALIA, TAENIODONTA); DETERMINING LOCOMOTOR ADAPTATIONS IN PALEOGENE MAMMALS

B19 **A. C. Demers, J. P. Hunter** COMPATIBILITY OF THE PATTERNING CASCADE MODEL OF TOOTH DEVELOPMENT WITH PERIPTYCHID "CONDYLARTH" MOLAR DIVERSITY

B20 **H. P. Püschel, S. L. Shelley, T. E. Williamson, J. R. Wible, S. Brusatte** TESTING THE PHYLOGENY OF PERIPTYCHIDAE AND "ARCHAIC" PALEOCENE MAMMALS UNDER DIFFERENT OPTIMALITY CRITERIA

B21 **T. Engler, T. Martin** INFERRING DIETARY ADAPTATIONS OF PALEOCENE STEM MACROSCELIDEA BY DENTAL TOPOGRAPHY ANALYSES

B22 **M. Kouvari, A. Herrel, R. Cornette** WHAT CAN MORPHOLOGICAL CHANGES THROUGH TIME TELL US ABOUT DIET AND HUMAN-DRIVEN HABITAT CHANGES? THE CASE OF THE ETRUSCAN SHREW IN CORSICA

B23 **K. L. Garland, L. Hautier, S. Ferreira-Cardoso, M. Wright, Q. Martinez, P. Fabre, R. Lebrun, F. Delsuc** EXPLORING THE OLFACTORY CAPABILITIES OF ANT-EATING MAMMALS USING THE CRIBRIFORM PLATE AS AN OSTEOLOGICAL PROXY

B24 **R. E. Narducci, V. B. Deleon, M. T. Silcox, J. I. Bloch** ENDOCRANIAL SHAPE VARIATION IN FOSSIL AND MODERN XENARTHRANS USING 3D GEOMETRIC MORPHOMETRICS

B25 **A. Pearson, P. Polly, E. Bruner** TEMPORAL LOBE VARIATION IN EXTANT AND FOSSIL OLD WORLD MONKEYS (CATARRHINI, CERCOPITHECOIDEA)

B26 **A. W. Peng, S. S. Hopkins, E. B. Davis** MAMMALIAN MORPHOLOGICAL DISPARITY IN THE CONTEXT OF LANDSCAPE EVOLUTION AND TECTONISM IN THE MIOCENE OF NORTH AMERICA

B27 **T. L. Campbell, T. J. Dewitt, D. J. De Ruiter** ANALYSIS OF SOUTHERN AFRICAN PLEISTOCENE RODENT HUMERI FROM SWARTKRANS: MEMBERS 1–3

B28 **T. C. Hunt, C. E. Rinaldi** ENAMEL SCHMELZMUSTER INFLUENCES ENAMEL FRACTURE PATTERNS AND PROMOTES SHARPENING OF EVERGROWING INCISORS IN *CASTOR* AND *CASTOROIDES*

B29 **E. A. Shirley, D. C. Fisher, M. D. Cherney, A. N. Rountrey, J. J. El Adli, A. V. Protopopov, V. V. Plotnikov, S. Grigoriev** DOUBLE-SCANNING AND GAUSSIAN BLURRING IMPROVE QUALITY OF PALEONTOLOGICAL CT DATA: EXPERIMENTS WITH TWO MAMMOTH TUSKS

WEDNESDAY - SATURDAY, OCTOBER 9-12, 2019
EDUCATION AND OUTREACH POSTER SESSION
GREAT HALL 1&2
Authors with odd-numbered boards must be present from 4:15 - 6:15 p.m. Wednesday, October 9

Authors with even-numbered boards must be present from 4:15 - 6:15 p.m. Friday, October 11

B30 **T. Rodrigues** PALEONTOLOGY EDUCATION THROUGH PALEOART: A TWO-YEAR EXPERIENCE IN A BRAZILIAN HIGH SCHOOL

B31 **P. J. Bishop, A. Cuff, K. Michel, L. Kermode, J. R. Hutchinson** ENGAGING AND EXCITING PRE-UNIVERSITY STUDENTS IN STEM VIA 3D MODELLING OF DINOSAUR ANATOMY AND BIOMECHANICS

B32 **A. K. Hastings, C. Vargas-Grant, S. Sahlstrom, C. Reuss, C. Hart** 3D PRINTING OF THE GIANT SNAKE *TITANOBOA* AS A MEANS OF STEM ENGAGEMENT IN HIGH SCHOOL PROGRAMMING

B33 **R. G. Figueiredo** CREATING SCIENCE OUTREACH MATERIALS AS A TOOL FOR SCIENTIFIC LITERACY IN HIGH SCHOOL: EXAMPLES FROM PALEONTOLOGY AND NATURAL HISTORY

B34 **S. G. Strait, L. Lester, J. Cantrell** UNIVERSITY OUTREACH SERVING RURAL COMMUNITIES: WEST VIRGINIA SCIENCE ADVENTURES K–12 STEM SUMMER CAMPS

B35 **A. Torices, M. Ferrer Ventura, P. Navarro Lorbes, R. San Juan Palacios** WALKING WITH DINOSAURS: THE USE OF PALEOICHNOLOGICAL SITES AS TOOLS FOR EDUCATION AND OUTREACH

B36 **T. L. Adams, D. Lehrmann, E. Deschner, A. Lehrmann, E. J. Blake, M. B. Suarez, A. Godet** DINOSAUR TRACKS AS AN EDUCATIONAL RESOURCE: REDISCOVERING THE HERITAGE MUSEUM OF THE TEXAS HILL COUNTRY

B37 **E. L. Bernard, D. J. Ward, A. Ward** SHARKS' TEETH, SHELLS, AND CITIZEN SCIENCE

B38 **R. A. Lawrence, S. Hocknull** ENGAGING THE PUBLIC WITH SMALL VERTEBRATE FOSSILS AND UTILIZING CITIZEN SCIENCE TO MAXIMISE SCIENTIFIC DISCOVERY AT CAPRICORN CAVES, CENTRAL EASTERN QUEENSLAND, AUSTRALIA

B39 **T. Stidham** PRACTICES FOR NATURAL HISTORY MUSEUM PROGRAMS TO CLOSE THE DISABILITY ENGAGEMENT GAP FOR PEOPLE WITH THE AUTISM SPECTRUM DISORDER

B40 **R. L. Lauer, E. L. Bernard, D. J. Ward, B. H. Lauer, A. E. Ward** A COMPARISON BETWEEN THE EDUCATIONAL OUTREACH PROGRAMS DEVELOPED BY THE LAUER FOUNDATION, CHICAGO, USA AND THE FOSSIL FISH SECTION OF THE NATURAL HISTORY MUSEUM, LONDON, UK

B41 **A. E. Marcy, L. D. White** SCIENTIFIC METHOD ON THE MOVE: GAMES AND INTERACTIVES CONVEY THE DYNAMIC, COLLABORATIVE NATURE OF SCIENCE

B42 **J. H. Nestler, S. K. Drumheller, M. T. Lam, A. C. Pritchard, M. R. Borths, M. E. Leone Gold, J. H. Miller** HALF A DECADE OF LARGE-SCALE SCIENCE OUTREACH: USING THE INTERNET FORUM ASKSCIENCE TO CONNECT WITH THE PUBLIC

B43 **G. Santos, L. Lundgren, M. Barboza-Ramirez, M. J. Ziegler, B. Stoneburg** COSPLAY FOR SCIENCE: UTILIZING POP CULTURE NARRATIVES AS A MEANS FOR SCIENCE EDUCATION OUTSIDE TRADITIONAL LEARNING CENTERS

B44 **S. M. Rutzky** FUNDING MEANINGFUL RESEARCH EXPERIENCES ENCOURAGES UNDERGRADUATES TO PURSUE DEGREES IN PALEONTOLOGY AND GEOSCIENCE

B45 **L. D. White, D. C. Pagnac, G. Bowser** FIELDWORK INSPIRING EXPANDED LEADERSHIP AND DIVERSITY (FIELD): OVERCOMING BARRIERS TO FIELDWORK IN PALEONTOLOGY

B46 **A. W. Kellner, J. M. Sayão** THE PALEOANTAR PROJECT—COMBINATION OF SCIENCE, EDUCATION AND OUTREACH FOCUSING ON ANTARCTICA

B47 **S. S. Sumida, S. Walker** THE PATTERNS PROJECT—PHYLOGENY-DRIVEN, ANATOMICAL TAXON TRANSFORMATION AS EDUCATION RESOURCE FOR NATURAL SCIENCES: USING DIGITAL MORPHING ANIMATION TO INTERPOLATE STRUCTURES AND ENHANCE EDUCATION AND OUTREACH IN VERTEBRATE PALEONTOLOGY

B48 **K. Fox-Dobbs, T. Hill, D. Ibarra, J. Oster, P. Workshop Participants** A CALL TO ACTION AFTER THE PALEO TO POLICY WORKSHOP: HOW TO BUILD BRIDGES BETWEEN PALEONTOLOGICAL RESEARCH AND DECISION MAKING

B50 **S. Turner, A. Berta** "BONE HUNTERS" PROJECT—AUSTRALASIAN WOMEN IN VERTEBRATE PALEONTOLOGY

B51 **S. Hinic-Frlog, R. R. Reisz** USING FOSSIL SCIENTIFIC STORIES AS TOOLS TO ENGAGE STUDENTS WITH SCIENTIFIC LITERACY LEARNING OUTCOMES IN A CORE DEPARTMENTAL CURRICULUM

WEDNESDAY - SATURDAY, OCTOBER 9-12, 2019
PREPARATORS' SESSION
GREAT HALL 1&2
Authors must be present from 4:15 - 6:15 p.m. Thursday, October 10

B52 **T. Sato, A. Shinya** A PRACTICAL GUIDE TO START A NEW VERTEBRATE FOSSIL PREPARATION LAB

B53 **A. Shinya, C. J. Van Beek, P. Makovicky** CHALLENGES IN THE FIELD: COLLECTING WET VERTEBRATE FOSSILS WITH THE APPLICATION OF ACRYSOL WS24, ACRYLOID B72, AND CYANOACRYLATE CONSOLIDANTS

B54 **D. J. Ward, A. E. Ward** SIEVING WITHOUT TEARS: THE FIRST 40 YEARS OF AUTOMATED SEDIMENT SCREENING FOR MICROVERTEBRATES

B55 **M. R. Fair, P. J. May, S. J. Jabo, G. Dallman, A. S. Madill** REMOVING ASBESTOS FROM RECONSTRUCTED AREAS OF SPECIMENS AT THE SMITHSONIAN MUSEUM OF NATURAL HISTORY SAFELY AND WITH THE LEAST IMPACT TO THE SPECIMEN

B56 **P. May, D. Evans, A. Madill, M. Fair** UNEARTHING A GIANT: THE MAKING OF *ZUUL*

B57 **J. E. Wilkinson** ACID PREPARATION OF CARBONACEOUS FOSSIL MATERIAL USING A MEDICAL INTRAVENOUS KIT FOR TARGETED DELIVERY OF 7% ACETIC ACID SOLUTION.

B58 **S. R. Johnston, A. Davidson** PHOTOGRAPHS AND FOSSIL FILLINGS: A REVERSIBLE POLYESTER FILL AND UTILIZING NATIVE IPHONE APPS FOR COMPREHENSIVE PHOTO DOCUMENTATION

B59 **M. Ferrer Ventura, A. Torices, X. Mas I Barberà, R. San Juan Palacios, P. Navarro Lorbés** THE USE OF TRADITIONAL MORTARS AND HIDROFUGANTS IN RESTORATION AND PRESERVATION OF PALEOICHNOLOGIAL SITES

B60 **V. R. Rhue** MANAGEMENT OF COLLECTIONS CARE PROJECTS: REFINING THE APPROACH TO CURATION WORKFLOWS AND PERSONNEL TRAINING

B61 **B. A. Lauters** COMPARATIVE ANALYSIS OF PARALOID B-72 AND BUTVAR B-76 DISSOLVED IN ACETONE SOLUTIONS

B62 **E. Ghezzo, M. Massironi, E. B. Davis** HIGH RESOLUTION REMOTE SENSING APPLIED TO FOSSIL DISCOVERY: OVERVIEW AND PROSPECTS

B63 **R. Aguilar** MILLIONS OF YEARS, DOZENS OF SAMPLES, ONE SINGLE SCAN: NEW METHODS TO RAPIDLY INCREASE THE NUMBER OF SPECIMENS CAPTURED IN A SINGLE HIGH QUALITY SCAN.

WEDNESDAY AFTERNOON, OCTOBER 9, 2019
REGULAR POSTER SESSION I
GREAT HALL 1&2
Authors must be present from 4:15 - 6:15 p.m. Wednesday, October 9

B64 **N. T. Rasolofomanana, K. E. Samonds, L. R. Godfrey, M. Andriambelomanana, T. H. Andrianavalona, N. T. Ramihangihajason, R. B. Rakotozandry, B. Z. Nomenjanahary, M. Irwin, B. Crowley** A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR) WITH IMPLICATIONS FOR THE CHRONOLOGY OF HABITAT AND MEGAFAUNAL COMMUNITY CHANGE ON MADAGASCAR'S CENTRAL HIGHLANDS

B65 **M. P. Jovanovic, H. Blain, J. Bisbal-Chinesta, D. Djuric, K. Bogicevic, D. Nenadic, J. Agusti** LAST NEANDERTHALS VS. *HOMO SAPIENS*: NEW PALEOENVIRONMENTAL AND PALEOCLIMATIC DATA USING THE SMALL VERTEBRATE ASSEMBLAGES FROM SERBIA (BALKAN PENINSULA, SOUTHEASTERN EUROPE)

B66 **T. Ramm, K. M. Thorn, C. Hipsley, J. Mueller, S. Hocknull, J. Melville** REPTILE DIVERSITY OF MCEACHERN'S CAVE, A LATE PLEISTOCENE TO HOLOCENE FOSSIL DEPOSIT FROM VICTORIA, AUSTRALIA

B67 **D. T. Ledesma, M. Kemp** USING FOSSILS TO UNDERSTAND THE IMPACTS OF CLIMATE CHANGE ON HERPETOFAUNA IN CENTRAL TEXAS

B68 **A. Folie, A. Martínez Monzón, J. López-García, I. Lozano-Fernández, H. Blain** AMPHIBIANS AND SQUAMATES FROM THE LATE PLEISTOCENE OF CAVERNE MARIE-JEANNE (BELGIUM)

B69 **B. H. Lauer, R. H. Lauer, E. L. Bernard, C. J. Duffin, E. V. Popov, D. J. Ward** OBSERVATIONS ON THE MESOZOIC CHIMAEROID, *ELASMODECTES* NEWTON 1878

B70 **R. M. Lindoso, J. Maisey, I. D. Carvalho** BRAZILIAN CRETACEOUS FISHES DISTRIBUTION SHED LIGHT ON ECOSYSTEMS IN WESTERN GONDWANA

B71 **S. Turner, R. Soler-Gijon, E. Siebert, M. McCurry, S. Avery** THE DENTITION AND SKELETON OF *MOOREODONTUS*: NEW INSIGHTS INTO THE ORIGIN AND DEVELOPMENT OF THE TRIASSIC XENACANTH SHARKS

B72 **D. J. Ehret, K. M. Claeson** CHONDRICHTHYANS AND OSTEICHTHYANS FROM THE LATE CRETACEOUS (CAMPANIAN) ELLISDALE SITE, MONMOUTH COUNTY, NEW JERSEY

B73 **P. A. Holroyd** ASSESSING THE IMPACT OF SAMPLING BIASES AND TECTONIC CONTROLS ON PALEOGENE MARINE VERTEBRATES FROM THE EASTERN NORTH PACIFIC

B74 **M. D. Gottfried, R. E. Fordyce** EXPANDING THE SCOPE OF MESOZOIC AND CENOZOIC CHONDRICHTHYAN AND BONY FISH RECORDS FROM NEW ZEALAND

B75 **C. E. Syme** THE FIRST COMPREHENSIVE RECORD OF ELASMOBRANCHS FROM THE MID-PALEOCENE BOONGEROODA GREENSAND MEMBER OF WESTERN AUSTRALIA

B76 **C. J. Noguera, E. L. Bernard, R. Belben, R. J. Twitchett** IMPACT OF EOCENE–OLIGOCENE GLOBAL COOLING ON THE SIZE OF LAMNIFORM SHARKS

B77 **A. W. Gale** FIRST RECORDS OF THE SAWFISHES *PRISTIS* AND *ANOXYPRISTIS* FROM THE OLIGOCENE OF NORTH AND SOUTH CAROLINA, USA

B78 **T. Ziegler, D. Hocking, E. M. Fitzgerald** AN ASSOCIATED SPECIMEN OF THE LAMNIFORM SHARK *CARCHAROCLES ANGUSTIDENS* FROM VICTORIA, AUSTRALIA, AND EVIDENCE OF POST-MORTEM FAUNAL SUCCESSION

B79 **K. Shimada** THE BODY SIZE OF MEGATOOTHED SHARK, *OTODUS MEGALODON* (LAMNIFORMES, OTODONTIDAE), REVISITED

B80 **M. L. Griffiths, M. A. Becker, H. A. Maisch Iv, E. R. Kast, A. . Akhtar, R. A. Eagle, S. L. Kim, D. M. Sigman, J. A. Higgins, K. Shimada** THE EVOLUTION AND EXTINCTION OF *OTODUS MEGALODON*: NEW INSIGHTS FROM NITROGEN, CALCIUM, AND 'CLUMPED' ISOTOPE RATIOS

B81 **V. J. Perez** CHONDRICHTHYAN DIVERSITY OF FLORIDA IN RESPONSE TO CENOZOIC CLIMATE CHANGE

B82 **H. Wang, Y. Wang** DEALING WITH THE UNKNOWN DATA IN MAMMALIAFORM PHYLOGENY

B83 **M. Celik, M. J. Phillips** ACCOUNTING FOR PHYLOGENETIC AND TEMPORAL CONFLICT AMONG ANATOMICAL PARTITIONS IDENTIFIES AN END-TRIASSIC ORIGIN OF CROWN MAMMALS

B84 **T. Martin, A. Averianov, J. A. Schultz, A. H. Schwermann, O. Wings** LATE JURASSIC SYNAPSIDS AND MAMMALS FROM THE LANGENBERG QUARRY (NORTHERN GERMANY)

B85 **T. H. Rich, T. Flannery, A. R. Evans, M. White, T. Ziegler, A. Maguire, P. Vickers-Rich** AFFINITIES OF AUSTRALIAN TRIBOSPHENIC MESOZOIC MAMMALS

B86 **C. S. Scott, C. Sullivan, D. A. Eberth, D. R. Braman** NORTHERNMOST RECORD OF LANCIAN (LATEST CRETACEOUS) MAMMALS

B87 **A. J. Ashbaugh, J. M. Theodor, C. Scott** P4 SIZE VERSUS SHAPE IN DISCRIMINATING SPECIES OF *MESODMA* AND *NEOPLAGIAULAX* (MAMMALIA, MULTITUBERCULATA): DOES SIZE MATTER?

B88 **S. V. Robson, C. Scott, J. M. Theodor** BONY LABYRINTH MORPHOLOGY OF THE PANTODONT *CAENOLAMBDA PATTERSONI*

B89 **P. E. DePolo, T. E. Williamson, S. L. Shelley, S. L. Brusatte** A MIXED ASSEMBLAGE OF PALEOCENE MAMMALS FROM THE SAN JUAN BASIN, NEW MEXICO, USA

B90 **S. Ting, X. Wang, J. Meng** CRANIAL MORPHOLOGY OF *HSIANGOLESTES* (MAMMALIA, INSECTIVORA) AND *NARANIUS* (MAMMALIA, CIMOLESTA) AND THE PHYLOGENY OF BASAL INSECTIVORES

B91 **S. Zack** THE FIRST NORTH AMERICAN *PROPTERODON* (MAMMALIA, HYAENODONTA) FROM THE LATE UINTAN OF UTAH

B92 **Y. Wang, Q. Li, B. Bai, X. Jin, F. Mao, J. Meng, K. C. Beard** NEW DATA ON THE PALEOGENE STRATIGRAPHY AND MAMMALIAN PALEONTOLOGY OF THE ERLIAN BASIN, INNER MONGOLIA, CHINA AND ITS IMPLICATIONS FOR ASIAN PALEOGENE BIOCHRONOLOGY

B93 **T. J. Orr, L. Lawrence, E. M. Roberts, M. D. Schmitz, P. M. O'Connor, C. Mtelela, N. J. Stevens** HIGH-PRECISION TEMPORAL, PALEOCLIMATIC, AND PALEOENVIRONMENTAL ANALYSIS OF OLIGOCENE VERTEBRATE-BEARING SEQUENCES IN THE RUKWA RIFT BASIN, TANZANIA

B94 **N. J. Stevens, E. M. Roberts, C. Mtelela, P. M. O'Connor** LATE OLIGOCENE MACROSCELIDEANS FROM THE NSUNGWE FORMATION, RUKWA RIFT BASIN, TANZANIA

B95 **P. Li, P. E. Morse, R. F. Kay** DENTAL TOPOGRAPHIC CHANGE AND DIETARY INFERENCE IN *HOMUNCULUS PATAGONICUS* AMEGHINO, 1891 (MAMMALIA, PRIMATES)

B96 **H. Insani, M. Takai** SHAPE TRANSFORMATION MODELS TO PREDICT THE EXTINCTION TIME OF *MACACA NEMESTRINA* IN JAVA ISLAND, INDONESIA

B97 **G. San Martin Flores, L. Nagendran, M. M. Lang, M. T. Silcox** CRANIAL ENDOCASTS OF COLUGOS, AND THEIR RELEVANCE TO UNDERSTANDING THE EARLY PHASES OF THE EVOLUTION OF THE BRAIN IN EUARCHONTA AND PRIMATES

B98 **X. Xu** A REVIEW OF MESOZOIC FOSSIL FEATHER MORPHOLOGIES: PROBLEMS AND PROSPECTS

B99 **M. McNamara** PRESERVATION AND PALEOBIOLOGICAL APPLICATIONS OF FOSSIL VERTEBRATE INTEGUMENT: INSIGHTS FROM TISSUE ULTRASTRUCTURE, CHEMISTRY, AND TAPHONOMIC EXPERIMENTS

B100 **L. Kocsis, L. Leuzinger, M. Fernández, Z. Luz, T. Vennemann, A. Ulianov** GEOCHEMICAL CHARACTERIZATION OF LATE CRETACEOUS MARINE REPTILES AND FISH FROM ANTARCTICA AND PATAGONIA

B101 **T. L. Durham** STABLE ISOTOPE ANALYSES ($\delta^{13}C$, $\delta^{18}O$) OF FOSSIL REPTILE REMAINS FROM THE GRAY FOSSIL SITE, SOUTHERN APPALACHIANS, TENNESSEE

B102 **P. V. Ullmann, K. Macauley, R. D. Ash** GEOCHEMICAL TAPHONOMY OF *TYRANNOSAURUS REX* MOR 1125, THE FIRST CRETACEOUS FOSSIL TO YIELD ENDOGENOUS PROTEIN SEQUENCES

B103 **G. E. Webb, K. J. Ferguson, A. A. Chagas, V. N. Vakil, G. J. Price, R. V. Burne** TRACE ELEMENTS OF TERRESTRIAL SURFACE WATERS AND BONE DIAGENESIS: A LEARNING CURVE

B104 **E. B. Davis, E. Ghezzo, M. Massironi, S. Malavasi, G. Bianucci, A. Gioncada, A. D. Marsh, W. Parker, S. S. Hopkins** HIGH RESOLUTION REMOTE SENSING APPLIED TO PALEONTOLOGY: CASE STUDIES FROM SATELLITE IMAGERY AND CONVENTIONAL CAMERA PHOTOS

B105 **J. Bevitt, R. R. Reisz, B. Gee, M. E. Jones, M. A. White** NEUTRON MICRO-CT AS AN EMERGING NON-DESTRUCTIVE TOOL FOR PALEONTOLOGY

B106 **J. Anquetin, G. Billet** TOWARDS A MORE COST-EFFECTIVE, TRANSPARENT, AND OPEN PUBLICATION WORKFLOW: PEER COMMUNITY IN PALEONTOLOGY (PCI PALEO), A COMMUNITY-DRIVEN PEER REVIEW PLATFORM FOR PALEONTOLOGY

B107 **T. M. Richards, P. E. Stumkat, S. W. Salisbury** NEW CRESTED PTEROSAUR MATERIAL FROM THE LOWER CRETACEOUS (ALBIAN) TOOLEBUC FORMATION OF QUEENSLAND, AUSTRALIA, AND THE EVOLUTION OF AUSTRALIAN PTEROSAURS

B108 **H. Chen, S. Jiang, X. Cheng, R. Qiu, X. Wang** SHEDDING NEW LIGHT ON THE CONFIGURATION OF THE PTERYGOID AND THE ECTOPTERYGOID IN DERIVED PTEROSAURS THROUGH CT SCANNING

B109 **M. Sprague, M. A. McLain** A LARGE PTEROSAUR HUMERUS FROM BONE CABIN QUARRY, MORRISON FORMATION, COLORADO

B110 **F. G. Cardozo, G. Sobral, T. Rodrigues** ECOLOGICAL NICHES AMONG PTEROSAURS FROM THE SOLNHOFEN ARCHIPELAGO

B111 **B. W. Griffin, O. E. Demuth, E. Martin-Silverstone, E. J. Rayfield** SIMULATED RANGE OF MOTION MAPPING OF DIFFERENT HIP POSTURES DURING LAUNCH OF A MEDIUM SIZED ORNITHOCHEIRID PTEROSAUR

B112 **S. J. Nesbitt** A NEW DINOSAUR FROM THE *COELOPHYSIS* QUARRY (?END NORIAN) INDICATES THAT LOW LATITUDE DINOSAURIAN ASSEMBLAGES REMAINED SIMILAR IN CLADE COMPOSITION THROUGHOUT THE TRIASSIC PERIOD

B113 **F. Knoll, S. Lautenschlager, A. Serrano-Martínez, F. Ortega** PALEONEUROLOGY OF A NEW THEROPOD SPECIMEN FROM THE 'ARGILES DE L'IRHAZER', MIDDLE JURASSIC OF NIGER

B114 **P. J. Makovicky, N. Smith, A. F. Andersen, W. Hammer** BRAINCASE ANATOMY AND A DIGITAL ENDOCAST OF *CRYOLOPHOSAURUS ELLIOTI* (DINOSAURIA: NEOTHEROPODA)

B115 **H. Dai, X. Xu** A NEW MEGALOSAURID THEROPOD FROM THE MIDDLE JURASSIC XINTIANGOU FORMATION OF CHONGQING, PEOPLE'S REPUBLIC OF CHINA AND ITS IMPLICATION FOR EARLY TETANURAN EVOLUTION

B116 **M. Moreno Azanza, R. Coimbra, E. Puértolas-Pascual, J. Russo, B. Bauluz, O. Mateus** CRYSTALLOGRAPHY OF *LOURINHANOSAURUS* EGGSHELLS (DINOSAURIA, THEROPODA, ALLOSAUROIDEA)

B117 **S. B. Gutherz, J. R. Groenke, P. M. O'Connor, J. Sertich** PALEOPATHOLOGY IN NEW MATERIALS OF *MAJUNGASAURUS CRENATISSIMUS* FROM THE MAEVARANO FORMATION, NORTHWESTERN MADAGASCAR

B118 **K. K. Voegele, P. V. Ullmann, J. Grove, R. Nellermoe** CHARACTERIZING THE ONTOGENETIC STAGE OF A VERY LARGE SPECIMEN OF *ALLOSAURUS* FROM THE JURASSIC OF WYOMING WITH SUBADULT CHARACTERISTICS

B119 **H. Suzuki, Y. Kobayashi, M. Kano, T. Karasawa, S. Hayashi, A. Ota, T. Miyaji** A THEROPOD REMAIN FROM THE UPPER CRETACEOUS YEZO GROUP, HABOROGAWA FORMATION IN ASHIBETSU CITY, HOKKAIDO PREFECTURE, JAPAN

B120 **D. W. Larson, K. Brink** A SMALL THEROPOD TOOTH ASSEMBLAGE FROM THE ST. MARY RIVER FORMATION OF SOUTHERN ALBERTA, CANADA: IMPLICATIONS FOR IDENTIFYING ISOLATED THEROPOD TEETH AND NORTH AMERICAN THEROPOD BIOGEOGRAPHY

B121 **K. A. Beguesse, A. Canoville, L. L. Herzog, L. Zanno** BONE PATHOLOGIES IN THE EARLY CRETACEOUS THERIZINOSAURIAN *FALCARIUS UTAHENSIS*

B122 **N. Ikegami, J. Scannella, Y. Tomida** ADDITIONAL THERIZINOSAUROID BONES COLLECTED FROM THE UPPER CRETACEOUS MIFUNE GROUP, KUMAMOTO, JAPAN

B123 **C. Tsogtbaatar, Y. Kobayashi** A NEW ORNITHOMIMID (THEROPODA, ORNITHOMIMOSAURIA) FROM THE UPPER CRETACEOUS NEMEGT FORMATION OF BUGIIN TSAV, MONGOLIA

B124 **R. Hirayama, T. Tsuihiji, H. Uno** A TYRANNOSAUROID TOOTH FROM THE LATE CRETACEOUS (TURONIAN) OF NORTHERN JAPAN

B125 **M. M. Rhodes, P. J. Currie** HOMOLOGY OF THE MICRORAPTORINE LATERAL PUBIC TUBERCLE

B126 **M. J. Powers, P. J. Currie** DISCRETE VARIATION IN MAXILLAE OF EUDROMAEOSAUR DINOSAURS AND ITS RELATION TO TRENDS IN SNOUT MORPHOLOGY

THURSDAY MORNING, OCTOBER 10, 2019
ROMER PRIZE SESSION
MEETING ROOM M4
MODERATORS: Kenneth Angielczyk and Julia Clarke

8:00 **A. Elsler** HETEROGENEOUS EVOLUTIONARY RATES DURING THE FIRST HALF OF TERRESTRIAL TETRAPOD EVOLUTION

8:15 **D. Foffa** DIETARY AND HABITAT PARTITIONING OF JURASSIC MARINE REPTILE ECOSYSTEMS

8:30 **M. M. Johnson** WHAT ARE TELEOSAURIDAE AND *STENEOSAURUS*? THE TAXONOMT, SYSTEMATICS, AND ECOMORPHOLOGICAL DIVERSITY OF TELEOSAUROIDEA (CROCODYLOMORPHA, THALATTOSUCHIA)

8:45 **A. Krahl** MUSCLE RECONSTRUCTIONS AND HUMERUS AND FEMUR FINITE ELEMENT ANALYSES OF *CRYPTOCLIDUS EURYMERUS* (PLESIOSAURIA) SUPPORT UNDERWATER FLIGHT AND FLIPPER TWISTING

9:00 **G. F. Funston** GROWTH AND BEHAVIOUR IN OVIRAPTOROSAURS

9:15 **S. W. Evers** NEW INSIGHTS INTO THE EVOLUTION OF SECONDARILY MARINE LIFESTYLES, MARINE ADAPTATION, AND DIVERSIFICATION OF TURTLES

9:30 **D. F. Terrill** STRONTIUM ISOTOPES: A NEW TOOL FOR EXPLORING MIGRATORY BEHAVIOURS IN ORNITHISCHIAN DINOSAURS

9:45 **S. A. Singh** TROPHIC MORPHOLOGY REVEALS THE ECOLOGICAL DYNAMICS OF EARLY MESOZOIC HERBIVORES

10:15 **C. G. Klein** MOLECULAR AND MORPHOLOGICAL PATTERNS OF SURVIVAL, NOT EXTINCTION, OF SNAKES THROUGH THE CRETACEOUS–PALEOGENE MASS EXTINCTION

10:30 **K. M. Thorn** ONE SKINK, TWO SKINK, BIG SKINK, BLUE SKINK: MIOCENE ORIGINS AND PLIO–PLEISTOCENE GIGANTISM IN THE AUSTRALASIAN GENUS *TILIQUA* (SQUAMATA, SCINCIDAE)

10:45 **R. J. Brocklehurst** ON THIN AIR: VENTILATION MECHANICS IN LIVING AND FOSSIL BIRDS

11:00 **R. J. Haupt** MAKING SPACE FOR GROUND SLOTHS: TESTING THE POTENTIAL FOR MODERN SLOTH STABLE ISOTOPE OFFSETS TO REINTERPRET GROUND SLOTH DIETARY ECOLOGY

11:15 **A. Lanzetti** DEVELOPING A NEW HABIT: ONTOGENY TRACKS THE EVOLUTION OF FILTER FEEDING IN BALEEN WHALES

11:30 **S. D. Arman** INHERENT DIETARY FLEXIBILITY WAS KEY TO THE EVOLUTIONARY SUCCESS OF KANGAROOS

11:45 **B. P. Tanis** LOOSENING THE MACROEVOLUTIONARY RATCHET: DOES DIETARY PLASTICITY ALTER MORPHOLOGICAL INSIGHTS INTO CANID EVOLUTION?

12:00 **S. Kealy** THE APPLICATION OF PHYLOGEOGRAPHY TO INVESTIGATE POSSIBLE ANTHROPOGENIC TRANSLOCATIONS: A PRELIMINARY ANALYSIS OF THE CUSCUS (PHALANGERIDAE)

THURSDAY MORNING, OCTOBER 10, 2019
TECHNICAL SESSION VI: MAMMALS II
MEETING ROOM M1&2
MODERATORS: Suzanne Cote and Dorien de Vries

8:00 **E. H. Reed** FOSSIL RECORD OF THE SOUTHERN BENT-WING BAT (*MINIOPTERUS ORIANAE BASSANII*) FROM QUATERNARY DEPOSITS AT NARACOORTE CAVES, SOUTH AUSTRALIA: IMPLICATIONS FOR CONSERVATION OF A CRITICALLY ENDANGERED SPECIES

8:15 **C. Lopez-Aguirre, A. Link** DENTAL TOPOGRAPHY ANALYSIS AND DIETARY INFERENCE OF THE MIOCENE NEOTROPICAL BAT *NOTONYCTERIS MAGDALENENSIS* FROM LA VENTA, COLOMBIA

8:30 **J. L. Alumbaugh, K. Samonds, S. M. Goodman, L. Godfrey** A MORPHOMETRIC ASSESSMENT OF MODERN AND EXTINCT *MACRONYCTERIS* SPP. (CHIROPTERA, HIPPOSIDERIDAE) ON MADAGASCAR

8:45 **D. De Vries, H. M. Sallam, E. R. Seiffert** DENTAL TOPOGRAPHIC EVOLUTION IN RODENTS ACROSS THE EOCENE–OLIGOCENE BOUNDARY IN THE FAYUM DEPRESSION, EGYPT

9:00 **S. S. Hopkins, J. J. Calede** OLIGO-MIOCENE APLODONTIOID RODENTS REVEAL FAUNAL AND ECOLOGICAL RELATIONSHIPS BETWEEN CENTRAL OREGON AND WESTERN MONTANA

9:15 **J. Cramb, S. Hocknull, G. Price** A TALE OF TWO MICE: *POGONOMYS* AND *LEGGADINA* (RODENTIA, MURINAE) FROM PLEISTOCENE CAVE DEPOSITS AT MT ETNA, EASTERN QUEENSLAND, AUSTRALIA

9:30 **A. E. Marcy, K. C. Rowe, E. Sherratt, T. Guillerme, M. J. Phillips, V. Weisbecker** INTRINSIC CONSTRAINTS APPEAR TO UNDERLIE STRONG ALLOMETRIC PATTERNS IN AUSTRALIAN RODENT DIVERSITY

9:45 **M. M. Lang, G. San Martin Flores, O. Bertrand, L. Nagendran, S. Lopez-Torres, M. T. Silcox** ENDOCRANIAL SHAPE VARIATION WITHIN EUARCHONTOGLIRES USING 3D GEOMETRIC MORPHOMETRICS

10:15 **G. Sansalone, K. Allen, J. Ledogar, S. Ledogar, A. Profico, S. Wroe, P. Raia** THINK BIG: EVOLUTIONARY ALLOMETRY AS A MAJOR FACTOR IN RATES OF MORPHOLOGICAL EVOLUTION OF THE PRIMATE BRAIN SHAPE

10:30 **L. M. MacLatchy, J. M. Kingston, M. M. Malone** DIETARY NICHES OF EARLY MIOCENE FOSSIL HOMINOIDS FROM UGANDA

10:45 **J. Kingston, L. MacLatchy, M. Malone** ISOTOPIC VARIATION IN MODERN HOMINOID DIETARY NICHES: IMPLICATIONS FOR INTERPRETING THE FOSSIL PRIMATE RECORD

11:00 **T. M. Smith, D. R. Green, I. S. Williams** WEEKLY-SCALE OXYGEN ISOTOPE MEASUREMENTS IN PRIMATE TEETH REVEAL ANCIENT ENVIRONMENTAL VARIATION

11:15 **D. R. Begun** *NAKALIPITHECUS* AND HOMININE ORIGINS

11:30 **S. Cote, K. McNulty, J. Kelley** AN UNUSUAL FOSSIL HOMINOID ASSEMBLAGE FROM TINDERET, KENYA

11:45 **J. L. Cantalapiedra, M. Alberdi, J. Prado, H. Zhang, O. Sanisidro, F. Blanco, J. Saarinen** ECOLOGICAL FUNCTION AND MACROEVOLUTIONARY PATTERNS IN PROBOSCIDEANS

12:00 **O. Sanisidro Morant, J. López Cantalapiedra, S. Cote** A REVIEW OF AFRICAN ELASMOTHERES (MAMMALIA, RHINOCEROTIDAE) AND THEIR ROLE ON EARLY MIOCENE MIGRATION EVENTS INTO EAST AFRICA

THURSDAY MORNING, OCTOBER 10, 2019
TECHNICAL SESSION VII: ARCHOSAURS
MEETING ROOM M3
MODERATORS: Elizabeth Martin-Silverstone and Alan Turner

8:00 **J. A. Schwab, M. T. Young, J. M. Neenan, S. Walsh, L. M. Witmer, Y. Herrera, K. Dollman, S. Brusatte** BACK TO THE SEA—ADAPTATIONS OF THE TYMPANIC SYSTEM IN THALATTOSUCHIAN CROCODYLOMORPHS

8:15 **D. Pol, P. C. Sereno** NEW JURASSIC AND CRETACEOUS NEOSUCHIANS FROM THE SAHARA ADD TO AFRICA'S REMARKABLE CROCODYLIFORM DIVERSITY AND ITS PALEOGEOGRAPHIC CONNECTIONS WITH NORTHERN LANDMASSES

8:30 **A. H. Turner, A. Watanabe, A. R. Beyl, A. H. D'Amore, E. Wilberg, J. H. Smaers, P. M. Gignac** ECOMORPHOLOGICAL AND ALLOMETRIC SIGNATURES IN ENDOCRANIAL SHAPE IN CROCODYLIANS

8:45 **M. A. White, P. Bell, N. E. Campione, G. Sansalone, T. Brougham** A NEW CROCODYLIFORM FROM THE WINTON FORMATION (CA 95 MA) OF QUEENSLAND (AUSTRALIA)

9:00 **M. Rubin** A NEW ALLIGATORINE FROM THE MIDDLE EOCENE OF UTAH AND THE ORIGINS OF MODERN ALLIGATOR

9:15 **J. Ristevski, G. J. Price, I. H. Sobbe, R. E. Molnar, J. Louys, J. Cramb, A. D. Nguyen, J. Zhao, Y. Feng, L. Beirne** A NEW ZIPHODONT EUSUCHIAN FROM THE PLEISTOCENE OF QUEENSLAND, AND IMPLICATIONS FOR AUSTRALASIA'S ZIPHODONT CROCODYLIAN DIVERSITY

9:30 **P. C. Sereno, D. Pol** AN AGILE UNARMORED NOTOSUCHIAN FROM CENOMANIAN-AGE ROCKS IN NIGER INITIATE THE PARTITIONING OF THE GONDWANAN PLEXUS OF *ARARIPESUCHUS* SPECIES

9:45 **J. M. Clark, B. B. Britt, D. J. Chure, G. F. Engelmann, S. M. Denarie, A. Ruebenstahl, B. C. Theurer, R. Esplin** A NEW BASAL CROCODYLOMORPH FROM THE NUGGET SANDSTONE OF UTAH—THE MOST COMPLETELY KNOWN "SPHENOSUCHIAN"

10:15 **R. S. Seymour, M. Ezcurra, D. Henderson, M. E. Jones, S. C. Maidment, C. V. Miller, S. J. Nesbitt, D. Schwarz, C. Sullivan, E. Wilberg** LARGE NUTRIENT FORAMINA IN FOSSIL FEMORA INDICATE INTENSE LOCOMOTOR AND METABOLIC ACTIVITY IN TRIASSIC ARCHOSAUROMORPHS AND THE PSEUDOSUCHIAN LINEAGE

10:30 **J. D. Fortner** PHYTOSAUR TOOTH DENTIN REVEALS NORIAN ARIDIFICATION PROCESSES INFLUENCED THE DIAGENETIC ENVIRONMENT OF THE CHINLE FORMATION

WITHDRAWN

10:45 **A. H. Pentland, S. F. Poropat, T. Sloan, R. A. Elliott, H. A. Elliott, J. A. Elliott, D. A. Elliott** A NEW ORNITHOCHEIRID PTEROSAUR FROM THE WINTON FORMATION (CENOMANIAN–LOWER TURONIAN) OF NORTHEAST AUSTRALIA: PALEOBIOGEOGRAPHIC AND PALEOECOLOGICAL IMPLICATIONS

11:00 **M. Qvarnström, E. Elgh, K. Owocki, P. E. Ahlberg, G. Niedźwiedzki** FILTER FEEDING IN LATE JURASSIC PTEROSAURS SUPPORTED BY COPROLITE CONTENTS

11:15 **A. W. Kellner, T. Rodrigues, R. G. Figueiredo, L. C. Weinschütz, G. A. Souza, A. S. Costa, C. W. Mueller, J. M. Sayão** FIRST PTEROSAUR (PTERODACTYLOIDEA) SPECIMENS FROM THE ANTARCTIC PENINSULA

11:30 **E. Martin-Silverstone, D. M. Unwin, P. M. Barrett** A NEW, THREE-DIMENSIONALLY PRESERVED MONOFENESTRATAN PTEROSAUR FROM THE MIDDLE JURASSIC OF SCOTLAND AND THE COMPLEX EVOLUTIONARY HISTORY OF THE SCAPULO-VERTEBRAL ARTICULATION

11:45 **A. K. Behrensmeyer, R. L. Whatley, A. J. Fitch, W. Parker, S. McIntire, A. C. Pritchard, B. Kligman, R. G. Cline** TAPHONOMY AND PALEOCOMMUNITY RECONSTRUCTION OF A PTEROSAUR-BEARING FOSSIL ASSEMBLAGE IN THE UPPER TRIASSIC OF ARIZONA

12:00 **Y. Zhang, W. Morita, J. Jernvall** TOWARDS AN ADVANCED WEIGHTING APPROACH TO ACCOUNT FOR CHARACTER INTERDEPENDENCIES IN AN ADJUSTED PARSIMONY METHOD, FOR PHYLOGENETIC INFERENCE USING PHENOTYPIC DATA

THURSDAY AFTERNOON, OCTOBER 10, 2019
TECHNICAL SESSION VIII: MAMMAL CRANIAL EVOLUTION
MEETING ROOM M3
MODERATORS: Julia Schultz and Juri Miyamae

1:45 **J. Benoit, I. Ruf, J. A. Miyamae, V. Fernandez, P. G. Rodigues, B. S. Rubidge** THE INFRAORBITAL FORAMEN IN CYNODONTS AND MAMMALS: ORIGIN OF WHISKERS AND HOMOLOGY

2:00 **J. A. Miyamae, B. Bhullar** SENSING OR SUCKLING? THE EVOLUTION OF MAMMALIAN FACIAL MUSCLES

2:15 **J. Meng, F. Mao, Y. Wang, C. Li** EVOLUTION OF THE MAMMALIAN JAW JOINT AND MIDDLE EAR AT THE STAGE OF BASAL THERIANS

2:30 **A. Goswami, A. Fabre, E. Noirault, R. Felice, J. Clavel, A. Watanabe, P. Fabre, A. Curtis, N. Simmons, D. L. Fox, M. Churchill, B. L. Beatty, J. Geisler** INTEGRATION, EXTINCTION, CLIMATE, AND THE EVOLUTION OF THE PLACENTAL MAMMAL CRANIUM

2:45 **J. A. Schultz, K. T. Stilson, M. C. Granatosky, M. F. Laird, Z. Luo, C. F. Ross** NEW INSIGHTS INTO FEEDING PERFORMANCE OF THE VIRGINIA OPOSSUM (*DIDELPHIS VIRGINIANA*) AND IMPLICATIONS FOR THE EVOLUTION OF MAMMALIAFORM MASTICATION

3:00 **P. F. Viacava, S. P. Blomberg, M. Phillips, V. Weisbecker** A 3D GEOMETRIC MORPHOMETRIC ASSESSMENT OF INTERPOPULATIONAL CRANIAL DIVERSITY OF THE MARSUPIAL *DASYURUS HALLUCATUS*

3:15 **B. Mennecart, L. Costeur** LARGE SCALE STUDY OF THE BONY LABYRINTH: A 3D GEOMETRIC MORPHOMETRICS ANALYSIS OF THE RUMINANT INNER EAR EVOLUTION

3:30 **S. J. Hand, M. Archer, K. N. Armstrong, R. M. Beck, P. Guarino-Vignon, T. Hung, C. Lopez-Aguirre, L. A. Wilson** THE EVOLUTION OF PECULIAR CRANIAL MORPHOLOGY IN NASAL-EMITTING TRIDENT BATS (CHIROPTERA, RHINONYCTERIDAE) FROM THE AUSTRALIAN MIOCENE

3:45 **C. Jacquemetton, M. Juhn, D. Bird, J. Schoenebeck, Z. Tseng, B. Van Valkenburgh** OLD DOGS AND NEW: HOW DOMESTIC DOG SKULL SHAPE VARIATION MIRRORS THAT OF EXTINCT CANIDS

4:00 **G. E. Roessner, X. Wang, S. Wang** NEW FOSSILS FROM ASIA WIDEN EARLY ANTLER DIVERSITY AND INCLUDE OLDEST ANTLERS KNOWN

THURSDAY AFTERNOON, OCTOBER 10, 2019
TECHNICAL SESSION IX: SQUAMATES AND HERPETOFAUNAS
MEETING ROOM M4
MODERATORS: John Jacisin and Simon Scarpetta

1:45 **E. Amson, R. Ebel, J. Mueller** CRANIAL BONE INNER STRUCTURE AND FOSSORIALITY IN LEPIDOSAURIA

2:00 **W. Phantratanamongkol, J. Head** FOSSIL AND EXTANT MORPHOLOGIES REVEAL REPEATED DEVELOPMENT OF DISTAL HIND LIMBS IN THE EVOLUTION OF SNAKES

2:15 **A. Bolet, T. L. Stubbs, J. A. Herrera-Flores, M. J. Benton** NEW INSIGHTS ON LEPIDOSAUR EVOLUTION AS INFORMED FROM EVOLUTIONARY RATES AND DISPARITY ANALYSIS

2:30 **K. K. Formoso, M. Habib, D. Bottjer** REASSESSING THE MOSASAUR PECTORAL GIRDLE AND ITS ROLE IN SWIMMING FUNCTION: NOT ENTIRELY WHALE-LIKE AFTER ALL

2:45 **J. J. Jacisin, A. M. Lawing** SNAKE VERTEBRAL SHAPE AS AN ECOMETRIC METHOD, AND ITS IMPLICATIONS FOR SNAKE DISTRIBUTIONS AT LOCAL TO REGIONAL SCALES.

3:00 **S. G. Scarpetta** THE FIRST KNOWN FOSSIL OF *UMA* DEMONSTRATES EXAPTATION AND ECOLOGICAL EVOLUTION IN A SPECIALIZED CLADE

3:15 **M. F. Bonnan, L. M. Crisp, A. Barton, J. Dizinno, K. Muller, J. Smith, J. Walker** EXPLORING ELBOW KINEMATICS OF THE CENTRAL BEARDED DRAGON (*POGONA VITTICEPS*) USING XROMM: IMPLICATIONS FOR ANCESTRAL AMNIOTE ELBOW FUNCTIONAL MORPHOLOGY

3:30 **L. E. Roberts, J. J. Head** ELUCIDATING CRYPTIC AXIAL SKELETAL REGIONALIZATION IN REPTILIA: IMPLICATIONS FOR VERTEBRATE EVOLUTIONARY-DEVELOPMENTAL HISTORY

3:45 **J. I. Bloch, Y. Zaim, D. C. Kalthoff, J. R. Bourque, C. A. Brochu, J. J. Head, D. M. Boyer, J. Zonneveld, R. L. Ciochon, G. F. Gunnell** NEW TERRESTRIAL VERTEBRATES FROM THE PALEOGENE OF INDONESIA

4:00 **K. Weber, D. E. Winkler, T. Kaiser, E. Schulz-Kornas, T. Tütken** THE GOOD, THE BAD, AND THE UGLY—ALTERATION EFFECTS ON DENTAL MICROWEAR TEXTURES AND THEIR IMPLICATIONS FOR DIET RECONSTRUCTION

THURSDAY AFTERNOON, OCTOBER 10, 2019
PREPARATORS' SESSION
MEETING ROOM M1&2
MODERATORS: Matthew Miller and Vanessa Rhue

1:45 **M. T. Miller, A. Millhouse, H. Little** PITFALLS AND SUCCESSES: THE EVOLUTION OF THE NATIONAL MUSEUM OF NATURAL HISTORY (SMITHSONIAN INSTITUTION) PALEOBIOLOGY COLLECTIONS VOLUNTEER CATALOGING PROGRAM

2:00 **C. J. Van Beek, A. Shinya** PREPARATION OF WET VERTEBRATE FOSSILS: DEVISING STRATEGIES TO MITIGATE DAMAGE

2:15 **J. R. Groenke, P. M. O'Connor, L. Dougan, S. H. Burch, R. R. Rogers** DIGITAL AND MECHANICAL PREPARATION OF DELICATE SKELETAL REMAINS FROM AN UPPER CRETACEOUS BONEBED IN MADAGASCAR

2:30 **M. Pinsdorf** COMPACTED FIBERGLASS ARMATURE FOR SUPPORTING SMALL FOSSIL SPECIMENS

2:45 **C. J. Burke, T. H. Worthy, A. B. Camens** TECHNIQUES FOR SUCCESSFUL COLLECTION OF PLEISTOCENE MEGAFAUNA MATERIAL FROM LAKE CALLABONNA FOSSIL RESERVE, SOUTH AUSTRALIA.

3:00 **G. Dallman, W. F. Simpson, L. Geiger** MOVING AND UPDATING THE MOUNTED *TYRANNOSAURUS REX*, "SUE"

3:15 **S. A. Williams, A. A. Atwater, R. J. Harmon, J. Scannella** MOVING MAMMOTHS AND MOR: HOW TO SURVIVE YOUR COLLECTIONS MOVE

3:30 **K. S. Bader, D. E. Wagner, M. W. Colbert, E. L. Lundelius** PREPARATION OF INDURATED CAVE DEPOSITS FROM BARROW ISLAND, WESTERN AUSTRALIA

3:45 **C. M. Gordon, B. T. Roach, W. G. Parker, D. E. Briggs** DISTINGUISHING REGURGITALITES AND COPROLITES: A CASE STUDY USING A TRIASSIC BROMALITE CONTAINING SOFT TISSUE FROM *REVUELTOSAURUS*

4:00 **K. J. Ferguson, G. J. Price, G. E. Webb** GEOCHEMICAL TRACE ELEMENT ANALYSES ON FOSSIL BONE: A PROVENANCE TOOL FOR EXISTING FOSSIL COLLECTIONS WITH POORLY DOCUMENTED LOCALITIES

THURSDAY AFTERNOON, OCTOBER 10, 2019
REGULAR POSTER SESSION II
GREAT HALL 1&2
Authors must be present from 4:15 - 6:15 p.m. Thursday, October 10

B64 **N. T. Rasolofomanana, K. E. Samonds, L. R. Godfrey, M. Andriambelomanana, T. H. Andrianavalona, N. T. Ramihangihajason, R. B. Rakotozandry, B. Z. Nomenjanahary, M. Irwin, B. Crowley** A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR) WITH IMPLICATIONS FOR THE CHRONOLOGY OF HABITAT AND MEGAFAUNAL COMMUNITY CHANGE ON MADAGASCAR'S CENTRAL HIGHLANDS

B65 **R. A. Lawrence, S. Hocknull, J. Cramb** LOST IN SPACE AND TIME: NEW QUATERNARY SMALL VERTEBRATE RECORDS FROM THE FITZROY RIVER BASIN OF TROPICAL QUEENSLAND, AUSTRALIA

B66 **C. J. Piper, P. Veth** PALEOECOLOGY AND OCEAN VIEWS: DECLINE OF MAMMAL SPECIES RICHNESS DURING LATE QUATERNARY ISLAND FORMATION IN THE MONTEBELLO ISLANDS, NORTH-WESTERN AUSTRALIA

B67 **N. K. Turner, L. H. Reed, L. Arnold** PALEONTOLOGICAL INVESTIGATION OF A MIDDLE PLEISTOCENE VERTEBRATE FOSSIL ASSEMBLAGE FROM SPECIMEN CAVE, NARACOORTE, SOUTH AUSTRALIA

B68 **T. L. Bampton, J. Tyler, F. McInerney, E. Reed** STABLE ISOTOPIC SIGNATURES OF FOSSILISED RODENT TEETH: FAUNAL RESPONSE TO CLIMATE CHANGE IN SOUTH-EASTERN AUSTRALIA DURING THE LATE QUATERNARY

B69 **E. A. Parker, L. A. Reed** NARACOORTE CAVES: INTERPRETING THE WORLD HERITAGE OF SOUTH-EASTERN SOUTH AUSTRALIA

B70 **P. Kondrashov, A. Agadjanian** SMALL MAMMAL AND MOLLUSC FAUNAS FROM THE MIDDLE PLEISTOCENE OF CENTRAL RUSSIA

B71 **G. D. Van Den Bergh, U. W. Prasetyo, E. Setiyabudi, M. R. Puspaningrum, I. Kurniawan, M. Storey** THE EARLY PLEISTOCENE TERRESTRIAL VERTEBRATE FAUNAL SEQUENCE OF JAVA, INDONESIA

B72 **M. Duval** DIRECT ESR DATING OF THE LATE MIDDLE PLEISTOCENE VERTEBRATE ASSEMBLAGE FROM KHOK SUNG LOCALITY, THAILAND

B73 **K. M. Magoulick** THE MAMMAL ASSEMBLAGE OF CRYSTAL CAVERNS AND A COMPARATIVE ANALYSIS OF CALIFORNIA CAVE DEPOSITS

B74 **J. Treloar, E. H. Reed** TAPHONOMIC ANALYSIS OF AUSTRALIAN OWL PELLET ASSEMBLAGES AS ANALOGUES FOR QUATERNARY DEPOSITS AT NARACOORTE CAVES, SOUTH AUSTRALIA

B75 **M. R. Puspaningrum, Y. R. Zaim, Y. R. Rizal, A. R. Aswan, A. T. Hascaryo, N. R. Rochim** GEOLOGICAL AND PALEONTOLOGICAL ASPECTS OF A NEW EARLY–MIDDLE PLEISTOCENE TERRESTRIAL VERTEBRATE FOSSIL-BEARING SITE IN WEST JAVA, INDONESIA

B76 **M. J. Powley, G. D. Van Den Bergh, I. Kurniawan, I. Sutisno** TAPHONOMIC CHANGES OF EARLY MIDDLE PLEISTOCENE *STEGODON* BONE ASSEMBLAGES FROM FLORES, INDONESIA

B77 **J. E. Cohen, L. R. Desantis, E. L. Lindsey, J. Meachen, F. R. O'Keefe, J. Southon, W. J. Binder** STABILITY OF DENTAL MESOWEAR SCORES THROUGHOUT THE LATE PLEISTOCENE IN LARGE UNGULATES FROM RANCHO LA BREA

B78 **S. A. McLeod, J. A. Hook** A PLEISTOCENE VERTEBRATE FAUNA FROM A GROUND SLOTH SITE, GYPSUM CAVE, NEVADA, USA

B79 **B. Choo, W. Zhao, X. Cui, L. Jia** AN EXCEPTIONALLY PRESERVED ANTIARCH AND OTHER DISCOVERIES FROM THE EARLY DEVONIAN GUANSHANPO FORMATION, PINGYIPU GROUP, SICHUAN

B80 **B. M. Wynd, T. Daeschler, M. R. Stocker** EVOLUTIONARY HOMOLOGY IN THE FIN-TO-LIMB TRANSITION: EVALUATING THE MORPHOLOGY OF FORAMINA IN A LATE DEVONIAN HUMERUS FROM THE CATSKILL FORMATION, CLINTON COUNTY, PENNSYLVANIA

B81 **C. Burrow, M. J. Newman, J. L. Den Blaauwen** *CHEIRACANTHUS* (ACANTHODII, ACANTHODIFORMES) FROM THE MIDDLE DEVONIAN OF SCOTLAND: NEW ANATOMICAL DATA AND NEW SPECIES

B83 **B. R. Peecook, A. W. Bronson, B. K. Otoo, C. A. Sidor** FRESHWATER FISH FAUNAS FROM TWO PERMIAN RIFT VALLEYS OF ZAMBIA, WITH BIOGEOGRAPHIC IMPLICATIONS FOR SOUTHERN PANGEA

B84 **C. J. Duffin** THE PRE-SCIENTIFIC USES OF FOSSIL SHARKS' TEETH

B85 **G. Fang, F. Wu, Y. Sun, C. Ji** A NEW SPECIES OF *SAURICHTHYS* (ACTINOPTERYGII, SAURICHTHYIDAE) EXTENDS ITS GROUP'S RANGE TO THE LATE TRIASSIC IN EASTERN TETHYS

B86 **R. W. Berrell, L. Cavin** REVISION OF *DUGALDIA EMMILTA* (TELEOSTEI, ICHTHYODECTIFORMES) FROM THE EARLY CRETACEOUS OF AUSTRALIA.

B87 **J. A. Lane, M. Ebert, V. Schawaroch** A RE-EVALUATION OF *'FURO' MICROLEPIDOTES* (NEOPTERYGII, HALECOMORPHI) FROM THE UPPER JURASSIC SOLNHOFEN ARCHIPELAGO OF GERMANY

B88 **J. Liu, G. Chen, M. Chang** PROGRESS IN THE STUDY OF PALEOGENE ICHTHYOFAUNA FROM ONSHORE BASINS AROUND BEIBU GULF OF CHINA

B89 **S. El-Sayed, A. M. Murray, M. Kora, M. Antar, E. Seiffert, H. M. Sallam** NEW PERCOMORPH FISH FROM THE LATE EOCENE QASR EL-SAGHA FORMATION, FAYUM, EGYPT

B90 **T. M. Frank, M. A. Bell** DOCUMENTING AN ECOLOGICAL REPLACEMENT EVENT FROM THE MIOCENE ON AN ECOLOGICAL TIMESCALE

B91 **H. M. Byrne, H. Blom, G. Niedźwiedzki, B. P. Kear, P. E. Ahlberg** VIRTUAL 3D-RECONSTRUCTION OF INCLUSIONS FROM THREE LARGE COPROLITES FROM AN EARLY TOURNAISIAN LAKE DEPOSIT.

B92 **B. K. Otoo, J. R. Bolt, E. Lombard, K. Tietjen, M. I. Coates, K. D. Angielczyk** NEW DIVERSITY IN EARLY TETRAPOD HIND LIMBS

B93 **K. Ito, T. Kinugasa, S. Ishigaki, D. Fujimoto, R. Hayashi, K. Yoshida** ANALYSIS OF "OFF-TRACKING" IN THE TURNING TETRAPOD TRACKWAY

B94 **L. B. Porro, J. R. May, H. Dutel, E. G. Martin-Silverstone, E. J. Rayfield** CRANIAL SUTURES AND MECHANICAL PERFORMANCE IN TETRAPOD SKULLS DURING THE WATER–LAND TRANSITION

B95 **D. Marjanović, M. Laurin, O. Lapauze** WHAT DO OSSIFICATION SEQUENCES TELL US ABOUT THE ORIGIN OF EXTANT AMPHIBIANS?

B96 **E. M. Teschner, D. Konietzko-Meier** MYSTERIOUS METOPOSAURIDS: PALEOHISTOLOGY HELPS TO UNDERSTAND INTERSPECIFIC VARIETY AMONG LATE TRIASSIC AMPHIBIANS

B97 **A. R. Guillaume, M. Moreno-Azanza, O. Mateus** NEW LISSAMPHIBIAN MATERIAL FROM THE LOURINHÃ FORMATION (LATE JURASSIC, PORTUGAL)

B98 **M. Jansen, J. Renaudie, S. Voigt, M. Buchwitz** RECONSTRUCTION OF AN ANCESTRAL AMNIOTE TRACKMAKER BASED ON TRACKWAY DATA, TRACKMAKER CORRELATION AND PHYLOGENY

B99 **A. Smith, J. C. Havstad** FOSSILS WITH FEATHERS AND PHILOSOPHY OF SCIENCE

B100 **D. P. Rhoda, S. Hellert, P. Polly** SHIFTING PATTERNS OF FUNCTIONAL INTEGRATION DURING THE EVOLUTION OF FLIGHT IN THEROPODS

B101 **R. M. Carney, H. Tischlinger, M. D. Shawkey** BIRDS OF A FEATHER: CALAMUS CORROBORATES IDENTITY OF *ARCHAEOPTERYX* WING COVERT

B102 **S. M. Nebreda, G. Navalon, M. Fabbri, J. A. Bright, C. R. Cooney, B. Bhullar, J. Marugán-Lobón, E. J. Rayfield** NEW PERSPECTIVES ON THE EVOLUTION OF THE AVIAN SKULL

B103 **M. Pérez-Pueyo, E. Puértolas-Pascual, M. Moreno-Azanza, P. Cruzado-Caballero, J. M. Gasca, J. I. Canudo** ON THE PRESENCE OF A PUTATIVE ORNITHURAE (AVES) IN THE LATE MAASTRICHTIAN VERTEBRATE FAUNAS FROM SOUTHERN PYRENEES (SPAIN)

B104 **T. Smith, G. Mayr** PALEOCENE AND EARLY EOCENE BIRD ASSEMBLAGES FROM THE SOUTHERN NORTH SEA BASIN

B105 **M. D. Richards, K. A. Matts, R. E. Fordyce** *PARAPTENODYTES*-LIKE FOSSIL PENGUINS FROM NEW ZEALAND—A BIOGEOGRAPHIC CLUE FROM THE LATE OLIGOCENE?

B106 **A. J. Tennyson** FOSSIL BIRD BONES FROM THE SUBANTARCTIC AUCKLAND ISLANDS

B107 **J. N. Anderson, T. Stidham, K. Padian** DIAGNOSIS OF THE PRINCIPAL TAXA OF TERATORNITHIDAE (AVES: ACCIPITRIFORMES), INCLUDING *TERATORNIS* MILLER 1909 AND ITS SPECIES *T. MERRIAMI* AND *T. WOODBURNENSIS*

B108 **G. M. Musser, Z. Li, J. A. Clarke** A NEW SPECIES OF EOGRUIDAE (AVES, GRUIFORMES) FROM THE MIOCENE OF THE LINXIA BASIN, GANSU, CHINA: EVOLUTIONARY AND CLIMATIC IMPLICATIONS

B109 **K. A. Prassack, L. C. Walkup, S. W. Starratt, E. C. Wan, W. K. Hart** A BIRD'S-EYE VIEW OF ANCIENT LANDSCAPES AT HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO, USA

B110 **D. Cashmore, P. Mannion, P. Upchurch, R. Butler** 10 YEARS OF DISCOVERY: REVISITING THE QUALITY OF THE SAUROPODOMORPH FOSSIL RECORD

B111 **A. Paulina Carabajal, C. Apaldetti, R. Martínez** PALEONEUROANATOMY OF A NEW RIOJASAURID (DINOSAURIA, SAUROPODOMORPHA) FROM THE LATE TRIASSIC OF ARGENTINA

B112 **A. Ballell, E. J. Rayfield, M. J. Benton** THE BASAL SAUROPODOMORPH *THECODONTOSAURUS*FROM THE LATE TRIASSIC OF BRITAIN: OSTEOLOGICAL RE-DESCRIPTION, LIMB MUSCULATURE RECONSTRUCTION AND LOCOMOTION

B113 **B. P. Holbach** SKELETAL ONTOGENY OF *MASSOSPONDYLUS CARINATUS*

B114 **X. Ren, H. You** REFERRED SPECIMEN OF *CHUANJIESAURUS ANAENSIS* AS A NEW EARLY BRANCHING MAMENCHISAURID SAUROPOD TAXON FROM THE MIDDLE JURASSIC OF CHINA

B115 **F. M. Holwerda, D. Pol, J. Liston** EXPANDING CETIOSAURID DIVERSITY IN THE MIDDLE JURASSIC

B116 **K. Wiersma, P. Sander** THE GRIN OF THE CHESHIRE CAT: ISOLATED TOOTH ROWS AND OTHER DENTITION EVIDENCE FOR A RHAMPHOTHECA COMBINED WITH TEETH IN EUSAUROPOD DINOSAURS

B117 **T. Thulborn** SAUROPOD DINOSAUR TRACKS AND ASSOCIATED SEDIMENTARY STRUCTURES IN THE BROOME SANDSTONE (CRETACEOUS) OF WESTERN AUSTRALIA

B118 **T. Frauenfelder, N. E. Campione, P. Bell** TAXONOMIC IMPLICATIONS OF MEASUREMENT INDICES OF THE IDENTIFICATION OF ISOLATED SAUROPOD TEETH

B119 **J. C. Kosch, L. E. Zanno** TOOTH MORPHOMETRICS CAN DIFFERENTIATE MORRISON FORMATION DIPLODOCIDS

B120 **J. Foster, E. Tschopp, S. C. Maidment, W. E. Harcourt-Smith, M. Norell** GEOGRAPHICAL SEGREGATION DUE TO ECOLOGICAL COMPETITION AMONG LATE JURASSIC DIPLODOCID SAUROPODS FROM THE MORRISON FORMATION (WESTERN USA)

B121 **J. A. Fronimos** MORPHOLOGY AND NEUROVASCULAR ANATOMY OF A TITANOSAUR SAUROPOD OSTEODERM FROM THE UPPER CRETACEOUS OF BIG BEND NATIONAL PARK, TEXAS

B122 **Z. M. Boles, M. Heierbacher** A PATHOLOGIC TURTLE SHELL FROM THE PALEOGENE UPPER HORNERSTOWN FORMATION AT THE EDELMAN FOSSIL PARK, GLASSBORO, NEW JERSEY

B123 **L. L. Herzog, P. Makovicky, L. Zanno** COMPARATIVE OSTEOLOGY OF ENTOPLASTRA REVEALS THEIR DIAGNOSTIC UTILITY FOR DIFFERENTIATING NORTH AMERICAN HELOCHELYDRID SPECIES

B124 **B. P. Kear, L. Kool, M. S. Lee, D. Snitting, T. H. Rich, P. Vickers-Rich, M. Rabi** CRETACEOUS POLAR MEIOLANIFORM RESOLVES STEM TURTLE RELATIONSHIPS

B125 **E. M. Holt** NEW SPECIMENS REVEAL A HIGH ELEVATION, LOW DIVERSITY MIOCENE TESTUDINOID COMMUNITY IN EASTERN IDAHO, USA

FRIDAY MORNING, OCTOBER 11, 2019
TECHNICAL SESSION X: FISH
MEETING ROOM M1&2
MODERATORS: Elizabeth Dowding and Michael Coates

8:00 **M. Zhu, P. E. Ahlberg, J. Lu, B. Choo, X. Cui, Y. Zhu** EARLY OSTEICHTHYAN EVOLUTION: INSIGHTS FROM NEW DATA OF THE SILURIAN *MEGAMASTAX*

8:15 **Y. Zhu, M. Zhu, J. Lu, P. E. Ahlberg, X. Cui** A NEW SILURIAN BONY FISH CLOSE TO THE COMMON ANCESTOR OF CROWN GNATHOSTOMES

8:30 **J. A. Long, K. Trinajstic, A. Clement** EXCEPTIONALLY WELL-PRESERVED FISHES, INCLUDING A NEW POROLEPIFORM AND NEW ARTHRODIRES, FROM THE LATE DEVONIAN GOGO FORMATION OF WESTERN AUSTRALIA

8:45 **M. Coates, Z. Johanson, K. Tietjen** RETHINKING THE ASSEMBLY OF CHIMAEROID FISHES

9:00 **J. Lu, Y. Mou, L. Gu, M. Zhu, Y. Hu** MACHINE LEARNING BASED EARLY DEVONIAN VERTEBRATE MICROFOSSILS TOMOGRAPHY SEGMENTATION AND RECONSTRUCTION

9:15 **E. M. Dowding, M. C. Ebach** DEVONIAN BIOGEOGRAPHY: EVALUATING DATA AND AREAS

9:30 **T. Argyriou, C. Romano** NEW FINS OR OLD FINS? SKULL AND PECTORAL GIRDLE OF EARLY TRIASSIC '*PERLEIDUS*' *WOODWARDI* REVISITED USING μCT

9:45 **L. B. Bean, G. Arratia** OUTSTANDING MORPHOLOGY OF SOME MESOZOIC GONDWANAN FISH CONFLICTING PREVIOUS TAXONOMIC AND PHYLOGENETIC INTERPRETATIONS.

10:15 **J. Liston, A. Heyng** THE BEAST OF MÜHLHEIM: FIRST EVIDENCE OF A SOLNHOFEN MEGAPLANKTIVORE

10:30 **T. Daeschler, J. P. Downs, N. Lo, E. N. Carey, N. H. Shubin** *ASTEROLEPIS* SPP. AND OTHER ANTIARCH PLACODERMS FROM THE FRAM FORMATION (UPPER DEVONIAN, FRASNIAN) OF ELLESMERE ISLAND, NUNAVUT TERRITORY, CANADA

10:45 **K. M. Claeson, Z. Jinnah, J. A. Clarke, P. M. O'Connor, M. C. Lamanna** ABUNDANT LIZARDFISHES (AULOPIFORMES, BATHYSAURIDAE) IN AN EARLIEST PALEOGENE HORIZON IN ANTARCTICA CASTS LIGHT ON THE ORIGIN OF THE ASSEMBLAGE

11:00 **J. J. Cawley, G. Marramà, G. Carnevale, J. Kriwet** INVESTIGATION OF THE EVOLUTIONARY SUCCESS AND EXTINCTION OF PYCNODONT FISHES USING QUANTITATIVE METHODS

11:15 **F. Wu, M. Chang, D. He, G. Fang, T. Deng** PROGRESS IN THE RESEARCH ON THE CENOZOIC FISH FAUNA FROM THE TIBETAN PLATEAU

11:30 **M. Bazzi, N. Campione, B. Kear, H. Blom, P. E. Ahlberg** BIOTIC AND ABIOTIC DRIVERS OF SELACHIAN EVOLUTION THROUGHOUT THE CENOZOIC

11:45 **E. L. Bernard, S. Sinha, W. J. Pearson, L. T. Gallagher, R. J. Twitchett** ENVIRONMENTAL EFFECTS ON BODY SIZE IN LATE CRETACEOUS LAMNIFORM SHARKS FROM THE ENGLISH CHALK: UNLOCKING HIDDEN DATA IN HISTORIC COLLECTIONS TO ADDRESS KEY SCIENTIFIC QUESTIONS.

12:00 **R. L. McKeeby, M. D. Gottfried** QUANTITATIVE ANALYSIS OF ONTOGENETIC VARIATION IN THE DENTITION OF THE GREAT WHITE SHARK (*CARCHARODON CARCHARIAS*) WITH IMPLICATIONS FOR THE SHARK FOSSIL RECORD

FRIDAY MORNING, OCTOBER 11, 2019
TECHNICAL SESSION XI: MAMMALIAN PALEOECOLOGY AND MACROEVOLUTION
MEETING ROOM M3
MODERATORS: Melissa Pardi and John-Paul Zonneveld

8:00 **M. Viteri, M. Stegner, E. A. Hadly** DO RAPTOR PELLETS RECORD SMALL MAMMAL COMMUNITY COMPOSITION OR RAPTOR DIETARY PREFERENCE? A CASE STUDY IN YELLOWSTONE NATIONAL PARK

8:15 **J. Zonneveld, V. Long, A. Nguyen, T. R. Avalos, J. De Vos, L. A. Gonzalez, R. Joannes-Boyau, C. Yonge, R. L. Ciochon** TAPHONOMY OF VERTEBRATE FOSSILS FROM LANG TRANG CAVE: CHARACTERISTICS OF A PORCUPINE-GENERATED FAUNAL ASSEMBLAGE

8:30 **H. E. Smith, G. Price, Y. Rizal, J. Zaim, M. Puspaningrum, -. Aswan, A. Trihascaryo, M. Stewart, J. Louys** A TAPHONOMIC ANALYSIS OF A LATE PLEISTOCENE FOSSIL ASSEMBLAGE FROM NGALAU GUPIN, SUMATRA

8:45 **K. Suraprasit, H. Bocherens** STABLE ISOTOPE TRACKING ON TOOTH ENAMEL OF LARGE MAMMALS IN PENINSULAR THAILAND: IMPLICATIONS FOR THE HYPOTHESIS OF AN EQUATORIAL SAVANNA CORRIDOR DURING THE LATE MIDDLE PLEISTOCENE

9:00 **N. Fox, J. Southon, G. Takeuchi, A. Farrell, E. Lindsey, J. Blois** BASELINE SHIFTS IN SMALL MAMMAL COMMUNITIES AT RANCHO LA BREA TRACK LATE QUATERNARY ENVIRONMENTAL CHANGES IN SOUTHERN CALIFORNIA

9:15 **M. Stegner, E. A. Hadly** LATE HOLOCENE FAUNAL DYNAMICS IN A NORTHERN ROCKY MOUNTAIN FOREST COMMUNITY

9:30 **D. A. Fusco, K. M. Thorn, E. R. Shute, M. J. Tyler, N. R. Gibbs, L. J. Arnold, J. Sniderman, T. H. Worthy, G. J. Prideaux** MAMMALIAN RESPONSES TO LATE QUATERNARY ENVIRONMENTAL CHANGE IN EASTERN AUSTRALIA

9:45 **P. Roberts, O. Wedage, N. Amano** QUATERNARY EXTINCTIONS AND NON-EXTINCTIONS ON THE ISLAND OF SRI LANKA AND THEIR RELATIONSHIP TO LATE PLEISTOCENE *HOMO SAPIENS*

10:15 **T. J. Halliday, R. J. Garwood** GEOGRAPHIC PATCHINESS AND ITS EFFECT ON MACROEVOLUTIONARY INFERENCE

10:30 **J. Alroy** A WAY TO ACCOUNT FOR BIOGEOGRAPHIC BIAS IN ESTIMATING THE SPECIES RICHNESS OF NORTH AMERICAN CENOZOIC MAMMALS

10:45 **C. Badgley, T. Smiley, K. M. Loughney** LANDSCAPE PROCESSES AND DIVERSITY DYNAMICS OF NORTH AMERICAN MAMMALS

11:00 **F. Blanco, D. M. Martín-Perea, M. Domingo, J. Calatayud, I. Menéndez, M. Hernández Fernández , J. L. Cantalapiedra** NETWORK ANALYSIS UNVEILS THE FUNCTIONAL SUCCESSION OF IBERIAN MAMMALIAN FAUNAS OVER THE LAST 20 MILLION YEARS

11:15 **D. G. Hock, R. Secord** COMPARISON OF 'BIG DATA' USES IN PALEOECOLOGICAL MULTI-PROXY MODELS FOR NORTH AMERICAN MAMMALIAN PALEOECOLOGICAL INTERPRETATIONS

11:30 **M. T. Clementz, B. Carrapa, R. Feng** ECOLOGICAL RESPONSE TO LATE MIOCENE COOLING IN SOUTH AMERICA

11:45 **P. Polly** THE ASSEMBLY OF CAT COMMUNITIES IN THE NEW WORLD: ECOMETRICS AND NEOGENE FAUNAL TURNOVER

12:00 **M. I. Pardi, L. R. Desantis** CLARIFYING CLIMATE'S ROLE IN MEGAFAUNAL EXTINCTION THROUGH NICHE MODELING

FRIDAY MORNING, OCTOBER 11, 2019
TECHNICAL SESSION XII: DINOSAURS II
MEETING ROOM M4
MODERATORS: Emma Dunne and Lucy Leahey

8:00 **C. F. Kammerer, S. J. Nesbitt, J. J. Flynn, L. Ranivoharimanana, A. Wyss** A NEW LAGERPETID ARCHOSAUR FROM THE TRIASSIC OF MADAGASCAR AND THE IMPORTANCE OF MINIATURIZATION IN ORNITHODIRAN EVOLUTION

8:15 **R. N. Felice, A. Watanabe, A. Cuff, M. Hanson, D. Pol, B. S. Bhullar, M. A. Norell, L. M. Witmer, P. M. O'Connor, A. Goswami** DINOSAURS DISPARIFY DIFFERENTLY: CONTRASTING PATTERNS OF CRANIAL VARIATION AND MACROEVOLUTION ACROSS DINOSAURS AND CROCODYLOMORPHS

8:30 **M. Fabbri, D. S. Paredes, M. Cereghino, J. Botelho, B. Bhullar** CRACKING THE EVOLUTIONARY AND DEVELOPMENTAL LINK BETWEEN BRAIN AND SKULL IN ARCHOSAURIA: EVOLUTIONARY AND DEVELOPMENTAL PERSPECTIVES

8:45 **T. Brougham, N. E. Campione** BODY SIZE CORRELATES WITH DISCRETE CHARACTER MORPHOLOGICAL PROXIES IN DINOSAURS

9:00 **E. M. Dunne, A. Farnsworth, R. B. Benson, S. E. Greene, D. J. Lunt, R. J. Butler** CLIMATE AS A MAJOR CONTROL ON EARLY DINOSAUR GLOBAL DISTRIBUTION

9:15 **D. J. Button, L. B. Porro, M. E. Jones, P. M. Barrett** USING BIOMECHANICAL MODELLING TO INVESTIGATE AN ADAPTIVE RADIATION: A CASE STUDY IN DINOSAURIA

9:30 **R. Irmis, A. C. Mancuso, C. A. Benavente, J. H. Whiteside, R. Mundil** WERE DINOSAUR ORIGINS ASSOCIATED WITH SUDDEN GLOBAL CLIMATE CHANGE DURING THE CARNIAN PLUVIAL EVENT?

9:45 **E. T. Saitta, M. T. Stockdale, V. Bonhomme, N. R. Longrich, M. J. Benton, I. C. Cuthill, P. J. Makovicky** SEXUAL DIMORPHISM IN NON-AVIAN DINOSAURS AND OTHER EXTINCT TAXA: THE IMPORTANCE OF EFFECT SIZE STATISTICS IN PALEONTOLOGY

10:15 **E. C. Strickson, D. M. Wilkinson, J. R. Hutchinson, P. L. Falkingham** WHY DID SOME QUADRUPEDAL DINOSAURS HAVE SMALL FRONT FEET?

10:30 **K. E. Chapelle, J. Botha-Brink, J. N. Choiniere** INTRASKELETAL VARIATION IN *MASSOSPONDYLUS CARINATUS*: IMPLICATIONS FOR ONTOGENY

10:45 **A. Knapp, S. Alvarez-Carretero, R. J. Knell, D. W. Hone** GEOMETRIC MORPHOMETRIC EVIDENCE FOR RAPID EVOLUTION AND STRONG DIVERSIFYING SELECTION OF PUTATIVE SIGNALLING TRAITS IN HORNED DINOSAURS

11:00 **J. B. Scannella, H. N. Woodward** LONGEVITY AND GROWTH DYNAMICS OF *TRICERATOPS* AS REVEALED BY FEMORAL HISTOLOGY

11:15 **C. Bullar, M. J. Benton, Q. Zhao, M. Ryan** VARIATION IN BRAINCASE MORPHOLOGY AND PALEONEUROLOGY WITHIN CERATOPSIA

11:30 **L. G. Leahey, R. E. Molnar, S. W. Salisbury** MORE THAN *MINMI*: A NEW AUSTRALIAN ANKYLOSAURIAN DINOSAUR FROM THE LOWER CRETACEOUS (ALBIAN) OF QUEENSLAND, WITH IMPLICATIONS FOR UNDERSTANDING GLOBAL THYREOPHORAN DIVERSITY.

11:45 **W. Zheng, X. Xu** OSTEOLOGY OF *LIAONINGOSAURUS PARADOXUS* (ORNITHISCHIA: ANKYLOSAURIA) FROM THE LOWER CRETACEOUS OF LIAONING, CHINA, AND THE EARLY EVOLUTION OF ANKYLOSAURIDAE

12:00 **A. D. Dyer, A. R. LeBlanc, P. J. Currie** HISTOPATHOLOGY OF A PACHYCEPHALOSAUR FRONTOPARIETAL DOME

FRIDAY AFTERNOON, OCTOBER 11, 2019
SYMPOSIUM: QUARTERNARY EXTINCTIONS IN THE ASIA-PACIFIC: CAUSES AND CONSEQUENCES
MEETING ROOM M3
MODERATORS: Larisa DeSantis and Gilbert Price

1:45 **K. E. Westaway, R. Joannes-Boyau, A. Bacon, J. Louys, J. Zhao** DATING THE RISE AND FALL OF ORANGUTANS (HOMINIDAE, *PONGO* SP.) THROUGH THE QUATERNARY OF SOUTHEAST ASIA

2:00 **V. De Pietri, T. H. Worthy, P. Scofield, T. Cole, G. Wragg** AN EXTINCT SPECIES OF *PROSOBONIA* FROM HENDERSON ISLAND

2:15 **L. DeSantis, A. Saunders, G. Coulson, J. Dortch** DROUGHTS KILL: THE PALEOECOLOGY OF A LATE PLEISTOCENE MASS DEATH ASSEMBLAGE (LANCEFIELD SWAMP) IN AUSTRALIA WITH IMPLICATIONS FOR TODAY

2:30 **T. H. Worthy, L. H. Arnold, A. H. Camens, A. Chinsamy** REASSERTING THE SIGNIFICANCE OF THE QUATERNARY MEGAFAUNAL NECROPOLIS FROM LAKE CALLABONNA, SOUTH AUSTRALIA

2:45 **J. Louys, Y. Zaim, G. Price, Y. Rizal, A. Aswan, M. Puspaningrum, A. Trihascaryo, P. Higgins, P. Roberts** QUATERNARY EXTINCTION OF LARGE RAINFOREST HERBIVORES ON INDONESIA'S LARGEST ISLAND, SUMATRA

3:00 **M. Rabi, T. H. Worthy, S. Hawkins, S. Bedford, M. Spriggs** NEOLITHIC HUMAN-INDUCED EXTINCTION OF PREVIOUSLY UNRECOGNIZED GIANT TESTUDINID TORTOISES ENDEMIC TO MELANESIA

3:15 **N. Amano, T. Ingicco, P. Piper, F. Sémah, W. Saptomo, P. Roberts** LATE PLEISTOCENE TO MID-HOLOCENE PALEOECOLOGY OF EAST JAVA: EVIDENCE FROM CAVE SITES IN THE GUNUNG SEWU REGION

3:30 **J. K. Lubeek , G. Gully, Y. Zhang, R. L. Ciochon , R. Joannes-Boyau, S. Haberle, M. W. Morley, K. E. Westaway** KING KONG'S DEMISE: IMPLICATIONS FOR DIET AND EXTINCTION OF *GIGANTOPITHECUS BLACKI* FROM PLEISTOCENE CHINA BASED ON DENTAL MICROWEAR TEXTURE ANALYSIS

3:45 **J. Garvey, J. Field** PREDATORS AND PREY FROM THE MIDDLE PLEISTOCENE RECORD AT CUDDIE SPRINGS

4:00 **G. J. Price, J. Louys, I. H. Sobbe, J. Ristevski, R. E. Molnar** ECOLOGICAL FALLOUT AND TURNOVER IN THE DIVERSITY OF LATE QUATERNARY TERRESTRIAL PREDATORS OF AUSTRALIA

FRIDAY AFTERNOON, OCTOBER 11, 2019
TECHNICAL SESSION XIII: EARLY REPTILES
MEETING ROOM M1&2
MODERATORS: Mark MacDougall and Gabi Sobral

1:45 **G. Sobral, R. Schoch** A SMALL DIAPSID FROM THE LOWER KEUPER OF GERMANY AND THE ORIGIN OF AQUATIC REPTILES

2:00 **M. R. Stocker, S. J. Nesbitt, K. D. Angielczyk, C. A. Sidor, J. Fortner, S. L. Olroyd, J. K. Lungmus, R. M. Smith** AN EXCEPTIONALLY PRESERVED SMALL ARBOREAL REPTILE FROM THE UPPER PERMIAN USILI FORMATION OF TANZANIA

2:15 **B. B. Britt, A. C. Pritchard, D. J. Chure, G. F. Engelmann, R. D. Scheetz, B. C. Theurer, R. B. Esplin** STILL STRANGER THINGS: μCT IMAGES OF 3D DREPANOSAURS (SAINTS & SINNERS QUARRY, LATE TRIASSIC, EOLIAN NUGGET FM.) REVEALS BIZARRE MORPHOLOGIES INCLUDING A BEAK COMBINED WITH TRANSVERSELY WIDE TEETH, SAUROPOD-LIKE PNEUMATIC DORSAL VERTEBRAE, A CHEVRON THAT ARTICULATES WITH THE PELVIS, AND TRIPODAL ADAPTATIONS

2:30 **V. Vakil, G. E. Webb, A. G. Cook** VARIATION IN AUSTRALIAN CRETACEOUS SAUROPTERYGIAN AND ICHTHYOPTERYGIAN POSTCRANIAL MATERIAL

2:45 **B. Kligman, M. R. Stocker, S. J. Nesbitt, A. D. Marsh, W. Parker** NEW TRILOPHOSAURID SPECIES DEMONSTRATES EXTINCTION-DRIVEN DROP IN ALLOKOTOSAUR DIVERSITY ACROSS THE ADAMANIAN–REVUELTIAN BIOZONE BOUNDARY IN THE LATE TRIASSIC OF WESTERN NORTH AMERICA

3:00 **A. Verrière, J. Fröbisch, N. Fröbisch** PATTERNS OF OSSIFICATION IN THE VERTEBRAL COLUMN OF AMNIOTES AND THEIR ANCESTRAL CONDITION

3:15 **M. J. MacDougall, A. Verrière, T. Wintrich, A. R. LeBlanc, J. Fröbisch** CAUDAL AUTOTOMY IN MESOSAURID REPTILES AND ITS IMPLICATIONS FOR ANTI-PREDATORY BEHAVIOUR AND LOCOMOTION IN THE CLADE

3:30 **R. Chatterji, M. Hutchinson, M. E. Jones** A QUANTITATIVE ANALYSIS OF SKULL GROWTH AND EVOLUTION IN SEA TURTLES (TESTUDINATA, CHELONIOIDEA)

3:45 **T. Szczygielski, T. Sulej** LIMB MORPHOLOGY OF THE LATE TRIASSIC STEM TURTLE *PROTEROCHERSIS POREBENSIS* (PROTEROCHERSIDAE)

4:00 **R. R. Reisz, J. Bevitt, M. MacDougall** COMPLEXITY OF EARLY PERMIAN TERRESTRIAL VERTEBRATE COMMUNITY AT RICHARDS SPUR, OKLAHOMA IS REVEALED THROUGH NEUTRON TOMOGRAPHY

FRIDAY AFTERNOON, OCTOBER 11, 2019
TECHNICAL SESSION XIV: BIRD ORIGIN AND EVOLUTION
MEETING ROOM M4
MODERATORS: Michael Pittman and Aurore Canoville

1:45 **C. T. Griffin, J. Botelho, M. Hanson, M. Fabbri, S. J. Nesbitt, B. Bhullar** THE AVIAN PELVIS POSSESSES ANCESTRAL DINOSAURIAN AND ARCHOSAURIAN CHARACTER STATES EARLY IN ONTOGENY

2:00 **M. Pittman, T. Kaye, X. Wang, X. Zheng, S. Hartman, X. Xu** INTERNAL AND EXTERNAL FLIGHT-RELATED ANATOMY OF EARLY THEROPOD FLIERS REVEALED BY LASER-STIMULATED FLUORESCENCE FILLS KNOWLEDGE GAPS IN FUNCTIONAL MORPHOLOGY AND FLIGHT CAPABILITY

2:15 **T. Imai, Y. Azuma, S. Kawabe, M. Shibata, K. Miyata, M. Wang, Z. Zhou** FIRST NON-ORNITHOTHORACINE FOSSIL BIRD (THEROPODA, AVIALAE) FROM THE EARLY CRETACEOUS OF JAPAN: INCREASING OUR UNDERSTANDING ABOUT EVOLUTION AND PALEOBIOGEOGRAPHY OF STEM BIRDS

2:30 **H. Hu, J. O'Connor, S. Wroe, P. McDonald, Z. Zhou** FIRST COMPLETE SKULL THREE-DIMENSIONALLY RECONSTRUCTED FROM EARLY CRETACEOUS BIRDS

2:45 **J. Benito, B. Bhullar, D. Burnham, L. E. Wilson, D. Field** NEW *ICHTHYORNIS* SPECIMENS: SHEDDING NEW LIGHT ON MODERN BIRD ORIGINS

3:00 **S. Wang, D. Hu, R. Wang, X. Xu** A NEW BONY-CRESTED, EARLY-DIVERGING AVIALAN FROM THE LOWER CRETACEOUS JEHOL GROUP OF WESTERN LIAONING, CHINA AND ITS IMPLICATION FOR EARLY AVIALAN EVOLUTION

3:15 **S. Hellert, P. Polly, D. P. Rhoda** EVOLUTIONARY CONSTRAINT OF THE DIVERSIFICATION OF AVIAN LIMBS

3:30 **S. L. Baumgart, P. C. Sereno** PHYLOGENY REPETITIVELY CONSTRAINS BIRD MORPHOLOGY

3:45 **A. Canoville, M. H. Schweitzer, L. Zanno** DO FEMALE PENGUINS RESORT TO MEDULLARY BONE AS A SOURCE OF CALCIUM FOR THE EGGSHELL?

4:00 **D. B. Thomas, D. T. Ksepka, P. Scofield, T. A. Heath, W. Pett, E. Holvast, A. J. Tennyson** RECRUITMENT OF CROWN-CLADE PENGUINS INTO NEW ZEALAND

FRIDAY AFTERNOON, OCTOBER 11, 2019
REGULAR POSTER SESSION III
GREAT HALL 1&2
Authors must be present from 4:15 - 6:15 p.m. Friday, October 11

B64 **N. T. Rasolofomanana, K. E. Samonds, L. R. Godfrey, M. Andriambelomanana, T. H. Andrianavalona, N. T. Ramihangihajason, R. B. Rakotozandry, B. Z. Nomenjanahary, M. Irwin, B. Crowley** A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR) WITH IMPLICATIONS FOR THE CHRONOLOGY OF HABITAT AND MEGAFAUNAL COMMUNITY CHANGE ON MADAGASCAR'S CENTRAL HIGHLANDS

B65 **T. Tsubamoto, Y. Kunimatsu, F. K. Manthi, M. Nakatsukasa** NEW SPECIMENS OF *NYANZACHOERUS* (MAMMALIA, ARTIODACTYLA, SUIDAE, TETRACONODONTINAE) FROM THE UPPER MIOCENE NAKALI FORMATION, KENYA

B66 **M. O. Kubo, M. Fujita** DIETARY RECONSTRUCTION OF PLEISTOCENE DEER *CERVUS ASTYLODON* USING DENTAL MICROWEAR TEXTURE ANALYSIS

B67 **M. A. Dantas, A. Cherkinsky, H. Bocherens** ISOTOPIC DIET ($\delta^{13}C$) IN A MATHEMATICAL MIXING MODEL: REFINING THE FOOD RESOURCES THAT EXTINCT LARGE HERBIVORES ATE

B68 **T. Deng, X. Wang, S. Hou** REPLACEMENT OF ARTIODACTYLS FOR PERISSODACTYLS IN THE CENOZOIC MAMMALIAN FAUNAS OF THE TIBETAN PLATEAU

B69 **O. Cirilli, A. M. Jukar, R. Potts, L. Rook, R. L. Bernor** THE DEEP TIME ORIGIN OF AFRICAN ZEBRAS THROUGH THE EURASIAN "*EQUUS STENONINE*" LINEAGE

B70 **X. Lu, D. Tao** NEW POSTCRANIAL MATERIALS OF *ACERORHINUS YUANMOUENSIS* AND THE PHYLOGENY OF ACERATHERIINAE

B71 **N. Handa** A REVIEW OF THE MIOCENE RHINOCEROSES FROM JAPAN, AND PALEOBIOGEOGRAPHIC IMPLICATIONS

B72 **M. C. Coombs, S. Cote** CHALICOTHERES OF PAKISTAN: PIECING TOGETHER THE BIOGEOGRAPHIC PUZZLES OF A RARE PERISSODACTYL GROUP IN THE NEOGENE OF SOUTHERN ASIA

B73 **M. A. Khan, M. Asim** MIDDLE MIOCENE BOVIDS (MAMMALIA) FROM POTWAR PLATEAU, NORTHERN PAKISTAN

B74 **Y. Li, T. Deng, H. Hua** LOCOMOTIVE IMPLICATIONS OF THE 7.4 MA HIPPARIONINE FOSSILS FROM THE MIDDLE REACHES OF THE YELLOW RIVER AND THEIR PALEO-ECOLOGICAL SIGNIFICANCE

B75 **S. Ring, H. Bocherens, O. Wings, M. Rabi** DIVERGENT MAMMALIAN BODY SIZE IN A STABLE EOCENE GREENHOUSE CLIMATE

B76 **S. Sova, T. Häkkinen, W. Morita, J. Jernvall** RECONSTRUCTING COMPLEX PATTERNS OF ENAMEL ON A TOOTH WITH COMPUTATIONAL SIMULATIONS

B77 **A. Grass, P. Higgins, J. Meachen, A. Campbell** A GEOMETRIC MORPHOMETRIC EVALUATION OF EQUID TOOTH SHAPE AT NATURAL TRAP CAVE, WYOMING

B78 **R. Schellhorn** INNER EAR ORIENTATION REFLECTS HEAD POSTURE IN THE WOOLLY RHINO (PERISSODACTYLA, RHINOCEROTIDAE)

B79 **A. Norwood** TRACKING CLIMATE SEASONALITY IN EQUID TEETH THROUGH SERIAL SAMPLING OF ENAMEL ISOTOPES

B80 **B. Vera, A. C. Scarano** EVOLUTIONARY TRENDS OF *PROTYPOTHERIUM* LINEAGE THROUGHOUT THE MIOCENE–PLIOCENE OF SOUTH AMERICA

B81 **R. F. Souberlich, S. D. Ríos, C. Aquino, V. Ayala, A. E. Zurita, A. R. Miño Boilini, M. L. Idoyaga, E. Z. Herrera** PALEOMETRY: MOLECULAR AND ELEMENTAL CHARACTERIZATION OF THE SLOTH *CATONYX CUVIERI* (MAMMALIA, XENARTHRA, MYLODONTIDAE) FROM THE PLEISTOCENE–HOLOCENE OF PARAGUAY

B82 **T. Htun, D. R. Prothero, J. Hoffman, S. M. Lukowski** HOW DID MASTODONS GROW? ONTOGENETIC LONG BONE GROWTH IN THE AMERICAN MASTODON (*MAMMUT PACIFICUS*)

B83 **A. J. Larson** ONTOGENETIC CHANGES IN THE WOOLLY MAMMOTH (*MAMMUTHUS PRIMIGENIUS*)

B84 **R. Govender** LATE MIOCENE–EARLY PLIOCENE MARINE MAMMAL FAUNA FROM SOUTH AFRICA'S WEST COAST

B85 **S. Godfrey, O. Lambert** A DIVERSE MIOCENE TOOTHED WHALE (ODONTOCETI) FAUNA FROM CALVERT CLIFFS, ATLANTIC COASTAL PLAIN, U.S.A.

B86 **A. S. Gohar, M. S. Antar, D. A. Sabry, S. El-Sayed, H. M. Sallam** THE OLDEST RECORD OF BASILOSAURID WHALES FROM AFRICA AND ITS IMPLICATION FOR THE EARLY EVOLUTION OF PELAGICETI (MAMMALIA, CETACEA)

B87 **S. Chakraborty** NEW REMINGTONOCETID MATERIAL FROM THE MIDDLE EOCENE OF KUTCH, INDIA

B88 **T. Okamura, S. Fujiwara** THE RANGE OF ATLANTO-OCCIPITAL JOINT MOTION AS A NEW INDICATOR FOR THE FEEDING BEHAVIORS OF CETACEANS

B89 **J. Liú, Q. Li** AN EARLY TRIASSIC SAUROPTERYGIAN FROM SOUTH CHINA

B90 **H. P. Street, M. C. Mekarski, E. L. Bamforth, A. Smith, R. Tahara, H. C. Larsson** THE SKULL OF A YOUNG JUVENILE ELASMOSAUR FROM THE CAMPANIAN BEARPAW FORMATION OF SASKATCHEWAN, CANADA

B91 **S. R. Mohr, A. R. LeBlanc, M. W. Caldwell** REDESCRIPTION AND REASSIGNMENT OF "*LIODON*" *MOSASAUROIDES* TO THE GENUS *EREMIASAURUS* (SQUAMATA, MOSASAURIDAE)

B92 **A. R. Zietlow** CRANIOFACIAL ONTOGENY IN *TYLOSAURUS PRORIGER*

B93 **P. Bona, M. D. Ezcurra, V. Fernandez Blanco** NEW EMBRYOLOGICAL AND PALEONTOLOGICAL EVIDENCE SHEDS LIGHT ON THE EVOLUTION OF THE ARCHOSAUROMORPH ANKLE

B94 **H. S. Eddins, M. R. Stocker, S. J. Nesbitt** AUTOPODIA OF PHYTOSAURIA ARE CONSERVED WITHIN THE CLADE AND MAY REPRESENT THE ANCESTRAL CONDITION IN ARCHOSAURIA

B95 **A. Cossette, A. Grass** A MORPHOMETRIC ANALYSIS OF THE CROCODYLIAN SKULL TABLE: TRACKING ALLOMETRY AND PREDICTING ECOLOGY

B96 **S. K. Drumheller, P. M. Gignac, M. R. Stocker, L. Carroll-Garrett, E. Albee** TESTING THE EFFECTS OF PROXY SELECTION ON BITE-FORCE ESTIMATES GENERATED USING INDENTATION SIMULATIONS

B97 **K. H. To, S. J. Nesbitt, M. R. Stocker** AN EARLY-DIVERGING CROCODYLOMORPH FROM THE EARLY NORIAN (LATE TRIASSIC) OF DOCKUM GROUP, TEXAS

B98 **K. N. Dollman, J. M. Clark, J. N. Choiniere** THE EARLIEST OCCURRENCE OF MULTI-CUSPED DENTITION WITHIN CROCODYLOMORPHA

B99 **P. Rummy, X. Xu, X. Wu, F. Jin, D. Wen, B. Wang** A NEW NEOSUCHIAN CROCODYLOMORPH (REPTILIA, MESOEUCROCODYLIA) FROM THE MIDDLE CRETACEOUS LONGJING FORMATION, YANJI BASIN, NORTHEASTERN CHINA

B100 **T. L. Adams, K. A. Andrzejewski** REVISITING THE PROCTOR LAKE DINOSAUR LOCALITY: NEW INSIGHTS ON THE PALEOECOLOGY AND PALEOENVIRONMENT

B101 **L. J. Hart, P. Bell, E. T. Smith, S. W. Salisbury** A NEW BASAL EUSUCHIAN FROM THE GRIMAN CREEK FORMATION AT LIGHTNING RIDGE, NEW SOUTH WALES, AUSTRALIA.

B102 **C. P. Paragnani, S. F. Poropat, P. Vickers-Rich, T. H. Rich** AUSTRALIA'S OLDEST AND HIGHEST PALEOLATITUDE CROCODYLOMORPHS FROM THE LOWER CRETACEOUS EUMERALLA FORMATION (UPPER APTIAN–LOWER ALBIAN) OF DINOSAUR COVE, VICTORIA

B103 **A. K. Hastings, J. W. Moreno-Bernal, E. T. Whiting, A. F. Rincón, C. Jaramillo, J. I. Bloch** NEW FOSSILS OF *ANTHRACOSUCHUS* (CROCODYLOMORPHA) FROM THE PALEOCENE OF SOUTH AMERICA AND THE GEOGRAPHIC ORIGIN OF DYROSAURIDAE

B104 **C. A. Brochu, A. Adams, B. Benefit, A. Grossman, F. Kirera, T. Lehmann, C. Liutkus-Pierce, M. McCrossin, K. P. McNulty** GIANT DWARF CROCODILES—A NEW CLADE OF OSTEOLAEMINE CROCODYLIDS FROM THE MIOCENE OF KENYA

B104 **K. E. Samonds, C. A. Brochu, A. J. Adams, R. B. Rakotozandry** A NEW MIOCENE CROCODYLIFORM FROM THE ISLAND OF NOSY MAKAMBY, NORTHWESTERN MADAGASCAR

B105 **C. Chiotakis** DETERMINING AUSTRALIAN PLIO–PLEISTOCENE CROCODILIAN DIVERSITY USING THREE DIMENSIONAL MORPHOMETRICS OF DENTAL AND OSTEODERM REMAINS

B107 **R. Rakotozandry, H. T. Andrianavalona, K. E. Samonds** SUBFOSSIL CROCODYLIANS FROM A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR).

B109 **D. B. Norman** *SCELIDOSAURUS,* A POORLY KNOWN AND MISUNDERSTOOD ORNITHISCHIAN DINOSAUR

B110 **J. Russo, O. Mateus** A NEW ANKYLOSAUR DINOSAUR SKELETON FROM THE UPPER JURASSIC OF PORTUGAL

B111 **J. Park, Y. Lee, P. J. Currie, Y. Kobayashi, E. B. Koppelhus, R. Barsbold, S. Lee, S. Kim, O. Mateus** THREE NEW SKULLS OF THE LATE CRETACEOUS ARMORED DINOSAUR *TALARURUS PLICATOSPINEUS* MALEEV, 1952

B112 **L. Jia, H. You, S. Wang, S. Xu** NEW DISCOVERY OF ANKYLOSAUR FOSSILS FROM SHANXI PROVINCE, CHINA

B113 **C. A. Forster, M. R. Spencer, K. E. Poole, J. M. Clark, X. Xu** A NEW NEORNITHISCHIAN (CERAPODAN?) DINOSAUR FROM THE OXFORDIAN SHISHUGOU FORMATION OF CHINA: WHAT IS AN ORNITHOPOD?

B114 **B. Allison, T. Lamaster, H. M. Avrahami, L. Zanno** BUCCAL TOOTH DEVELOPMENT, REPLACEMENT RATE, AND MICROSTRUCTURE IN PARKSOSAURIDAE (DINOSAURIA: NEORNITHISCHIA)

B115 **M. C. Herne, J. P. Nair, P. Bell, S. A. Hocknull, S. W. Salisbury, A. M. Tait, A. R. Evans, R. E. Molnar, V. Weisbecker** AUSTRALIAN ORNITHOPOD DINOSAURS: RECENT DISCOVERIES AND IMPLICATIONS FOR ORNITHOPOD DIVERSITY AND RELATIONSHIPS

B116 **J. A. Case, M. C. Lamanna, R. C. Ely** AN ASSOCIATED ORNITHOPOD DINOSAUR HIND LIMB FROM THE UPPERMOST CRETACEOUS (MAASTRICHTIAN) LOPEZ DE BERTODANO FORMATION OF THE JAMES ROSS BASIN, WEST ANTARCTICA

B117 **A. Prieto-Marquez, J. R. Wagner, T. M. Lehman** AN UNUSUAL NON-SAUROLOPHID 'DUCK-BILLED' DINOSAUR FROM THE EARLY CAMPANIAN (CRETACEOUS) OF TRANS-PECOS TEXAS, AND THE ANCESTRAL HADROSAURIAN CREST

B118 **T. A. Gates, J. Sertich** REDIAGNOSIS OF *PARASAUROLOPHUS CYRTOCRISTATUS* BASED ON NEW MATERIAL FROM THE FRUITLAND FORMATION, NORTHWESTERN NEW MEXICO

B119 **J. Bourke, T. A. Gates, L. Zanno** NASAL PASSAGE GROWTH THROUGH ONTOGENY IN THE LAMBEOSAURINE *PARASAUROLOPHUS* (ORNITHOPODA: DINOSAURIA)

B120 **K. Chiba, M. J. Ryan, Y. Yamamoto, S. Konishi, T. Chinzorig, Z. Badamkhatan, P. Khatanbaatar, M. Saneyoshi, K. Tsogtbaatar** NEW INSIGHTS ON THE EVOLUTION OF THE NEOCERATOPSIAN FRILL: ORNAMENTATIONS ON *PROTOCERATOPS*

B121 **S. Ekhtiari, K. Chiba, S. Popovic, R. Crowther, G. R. Wohl, O. D. Geen, A. K. Wong, M. Crowther, N. Parasu, D. Evans** OSTEOSARCOMA IN A DINOSAUR: A DIAGNOSIS CONFIRMED THROUGH GROSS, RADIOGRAPHIC, AND HISTOLOGIC EXAMINATION

B122 **S. J. Rufolo, J. Mallon, M. Currie, T. W. Dudgeon, A. McDonald, S. Swan, T. C. Wyenberg-Henzler** NEW CONTRIBUTIONS TO THE CERATOPSID RECORD OF THE DINOSAUR PARK FORMATION FROM RECENT FIELDWORK ALONG THE SOUTH SASKATCHEWAN RIVER, ALBERTA, CANADA

B123 **S. R. Carpenter, M. A. Loewen, K. Chiba, E. K. Lund, E. M. Roberts** NEW CENTROSAURINE CERATOPSIANS FROM THE CAMPANIAN WAHWEAP FORMATION OF UTAH

B124 **D. J. Stefanski** CRANIOFACIAL ONTOGENY IN *PACHYCEPHALOSAURUS WYOMINGENSIS*

SATURDAY MORNING, OCTOBER 12, 2019
SYMPOSIUM: ORIGIN OF A SUNBURNT COUNTRY: DEVELOPMENT OF THE MODERN AUSTRALIAN VERTEBRATE FAUNA FROM THE LATE MIOCENE ONWARDS
MEETING ROOM M3
MODERATORS: Robin Beck and Pip Brewer

8:00 **R. M. Beck, R. K. Engelman, K. Travouillon** MACROEVOLUTIONARY DYNAMICS OF SOUTH AMERICAN AND AUSTRALIAN FAUNIVOROUS MARSUPIALS DURING THE NEOGENE

8:15 **P. Brewer** DIETARY NICHE SEPARATION IN LATE MIOCENE TO RECENT HYPSELODONT WOMBATS

8:30 **J. M. Nguyen** A FLOCK OF FOSSILS: NEW FOSSIL EVIDENCE ON THE EVOLUTION OF AUSTRALIAN SONGBIRDS (PASSERIFORMES)

8:45 **S. Wroe, R. Mitchell** CRUSHING IT: THE SPECIALISED CRANIAL MECHANICS OF AN EXTINCT SHORT-FACED KANGAROO

9:00 **P. M. Oliver, M. S. Lee, C. Hipsley** HOW 'OLD' IS THE AUSTRALIAN ARID ZONE: A HERP'S EYE VIEW ACROSS MOLECULES AND MORPH.

9:15 **A. M. Yates** THE LAST 10 MILLION YEARS OF AUSTRALIAN CROCODYLIAN HISTORY: A CASE OF OUT WITH THE OLD AND IN WITH THE NEW

9:30 **K. Travouillon, T. Myers, K. H. Black, Y. Gurovich, R. Beck, J. Louys, G. Price, M. Archer, S. J. Hand, J. Muirhead** FOSSIL EVIDENCE FOR A MIOCENE TURNOVER IN AUSTRALIAN BANDICOOT DIVERSITY AND A PLIOCENE ORIGIN FOR THE MODERN GENERA

9:45 **G. J. Prideaux, A. I. Crichton, E. R. Shute, J. M. Nguyen, L. J. Arnold, B. J. Pillans** VERTEBRATE RESPONSES TO PLEISTOCENE ENVIRONMENTAL CHANGE IN SOUTH-CENTRAL AUSTRALIA

10:15 **P. Priya** RECONSTRUCTING THE LATE PLEISTOCENE CLIMATE SEQUENCE AT ALEXANDRA CAVE, NARACOORTE, SOUTH AUSTRALIA, USING SINGLE-GRAIN OPTICALLY STIMULATED LUMINESCENCE DATING AND PALEOENVIRONMENTAL PROXIES

10:30 **M. McDowell** THE PRE-EUROPEAN MAMMALS OF TASMANIA: WAS THE BASSIAN PLAIN A BRIDGE OR BARRIER?

10:45 **M. Archer, P. R. Fabian, M. Hari-Rajan, S. J. Hand, J. Wolfe, L. A. Wilson, T. Hung , A. Bongers** NEW CENOZOIC ACROBATID POSSUMS FROM THE RIVERSLEIGH WORLD HERITAGE FOSSIL DEPOSITS, AUSTRALIA, AND INVESTIGATION OF THEIR BIZARRE MIDDLE EAR STRUCTURE

11:00 **K. Butler, K. Travouillon, V. Weisbecker, A. R. Evans, L. Murphy, G. Price, M. Archer, S. J. Hand** FANGAROOS AND KANGAROOS: PHYLOGENY, PALEOECOLOGY, DIVERSIFICATION, AND EXTINCTION OF EARLY KANGAROOS (MARSUPIALIA, MACROPODIFORMES) FROM THE RIVERSLEIGH WORLD HERITAGE AREA

11:15 **I. A. Kerr** A UNIQUE ARTICULATED FOSSIL SHEDS LIGHT ON THE TAXONOMY OF TWO PLEISTOCENE SPECIES OF GIANT KANGAROO FROM THE GENUS *PROTEMNODON*

11:30 **H. L. Richards, J. W. Adams, E. M. Fitzgerald, A. R. Evans** THE FUNCTIONAL IMPLICATIONS OF GIGANTISM AND REMARKABLY LOW ELBOW MOBILITY WITHIN THE WEIRD EXTINCT MARSUPIAL MEGAFAUNA FAMILY PALORCHESTIDAE (DIPROTODONTIA, VOMBATOMORPHIA)

11:45 **A. B. Camens, T. H. Worthy** WALK LIKE A KANGAROO: NEW FOSSIL TRACKWAYS REVEAL A BIPEDALLY STRIDING MACROPODID IN THE PLIOCENE OF CENTRAL AUSTRALIA

12:00 **V. Weisbecker, L. A. Lange-Hodgson, R. M. Beck, T. Guillerme, A. R. Harrington, M. Phillips** HOW PHYLOGENETICALLY INFORMATIVE IS THE 3D BASICRANIAL TOPOLOGY OF MARSUPIAL MAMMALS?

SATURDAY MORNING, OCTOBER 12, 2019
TECHNICAL SESSION XV: FINS TO LIMBS
MEETING ROOM M1&2
MODERATORS: Zoe Kulik and Martin Sander

8:00 **Y. Hu, G. Young, J. Lu** CONSTRUCTIONAL MORPHOLOGY OF THE SHOULDER GIRDLE AND OPERCULAR SERIES OF THE UPPER DEVONIAN TETRAPODOMORPH *GOGONASUS* FROM WESTERN AUSTRALIA

8:15 **C. Bardua, M. Bon, A. Fabre, K. Das, D. C. Blackburn, E. L. Stanley, A. Herrel, A. Goswami** HIGH-DENSITY MORPHOMETRIC ANALYSIS OF MACROEVOLUTION AND PHENOTYPIC INTEGRATION OF THE ANURAN (FROG) CRANIUM

8:30 **M. E. Jones, L. E. Hill, R. B. Benson, S. E. Evans** THREE DIMENSIONAL SKELETONS OF MIDDLE JURASSIC STEM-GROUP SALAMANDERS FROM SCOTLAND, UK

8:45 **A. Fabre, C. Bardua, J. Clavel, R. Felice, D. C. Blackburn, E. L. Stanley, J. Streicher, A. Goswami** RAPID MORPHOLOGICAL EVOLUTION OF THE SALAMANDER SKULL IS CORRELATED WITH DIVERSIFICATION AND DISPERSION DURING PERIODS OF GLOBAL WARMING

9:00 **D. G. Demar, M. P. Oreska, M. T. Carrano, J. D. Gardner** THE EARLIEST KNOWN OCCURRENCES OF AN EDENTULOUS FROG AND POSSIBLE SIRENID SALAMANDER FROM THE CLOVERLY FORMATION (ALBIAN) OF WYOMING, U.S.A.

9:15 **P. Sander, M. Aberhan, J. Gravendyck, R. Kindlimann, D. Konietzko-Meier, M. Schobben, A. H. Schwermann, T. Wintrich** A NEW RHAETIAN BONEBED FROM GERMANY: IMPLICATIONS FOR THE END-TRIASSIC EXTINCTIONS IN THE MARINE REALM

9:30 **C. A. Sidor, P. Makovicky, J. A. McIntosh, N. Smith, R. M. Smith, N. J. Tabor, M. Whitney, C. H. Woolley** VERTEBRATE PALEONTOLOGY OF THE LOWER TRIASSIC FREMOUW FORMATION IN THE SHACKLETON GLACIER AREA (ANTARCTICA)

9:45 **S. S. Sumida, D. S. Berman, H. C. Maddin, A. C. Henrici, T. Martens, D. Scott, R. R. Reisz** A NEW PRIMITIVE CASEASAURIAN SYNAPSID FROM THE EARLY PERMIAN OF CENTRAL GERMANY AND ITS IMPLICATIONS FOR THE EVOLUTION OF DENTITIONS, DIETS, AND HERBIVORY OF CASEIDS

10:15 **E. Bendel, C. F. Kammerer, J. Fröbisch** STERNAL EVOLUTION IN SYNAPSIDA AND THE ORIGIN OF THE MAMMALIAN STERNUM

10:30 **A. M. Musser, M. C. Lamanna, A. G. Martinelli, S. W. Salisbury, S. Ahyong, R. Jones** THE FIRST NON-MAMMALIAN CYNODONTS FROMAUSTRALIA AND THE UNUSUAL NATURE OF AUSTRALIAN CRETACEOUS CONTINENTAL TETRAPOD FAUNAS

10:45 **D. P. Groenewald, M. O. Day, C. R. Penn-Clarke, B. S. Rubidge** BIOSTRATIGRAPHY OF THE LOWERMOST BEAUFORT GROUP IN THE MAIN KAROO BASIN, SOUTH AFRICA: IMPLICATIONS FOR MID- TO LATE-PERMIAN FAUNAL PROVINCIALISM AND KAROO BASIN DEVELOPMENT

11:00 **M. R. Whitney, K. D. Angielczyk, C. A. Sidor, B. R. Peecook** COMPARATIVE HISTOLOGY OF DICYNODONT TUSKS REVEALS CRYPTIC DIVERSITY OF TISSUE COMPOSITION, DEVELOPMENT, AND ATTACHMENT STRATEGIES

11:15 **Z. T. Kulik, L. M. Marilao, C. A. Sidor** MORE THAN ONE WAY TO BE A BOSS: HISTOLOGICAL PERSPECTIVES ON CRANIAL BOSS DEVELOPMENT AND ITS EFFECT ON SUTURE MORPHOLOGIES

11:30 **A. E. Duhamel, J. Benoit, B. S. Rubidge, J. Liu** FILLING OLSON'S GAP? A RE-APPRAISAL OF *RARANIMUS DASHANKOUENSIS* (SYNAPSIDA, THERAPSIDA) USING CT SCANNING TECHNOLOGIES AND BAYESIAN ANALYSIS

11:45 **J. Fröbisch, V. Jelen, N. Brocklehurst** RATES OF MORPHOLOGICAL EVOLUTION IN ANOMODONTIA (THERAPSIDA) ACROSS THE END-PERMIAN MASS EXTINCTION

12:00 **J. Miller-Camp** ALLIGATORINE DIVERSITY DYNAMICS SUPPORT THE COMMON-CAUSE HYPOTHESIS OF MACROEVOLUTIONARY PATTERNS IN THE ROCK RECORD

SATURDAY MORNING, OCTOBER 12, 2019
TECHNICAL SESSION XVI: DINOSAURS III
MEETING ROOM M4
MODERATORS: James Neenan and Matt Lamanna

8:00 **J. P. Kirmse, M. J. Benton, M. C. Langer** OBSERVATIONS ON THE MORPHOLOGICAL SUPPORT FOR ORNITHOSCELIDA HUXLEY, 1870

8:15 **P. S. Druckenmiller, G. M. Erickson, C. M. Brown, D. B. Brinkman, P. M. Gignac, E. Millsap, T. Hunt, D. Kay, H. Fromknecht, A. Harper** PERINATAL REMAINS SHOW THAT NON-AVIAN AND AVIAN DINOSAURS NESTED IN THE LATE CRETACEOUS PALEO-ARCTIC OF NORTHERN ALASKA

8:30 **M. C. Lamanna, J. D. Porfiri, D. D. Dos Santos, R. D. Juárez Valieri, P. Gandossi, M. Baiano** A NEW AND WELL-PRESERVED EARLY-DIVERGING ABELISAURID (THEROPODA: CERATOSAURIA: ABELISAUROIDEA) FROM THE EARLY LATE CRETACEOUS OF NORTHERN PATAGONIA

8:45 **M. C. Langer, N. Martins, P. Manzig, G. Ferreira, J. Marsola, E. Fortes, L. Vidal, R. Lima, L. Sant'Ana, R. Lorençato, M. Ezcurra** A NEW DESERT-DWELLING NOASAURINE THEROPOD FROM THE CAIUÉ GROUP, CRETACEOUS OF SOUTH BRAZIL

9:00 **M. T. Carrano, M. A. Loewen, S. W. Evers** NEW INSIGHTS INTO *ALLOSAURUS FRAGILIS* MARSH, 1877 (DINOSAURIA, THEROPODA) FROM THE TOPOTYPE SPECIMEN, USNM 4734

9:15 **T. D. Carr** SIZE AND MASS DON'T COVARY WITH MATURITY AMONG ADULT SPECIMENS OF *TYRANNOSAURUS REX*

9:30 **L. Zanno, T. A. Gates** EVOLUTIONARY RATES IN TYRANNOSAUROIDS SUPPORT A MODEL OF ECOLOGICAL RELEASE LINKED TO THE EXTIRPATION OF CARCHARODONTOSAURIANS

9:45 **J. M. Neenan, R. B. Benson, J. S. Sipla, J. A. Georgi, S. A. Walsh, A. M. Balanoff, M. A. Norell, X. Xu, J. N. Choiniere** CONVERGENT SENSORY ECOLOGIES BETWEEN ALVAREZSAUROIDEA AND EXTANT TYTONID OWLS

10:15 **J. G. Napoli, B. S. Bhullar, A. H. Turner, M. A. Norell** THE ORIGIN OF DROMAEOSAURID HYPERCARNIVORY: INSIGHTS FROM MICRO-CT SCANNING OF *SHANAG ASHILE*

10:30 **M. Ma, X. Xu, S. Wang** CRANIAL ONTOGENETIC VARIATIONS OF *SINORNITHOMIMUS DONGI* (DINOSAURIA: ORNITHOMIMOSAURIA)

10:45 **S. Wang, M. Ma, P. Wu, J. Stiegler, M. Habib, C. Chuong** MORPHOGENESIS OF EXTANT FEATHER RACHIS HELPS CLARIFY THE VARIATIONS OF MESOZOIC FEATHERS

11:00 **P. M. O'Connor, A. H. Turner, J. R. Groenke, R. N. Felice, R. R. Rogers** A NEW AVIALAN FOSSIL FROM THE MAEVARANO FORMATION, MAHAJANGA BASIN, NW MADAGASCAR, EXPANDS KNOWN CRANIAL SHAPE DISPARITY AMONG MESOZOIC BIRDS VIA AN EXPANDED MAXILLA CONTRIBUTING TO ENHANCED ROSTRALIZATION

11:15 **T. L. Green, P. M. Gignac** ESTABLISHING A COMPARATIVE OSTEO-DEVELOPMENTAL FRAMEWORK FOR EVOLUTIONARY AND FUNCTIONAL STUDIES OF DINOSAUR HEADGEAR THROUGH ANALOGY TO SOUTHERN CASSOWARIES AND NEOGNATHOUS BIRDS

11:30 **N. Carroll, G. P. Wilson, D. G. Demar, L. M. Chiappe** A COPROLITE-PRESERVED FEATHER ASSEMBLAGE FROM THE UPPER CRETACEOUS HELL CREEK FORMATION

11:45 **T. R. Lyson, I. M. Miller, A. D. Bercovici** CHANGES IN DINOSAUR ECOSYSTEMS FROM THE HELL CREEK FORMATION LEADING UP TO THE CRETACEOUS-PALEOGENE BOUNDARY IN NORTH AMERICA

12:00 **T. Kubo** BIOGEOGRAPHICAL NETWORK ANALYSIS OF CRETACEOUS NON-AVIAN DINOSAURS AND BIOGEOGRAPHICAL CONNECTIONS OF AUSTRALIA TO OTHER CONTINENTS

SATURDAY AFTERNOON, OCTOBER 12, 2019
TECHNICAL SESSION XVII: MESOZOIC AND PALEOGENE MAMMALS
MEETING ROOM M1&2
MODERATORS: Luke Weaver and Sarah Shelley

1:45 **F. Mao, C. Li, Y. Wang, J. Meng** 3D-RECONSTRUCTION OF MULTIPLE SPECIMENS FROM THE LOWER CRETACEOUS OF CHINA REVEALS CHARACTER CO-EVOLUTION TOWARD THE BAUPLAN OF BASAL THERIANS

2:00 **S. Bi, J. R. Wible, X. Zheng, X. Wang** THE EARLY CRETACEOUS EUTHERIAN *AMBOLESTES* AND ITS IMPLICATIONS FOR THE EUTHERIAN-METATHERIAN DICHOTOMY

2:15 **L. N. Weaver, G. P. Wilson, E. J. Sargis, W. J. Freimuth, D. J. Varricchio** EXCEPTIONALLY PRESERVED SKELETONS FROM THE LATE CAMPANIAN OF MONTANA PROVIDE A UNIQUE GLIMPSE INTO THE PALEOBIOLOGY OF MULTITUBERCULATES

2:30 **A. L. Brannick, H. Z. Fulghum, S. M. Smith, G. P. Wilson** EXPLORING LATE CRETACEOUS PATTERNS OF TAXONOMIC AND ECOLOGICAL DIVERSIFICATION AMONG NORTH AMERICAN STEM MARSUPIALS (PEDIOMYIDS AND ALPHADONTIDS)

2:45 **T. E. Williamson, A. Flynn, D. J. Peppe, M. T. Heizler, C. E. Leslie, R. Secord, S. L. Shelley, S. Brusatte** A REVISED, HIGH-RESOLUTION AGE MODEL FOR THE PALEOCENE OF THE SAN JUAN BASIN, NEW MEXICO, USA AND IMPLICATIONS FOR FAUNAL AND FLORAL DYNAMICS DURING THE DAWN OF THE AGE OF MAMMALS

3:00 **J. R. Claytor, G. P. Wilson, W. A. Clemens** EARLIEST PUERCAN 1 (PU1) FAUNAS FROM MONTANA WITH INSIGHTS ON MAMMALIAN TAXONOMIC AND ECOLOGICAL RECOVERY AFTER THE K–PG MASS EXTINCTION EVENT

3:15 **S. L. Shelley, S. Brusatte, T. E. Williamson** HIGH LOCOMOTOR DIVERSITY IN EARLY PALEOGENE MAMMALS PROVIDES ECOMORPHOLOGICAL INSIGHT INTO EVOLUTION FOLLOWING THE END-CRETACEOUS MASS EXTINCTION

3:30 **B. T. Hovatter, G. P. Wilson** COMPOSITION OF NEWLY DESCRIBED EARLIEST TORREJONIAN (TO1) FAUNA FROM NORTHEASTERN MONTANA, U.S.A. REVEALS TAXONOMIC DIFFERENCES AMONG EARLY PALEOCENE FAUNAS IN THE WESTERN INTERIOR OF NORTH AMERICA AND HIGHLIGHTS NORTH-SOUTH PROVINCIALITY

3:45 **O. C. Bertrand, S. Brusatte, S. L. Shelley, J. R. Wible, T. E. Williamson, L. T. Holbrook, S. G. Chester, T. Smith, I. B. Butler, J. Meng** FIRST VIRTUAL ENDOCASTS OF TWO PALEOCENE ARCTOCYONIDS: A GLIMPSE INTO THE BEHAVIOR OF EARLY PLACENTAL MAMMALS AFTER THE END-CRETACEOUS EXTINCTION

4:00 **Y. Gong, Y. Wang, Y. Wang, F. Mao, B. Bai, H. Wang** DIET AND ECOLOGY OF TWO LOPHIALETIDS FROM THE EOCENE OF ERLIAN BASIN, CHINA: COMBINED EVIDENCE FROM MESOWEAR AND STABLE ISOTOPE ANALYSES

SATURDAY AFTERNOON, OCTOBER 12, 2019
TECHNICAL SESSION XVIII: EVOLUTIONARY AND FAUNAL STUDIES
MEETING ROOM M3
MODERATORS: Phil Bell and Matthew Phillips

1:45 **T. R. Simoes, O. Vernygora, M. W. Caldwell, S. E. Pierce** REPTILE MACROEVOLUTIONARY DYNAMICS ACROSS THE PERMIAN-TRIASSIC MASS EXTINCTION AND THE EMERGENCE OF NEW BODY PLANS

2:00 **P. R. Bell, N. E. Campione, E. T. Smith, L. Milan** MID-CRETACEOUS ENDEMICITY OF EASTERN AUSTRALIAN VERTEBRATE FAUNAS

2:15 **V. Fischer, L. C. Soul, R. B. Benson, M. S. Friedman** WANING AND WAXING MARINE REPTILE DIVERSITY PRIOR TO THE K-PG BOUNDARY

2:30 **C. Sullivan, F. Fanti, D. W. Larson, P. Bell, N. E. Campione, R. Sissons, M. Vavrek** THE UPPER CRETACEOUS WAPITI FORMATION OF NORTHERN ALBERTA, CANADA AS A UNIQUE WINDOW INTO THE CONTINENTAL VERTEBRATE FAUNA OF BOREAL LARAMIDIA DURING BEARPAW TIMES

2:45 **R. A. Close, R. B. Benson, R. J. Butler** SPECIES-AREA RELATIONSHIPS IN NORTH AMERICAN TERRESTRIAL TETRAPODS ACROSS THE CRETACEOUS/PALEOGENE BOUNDARY

3:00 **M. J. Phillips, C. Fruciano** EXPLAINING WHY MOLECULAR CLOCK ANALYSES MISSED THE POST K–PG DIVERSIFICATIONS OF MAMMALS AND BIRDS OBSERVED IN THE FOSSIL RECORD

3:15 **A. S. Schulp, O. Mateus, M. Polcyn, A. Gonçalves, L. L. Jacobs** ANGOLA AND ITS ROLE IN THE PALEOBIOGEOGRAPHY OF GONDWANA

3:30 **I. M. Miller, T. R. Lyson, A. Bercovici** PLANT EVOLUTION AND DIVERSIFICATION SHAPED VERTEBRATE ECOSYSTEMS DURING THE LATE CRETACEOUS AND EARLY PALEOGENE IN WESTERN NORTH AMERICA

4:00 **J. R. Moore** VERTEBRATE TAPHONOMY IN DISTRIBUTIVE FLUVIAL SYSTEMS

SATURDAY AFTERNOON, OCTOBER 12, 2019
TECHNICAL SESSION XiX: TERRESTRIAL LOCOMOTOR BIOMECHANICS
MEETING ROOM M4
MODERATORS: Christian Heck and Peter Bishop

1:45 **K. I. Lennie, S. Manske, C. Mansky, J. Anderson** USING TRABECULAR ANISOTROPY TO DETERMINE THE POTENTIAL FOR WALKING LIMBS IN A DIVERSE ARRAY OF EARLY TETRAPODS FROM BLUE BEACH, NOVA SCOTIA

2:00 **R. W. Blob, V. K. Young, V. D. Munteanu, C. J. Mayerl, K. M. Diamond, S. M. Kawano** BIOMECHANICAL RELEASE: LOADING REDUCTION AS A PATHWAY FOR MORPHOFUNCTIONAL CHANGE IN THE SKELETONS OF VERTEBRATES ACROSS EVOLUTIONARY TRANSITIONS IN HABITAT

2:15 **T. Hirasawa, S. Kuratani** DECIPHERING DEVELOPMENTAL CONSTRAINTS IN LIMB MUSCLES

2:30 **O. E. Demuth, E. J. Rayfield, J. R. Hutchinson** 3D LIMB BIOMECHANICS OF THE STEM-ARCHOSAUR *EUPARKERIA CAPENSIS*

2:45 **A. Cuff, A. Otero, J. R. Hutchinson** FUNCTIONAL DISPARITY IN TRIASSIC–JURASSIC ARCHOSAUR HINDLIMBS, AND IMPLICATIONS FOR MUSCULOSKELETAL MODELLING

3:00 **P. J. Bishop, A. Falisse, F. De Groote, J. R. Hutchinson** USING DYNAMIC OPTIMIZATION TO SIMULATE LOCOMOTION IN EXTANT AND EXTINCT ARCHOSAURS

3:15 **D. Dróżdż, T. Sulej** LIMB OSTEOLOGY AND PROBABLE DIGGING ADAPTATIONS IN THE AETOSAUR *STAGONOLEPIS OLENKAE* (ARCHOSAURIA: PSEUDOSUCHIA) FROM NORTHERN PANGEA

3:30 **M. D. Stein, L. A. Wilson, S. J. Hand, M. Archer** GEOMETRIC MORPHOMETRIC AND FINITE ELEMENT ANALYSIS OF THE MEKOSUCHINE CROCODILE FORELIMB AS AN ASSESSMENT OF LOCOMOTION

3:45 **A. Jannel, S. W. Salisbury, O. Panagiotopoulou** STANDING ON THE FEET OF GIANTS: FINITE ELEMENT ANALYSES OF SAUROPOD DINOSAURS HIND FEET AND THE EVOLUTION OF GIGANTISM

4:00 **C. Heck, H. Woodward Ballard** AN ARM AND A LEG: TESTING ONTOGENETIC POSTURE CHANGE IN *MAIASAURA PEEBLESORUM* THROUGH LIMB SCALING AND OSTEOHISTOLOGY

SATURDAY AFTERNOON, OCTOBER 12, 2019
REGULAR POSTER SESSION IV
GREAT HALL 1&2
Authors must be present from 4:15 - 6:15 p.m. Saturday, October 12

B64 **N. T. Rasolofomanana, K. E. Samonds, L. R. Godfrey, M. Andriambelomanana, T. H. Andrianavalona, N. T. Ramihangihajason, R. B. Rakotozandry, B. Z. Nomenjanahary, M. Irwin, B. Crowley** A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR) WITH IMPLICATIONS FOR THE CHRONOLOGY OF HABITAT AND MEGAFAUNAL COMMUNITY CHANGE ON MADAGASCAR'S CENTRAL HIGHLANDS

B65 **J. M. White, M. McCurry, A. R. Evans** EVALUATING THE DIET OF *HULITHERIUM* USING ORIENTATION PATCH COUNT (OPC)

B66 **Y. Gurovich, K. W. Ashwell** PHYLOGENY OF SOUTH AMERICAN MARSUPIAL *DROMICIOPS* THROUGH BRAIN TRAITS

B67 **A. C. Tschirn, A. B. Camens** NEW SKELETAL MATERIAL SHEDS LIGHT ON THE EVOLUTION AND PALEOBIOLOGY OF KOALAS

B68 **T. J. Churchill, M. Archer, S. J. Hand** A NEW HYPERSPECIALISED CARNIVOROUS DASYUROMORPHIAN MARSUPIAL FROM EARLY MIOCENE DEPOSITS IN THE RIVERSLEIGH WORLD HERITAGE AREA, NORTH-WESTERN QUEENSLAND

B69 **W. M. Parker, J. W. Adams, A. R. Evans** REVEALING THE PALEOBIOLOGY OF AUSTRALIA'S EXTINCT MEGAFAUNA USING SYNCHROTRON X-RAY FLUORESCENCE MICROSCOPY: A CASE STUDY OF MACROPODIFORMES

B70 **C. M. Janis, A. Wagstaffe, C. Kunz, E. J. Rayfield** BONE MICROANATOMY IN KANGAROOS INDICATES DIFFERENT MODES OF LOCOMOTION IN MACROPODINES AND STHENURINES

B71 **J. D. Van Zoelen, A. B. Camens, G. J. Prideaux** RESOLVING THE TAXONOMIC VALIDITY OF THE GIANT EXTINCT MARSUPIAL *NOTOTHERIUM* (DIPROTODONTIDAE) AND ITS RELATIONSHIP TO *ZYGOMATURUS*

B72 **M. L. Martin, N. M. Warburton, K. J. Travouillon, T. A. Fleming** A COMPARATIVE FUNCTIONAL ANALYSIS OF FORELIMB MORPHOLOGY IN AUSTRALIAN MARSUPIALS (MARSUPIALIA)

B73 **S. K. Pevsner** ANALYSIS OF ECOLOGICAL DIVERSIFICATION IN MARSUPIAL MAMMAL EVOLUTION BY MULTIVARIATE ANALYSES OF THEIR LIMB SKELETON IN BOTH EXTANT AND FOSSIL MARSUPIALS

B74 **A. H. Parker, M. Archer, S. J. Hand, T. Myers** TAPHONOMY AND PALEOCOMMUNITY STRUCTURE OF LD94 SITE, A MIDDLE MIOCENE FOSSIL DEPOSIT IN THE RIVERSLEIGH WORLD HERITAGE AREA, NORTHWESTERN QUEENSLAND

B75 **A. L. Atwater, X. Wang, K. D. Thomson, D. L. Hanneman, D. Stockli** A NEW SPECIES OF *PARATOMARCTUS* (CARNIVORA, CANIDAE) FROM THE MIDDLE MIOCENE OF MONTANA

B76 **Y. Li, S. Bi, T. Deng** SKULL REMAINS OF A SMALL FELINE (CARNIVORA, FELIDAE) FROM THE LATE MIOCENE DEPOSITS OF LINXIA BASIN (GANSU PROVINCE, CHINA)

B77 **F. O'Keefe, A. Brannick** SPACE-INDEPENDENT MEASURES OF MODULARITY IN GEOMETRIC MORPHOMETRICS, WITH AN EXAMPLE FROM *SMILODON* AND *CANIS DIRUS*

B78 **A. T. Salis, B. W. Schubert, J. Meachen, A. J. Cooper, K. J. Mitchell** TAXONOMY AND PHYLOGEOGRAPHY OF TWO EXTINCT NORTH AMERICAN QUATERNARY CARNIVORANS

B79 **D. S. Rovinsky, J. W. Adams, A. R. Evans, T. I. Pollock** SPECIALISATION OF CANINE SHAPE AND SHARPNESS IN POTENTIALLY SYMPATRIC SPECIES OF *DINOFELIS* (CARNIVORA, MACHAIRODONTINAE)

B80 **M. Balisi, J. Blois, A. Farrell, G. Takeuchi, E. Lindsey** CHARACTERIZING MESOCARNIVORE DISTRIBUTIONS AT RANCHO LA BREA

B81 **D. Flores, E. Eldridge, E. Elminowski, A. Hartstone-Rose** THE ROAR AND HOWL OF RANCHO LA BREA'S TOP PREDATORS

B82 **H. Chirchir, C. Ruff, K. Helgen, R. Potts** TRABECULAR BONE DENSITY IN ZOO AND WILD FELIDS

B83 **R. López-Antoñanzas, P. Peláez-Campomanes, D. Azar, G. Kachacha, A. Prieto-Márquez, F. Knoll** FIRST MYOCRICETODONTINAE (RODENTIA) FROM THE MIOCENE OF LEBANON

B84 **S. López-Torres, R. Bhagat, M. T. Silcox, Ł. Fostowicz-Frelik** FIRST VIRTUAL RECONSTRUCTION OF THE INNER EAR OF A FOSSIL RABBIT: LOCOMOTOR BEHAVIOUR AND HEARING SENSITIVITY OF *MEGALAGUS TURGIDUS* (EARLY OLIGOCENE OF NEBRASKA)

B85 **T. Kato, H. Yamano** DISCOVERY OF A NEW RODENT ASSEMBLAGE FROM THE LATE OLIGOCENE IN JAPAN

B86 **S. F. Alashqar, H. M. Sallam, S. El-Sayed, E. M. Seiffert** NEW PHIOCRICETOMYINE RODENTS (PHIOMORPHA, HYSTRICOGNATHI) FROM THE JEBEL QATRANI FORMATION, FAYUM DEPRESSION, EGYPT

B87 **T. A. Penkrot, S. P. Zack** NEW POSTCRANIA OF SCIURAVIDAE (RODENTIA): IMPLICATIONS FOR LOCOMOTION AND PHYLOGENY

B88 **M. A. El-Hares, H. M. Sallam, D. A. El-Mekkawy, S. El-Sayed, E. Seiffert** ICTHYOFAUNAL COPROLITES FROM THE LATE EOCENE DEPOSITS OF THE FAYUM DEPRESSION, EGYPT

B89 **N. A. Singh, Y. P. Singh, K. M. Sharma, N. P. Singh, R. Patnaik** ADDITIONAL FOSSILS REMAINS FROM THE HOMINOID BEARING LATE MIOCENE TAPPAR LOCALITY OF KUTCH, INDIA: IMPLICATION ON PALEOENVIRONMENT

B90 **M. J. Ziegler, D. W. Steadman, J. M. Jaeger, V. J. Perez, B. J. Macfadden** PALEOENVIRONMENTAL ANALYSIS OF AN UNUSUAL FOSSIL LOCALITY FROM THE LATE MIOCENE IN NORTHERN FLORIDA

B91 **K. M. Sharma, Y. P. Singh, N. A. Singh** RECORDS OF VERTEBRATE REMAINS FROM THE LATE TRIASSIC TIKI FORMATION, MADHYA PRADESH, INDIA: IMPLICATIONS ON GONDWANAN PALEOBIOGEOGRAPHY

B92 **G. S. Gonçalves, C. A. Sidor** A NEW DREPANOSAUROMORPH FROM THE CHINLE FORMATION OF PETRIFIED FOREST NATIONAL PARK, ARIZONA

B93 **M. Tałanda, T. Sulej** AN EARLY LATE TRIASSIC RHYNCHOCEPHALIAN FROM NORTHERN PANGEA SUGGESTS RELIC NATURE OF SOME BRITISH RHAETIAN VERTEBRATE ASSEMBLAGES

B94 **K. M. Jenkins, K. Schwenk, B. S. Bhullar, J. A. Gauthier** TOOTH ATTACHMENT IN AN ACRODONT AMPHISBAENID (SQUAMATA)

B95 **C. J. Bell, S. G. Scarpetta, D. Anderson** DIAGNOSTIC EFFICACY OF PUBLISHED MORPHOLOGICAL CHARACTERISTICS OF NORTH AMERICAN SAND LIZARDS

B96 **R. Allemand, J. Abdul-Sater, M. T. Silcox** ENDOCRANIAL ANATOMICAL CHANGES THAT ACCOMPANY THE LOSS OF LIMBS IN SQUAMATES

B97 **M. Riegler, E. L. Stanley, J. I. Bloch** DESCRIBING ENAMEL IN SQUAMATES: UTILIZING NON-DESTRUCTIVE CT SCANS TO CHARACTERIZE ENAMEL IN EXTANT AND EXTINCT LIZARD SPECIES

B98 **S. J. ElShafie** BODY SIZE CHANGES ACROSS LIZARDS AND CROCODYLIANS CORRESPOND TO CLIMATIC CHANGES THROUGH THE PALEOGENE IN THE WESTERN INTERIOR OF NORTH AMERICA

B99 **S. Onary, A. S. Hsiou, A. Palci** PRELIMINARY REASSESSMENT OF THE TAXONOMY AND SYSTEMATICS OF THE GENUS *BOAVUS* MARSH, 1871 (SERPENTES, BOOIDEA)

B100 **W. R. Callahan, C. M. Mehling, S. Ballwanz, T. W. Dudgeon** FIRST EVIDENCE OF CHAMPSOSAURS (DIAPSIDA:,NEOCHORISTODERA) FROM THE LATE CRETACEOUS OF THE ATLANTIC COASTAL PLAIN

B101 **Y. Lee, D. Kong, S. Jung** THE FIRST CHORISTODERAN TRACKWAY?

B102 **Y. Nakajima, R. Matsumoto, P. M. Sander, O. Sasaki, H. Kano, S. Hayashi, S. E. Evans** MINERALIZED NOTOCHORD-ASSOCIATED TISSUES PRESERVED IN FOSSIL CENTRA SUGGESTS A UNIQUE DEVELOPMENTAL PATTERN IN THE AXIAL SKELETON OF CHORISTODERA

B103 **M. B. Soares, C. L. Schultz, A. G. Martinelli, P. M. Fonseca, V. D. Paes Neto** SMALL CARNIVORE COPROLITES FROM THE LATE TRIASSIC OF SOUTHERN BRAZIL: PALEOBIOLOGICAL IMPLICATIONS

B104 **M. O. Day, J. Ramezani, R. Frazer, B. S. Rubidge** U–PB (CA-TIMS) AGE CONSTRAINTS ON THE MIDDLE PERMIAN LAND VERTEBRATE EVOLUTION FROM THE MAIN KAROO BASIN, SOUTH AFRICA

B105 **K. D. Angielczyk, C. P. Abbott, J. K. Lungmus, K. Keating** POSTCRANIAL ANATOMY OF THE LUANGWA BASIN CISTECEPHALID (THERAPSIDA, ANOMODONTIA): PHYLOGENETIC AND FUNCTIONAL IMPLICATIONS

B106 **K. R. Devlin, S. S. Sumida, D. S. Berman, A. C. Henrici, T. Martens** NEW INFORMATION ON THE HINDLIMB OF *DIMETRODON TEUTONIS*, A PELYCOSAURIAN-GRADE SPENACODONTID SYNPASID FROM THE EARLY PERMIAN BROMACKER LOCALITY OF CENTRAL GERMANY, AND SMALLEST KNOWN SPECIES OF *DIMETRODON*

B107 **J. Liu, J. Yi** NEW TETRAPODS FROM THE SUNJIAGOU FORMATION AND SHANGSHIHEZI (UPPER SHIHHOTSE) FORMATION, SHANXI, CHINA AND THEIR IMPLICATIONS

B108 **E. M. Knutsen** THE LAZARUS DICYNODONT—REASSESSING AUSTRALIAN CRETACEOUS MATERIAL

B109 **A. R. Beyl, S. J. Nesbitt, M. R. Stocker** THE LARGEST LAGERPETIDS: EVIDENCE FROM A NEWLY IDENTIFIED OTISCHALKIAN ASSEMBLAGE FROM THE LOS ESTEROS MEMBER (SANTA ROSA FORMATION) OF NEW MEXICO

B110 **M. B. McCabe, S. J. Nesbitt** THE FIRST PECTORAL AND FORELIMB MATERIAL ASSIGNED TO THE LAGERPETID *LAGERPETON CHANARENSIS*: COMPARING TO OTHER LAGERPETIDS AND OTHER AVEMETATARSALIANS

B111 **J. Botha, K. Chapelle, B. Weiss, J. N. Choiniere** LIFE HISTORY PATTERNS IN EARLY JURASSIC DINOSAURS FROM SOUTH AFRICA

B112 **S. Hartman** USING COMPARATIVE ANATOMY, TAPHONOMY, AND PHYLOGENETIC BRACKETING TO ASSESS RIB ORIENTATION IN NON-AVIAN DINOSAURS

B113 **M. Lambertz** ON THE HISTOLOGY AND DEVELOPMENT OF DINOSAURIAN POST-CRANIAL SKELETAL PNEUMATICITY

B114 **N. Campione, J. Mallon, R. Benson, A. R. Evans** ON THE POTENTIAL TO RECONSTRUCT A DIETARY CONTINUUM IN DINOSAURS

B115 **D. J. Varricchio, W. J. Freimuth, G. Panascí** THE RICH ICHNOLOGIC RECORD OF EGG MOUNTAIN FROM THE TWO MEDICINE FORMATION (UPPER CRETACEOUS) OF MONTANA, USA, PROVIDES INSIGHT INTO THE ENVIRONMENT, SEDIMENTOLOGY AND ECOLOGY OF A DINOSAUR NESTING SITE

B117 **S. Whitebone, G. F. Funston, P. J. Currie** AN UNUSUAL FOSSIL LOCALITY FROM THE LATE CRETACEOUS HORSESHOE CANYON FORMATION OF SOUTHERN ALBERTA, CANADA REVEALS RARE ELEMENTS OF A PALEOCOMMUNITY

B118 **A. M. Jukar, M. T. Carrano** THE STRUCTURE OF THE MAMMALIAN AND DINOSAURIAN HERBIVORE GUILD

B119 **C. N. Todd, E. M. Roberts, E. Knutsen, A. Rozefelds, H. Huang, C. Spandler** REFINED AGE AND GEOLOGICAL CONTEXT OF TWO OF AUSTRALIA'S MOST IMPORTANT JURASSIC VERTEBRATE TAXA (*RHOETOSAURUS BROWNEI* AND *SIDEROPS KEHLI*), SURAT BASIN, QUEENSLAND

B120 **E. M. Roberts, T. Beveridge, J. Ramezani, A. Titus** INTRAFORMATIONAL STRATIGRAPHIC CORRELATION OF VERTEBRATE LOCALITIES WITHIN THE UPPER CRETACEOUS KAIPAROWITS FORMATION TIED TO HIGH-PRECISION U–PB CA-ID-TIMS ZIRCON DATING OF 11 BENTONITE MARKER HORIZONS: IMPLICATIONS FOR EVOLUTIONARY AND ECOLOGICAL PATTER

B121 **A. R. Fiorillo, Y. Kobayashi, P. McCarthy** COMPARISON OF PALEOENVIRONMENTAL AND PALEOCLIMATOLOGICAL PARAMETERS OF CORRELATIVE DINOSAUR-BEARING LATE CRETACEOUS (CAMPANIAN–MAASTRICHTIAN) ROCK UNITS ACROSS ALASKA, USA: A REGIONAL PERSPECTIVE

B122 **B. S. Salem, H. M. Sallam, S. El-Sayed, W. Thabet, M. Antar, M. C. Lamanna** NEW DINOSAUR, PTEROSAUR, AND CROCODYLIFORM FOSSILS FROM THE UPPER CRETACEOUS (CENOMANIAN) BAHARIYA FORMATION OF THE BAHARIYA OASIS, EGYPT

B123 **B. H. Breithaupt, N. A. Matthews, T. L. Green, M. Belvedere** INSIGHTS INTO DINOSAUR TRACKING IN THE 21ST CENTURY USING PHOTOGRAMMETRIC ICHNOLOGY AND NEOICHNOLOGY OF EMUS

B124 **M. V. Connely, J. Cavigelli** TATE GEOLOGICAL MUSEUM—A VALUABLE RESOURCE FOR VERTEBRATE PALEONTOLOGICAL RESEARCH AS WELL AS ENHANCING LIBERAL ARTS EDUCATION

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

REVISITING THE PROCTOR LAKE DINOSAUR LOCALITY: NEW INSIGHTS ON THE PALEOECOLOGY AND PALEOENVIRONMENT

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Within the Twin Mountains Formation, the Proctor Lake Dinosaur Locality in central Texas is distinct from other Early Cretaceous Texas localities by having an abundance of vertebrate fossils representing a low diversity assemblage. This unique faunal assemblage is represented by at least 32 individuals of the small ornithopod *Convolosaurus marri*, an isolated tooth belonging to a small member of Dromaeosaurinae, and two small-bodied crocodyliforms, *Wannchampsus kirpachi* and a newly described species. This new diminutive crocodyliform is represented by a single partial skeleton with a complete dentary, trough-shaped mandibular symphysis, amphicoelous vertebrae, nearly square dorsal osteoderms, and elongated and gracile limbs. In addition, limb morphology indicates a parasagittal posture, an attribute associated with a terrestrial lifestyle. As a result, this new taxon represents the first occurrence of a terrestrial crocodyliform from the Cretaceous of Texas and whose presence at Proctor Lake may indicate an ecological shift as a result of environmental factors.
At Proctor Lake, the fossil bearing strata consist of 2 meters of reddish muds and sands. The cross-sectional profile contains stacked B horizons classified as well-developed calcic Vertisols which are interpreted to represent a semi-arid floodplain. Weathering indices of matrix collected from the paleosols estimate mean annual precipitation of ~330 mm/yr while crystallization temperature of pedogenic phyllosilicates indicate mean annual temperature of ~30 ± 3° C (approximately 13° C higher than modern temperatures at the same latitude). This environmental analysis provides contextual information to explain the depauperate nature of the Proctor Lake Dinosaur Locality, with a nearly monospecific dinosaur taxa, as well as the first transition to terrestriality for a neosuchian crocodyliform in North America.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

DINOSAUR TRACKS AS AN EDUCATIONAL RESOURCE: REDISCOVERING THE HERITAGE MUSEUM OF THE TEXAS HILL COUNTRY

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One of the most spectacular localities for dinosaur tracks in the Texas Hill Country is providing unique educational opportunities to undergraduate students. For the last four years, the Heritage Museum of the Texas Hill Country (HMTHC) has been allowing students, primarily non-science majors, to conduct field projects directly with the footprints. These class exercises are designed to teach students what is involved in a scientific research project; including project design, making observations and interpretations, testing hypotheses, and summarizing their results in a scientific report. Students acquire team building and critical thinking skills while collecting footprint data to discover what the fossil tracks reveal about Texas's ancient past. Additionally, two undergraduate geoscience students from Trinity University conducted an independent research project to study the geology of the dinosaur track bearing interval at HMTHC. They were responsible for measuring a stratigraphic section, collecting samples and analyzing samples through thin sections, as well as XRF and stable isotope measurements. From this data they were able to correlate the research locality to additional nearby dinosaur track sites to compare stratigraphic relationships and the environmental context of track preservation. This research not only provides insight on the connection of the tracks from HMTHC to other footprint localities in the area, but has provided a unique field experience for these students.
The HMTHC, between the communities of Sattler and Startzville in Comal County, preserves over 300 footprints from the early Cretaceous (~110 million years ago) Glen Rose Formation. Originally discovered in 1982, the HMTHC has been dedicated to conservation and protection of these fossil resources. They represent an important scientific and educational resource for the area, providing school groups, families, and dinosaur lovers of all ages a unique opportunity to experience fossils first hand. In addition, the HMTHC has been essential in the study of other dinosaur track and fossil localities throughout the Hill Country. Because dinosaur footprints have been an integral part of the human as well as geological history of Texas, it is imperative that this wonderful site and all of its natural resources be preserved for future generations.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

MILLIONS OF YEARS, DOZENS OF SAMPLES, ONE SINGLE SCAN: NEW METHODS TO RAPIDLY INCREASE THE NUMBER OF SPECIMENS CAPTURED IN A SINGLE HIGH-QUALITY SCAN.

AGUILAR, ROCIO, Museums Victoria/Monash University/University of Melbourne, Melbourne, Australia

High-resolution microcomputed tomography, or microCT, has become an increasingly valuable tool for the non-invasive visualization of small objects. MicroCT is particularly beneficial for the study of museum collections, which often contain millions of small, delicate, and unique objects not amenable to traditional preparation. Despite the increasing use of microCT in systematic biology, a major challenge remains in the practical imaging of high numbers of small specimens within a project scope, for example in the context of large-scale analyses of community change over time. This has proven difficult because of the need for specimens to remain motionless during scan time and because each individual must be digitally labelled to match the original specimen's identity. Here we outline steps developed for the high throughput microCT scanning of micro-fossils (~ 2mm), meant to facilitate advanced exploration of museum collections, and allow researchers with limited access to microCT facilities the opportunity to maximize their investments. We based our studies on micro-fossils from Capricorn Caves in Queensland, Australia, to study changes in morphology, ecology and distribution of reptiles, amphibians and mammals. We succeed in maximizing the quantity of samples per scan in order to obtain high quality 3D models and compare them to their modern counterparts. These steps should also be applicable to any small, dry objects of similar properties and size.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

NEW PHIOCRICETOMYINE RODENTS (PHIOMORPHA, HYSTRICOGNATHI) FROM THE JEBEL QATRANI FORMATION, FAYUM DEPRESSION, EGYPT

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The rich rodent assemblages from the Eocene–Oligocene deposits of the Jebel Qatrani Formation (Fayum Depression, Egypt) have important implications for our understanding of the origin and paleobiogeography of Hystricognathi, a diverse clade that is now represented by the Afro-Asiatic Hystricidae, New World Caviomorpha, and African Phiomorpha. Here we present previously undescribed material of the enigmatic hystricognath clade Phiocricetomyinae, from three different stratigraphic levels in the Jebel Qatrani Formation — the late Eocene Locality 41 (~34 Ma, the oldest and most productive quarry in the Formation) and the early Oligocene quarries E and I (~33 and ~29 Ma, respectively). These specimens document the entire lower and upper dentition aside from the upper permanent fourth premolar and upper third molar, as well as mandibular fragments and partial crania (the latter being crushed specimens from L-41). The new specimens differ from other phiomorph rodents in the Formation by exhibiting the following features in combination: relatively small size; no suppression of p4 formation and eruption; distal displacement of molar protoconids relative to metaconids; large and well developed hypoconulids on dp4 and m1; and no metalophulid II, mesoconid or mesolophid on the lower molars. Among other things, the p4s lack metalophulid I & II and anterior cingulids, with variations in the orientation of the hypolophid (e.g., connections with the anterior arm of the hypoconid or the posterolophid, or no connection). The p4 and m2 hypoconulids are weak and are sometimes submerged into the posterolophid. M1-2 have a strong metaconule connected to the hypocone, weak anterior arms of the hypocones, and no mesostyles. Bayesian tip-dating analysis of craniodental features consistently place the new phiocricetomyines closer to ~29 Ma *Phiocricetomys* than to the more primitive ~35 Ma phiocricetomyine

Talahphiomys from Libya. With the notable exception of the highly derived taxon *Phiocricetomys*, molar morphology in Phiocricetomyinae remained remarkably conservative through at least 5 million years of evolution.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

ENDOCRANIAL ANATOMICAL CHANGES THAT ACCOMPANY THE LOSS OF LIMBS IN SQUAMATES

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Endocasts are largely used to inform our understanding of the central nervous system of fossil taxa. However, as endocasts are not always an accurate reflection of the morphology of the brain (e.g., in some non-avian reptiles), it is important to determine what kinds of information can be deduced from endocranial anatomy. Here, we consider how the loss of limbs may affect endocranial morphology, and how these effects may vary among different lineages. We used the broadly diverse clade, Squamata, in which several lineages have independently evolved complete or partial limb reduction, involving a complex reorganization of the musculoskeletal, nervous, circulatory, respiratory, and digestive systems. Virtual endocasts of several limbless lizards (dibamids, pygopodids, scincids, gymnophthalmids, anguids, anniellids and diploglossids), as well as amphisbaenians and snakes, were reconstructed using microCT data, and assessed in relation to one another, and to limbed members of closely related groups. Our results reveal that a broad diversity of endocranial morphological patterns are associated with the limbless condition in squamates. Endocasts of limbless taxa share more similarities to endocasts of their four-limbed close relatives than to endocasts of other limbless squamates, indicating a strong phylogenetic effect. Some similarities are shared between taxa (e.g., absence of optic lobes), but they seem to be more closely related with fossoriality rather than with the loss of the limbs per se, suggesting an ecological impact on the endocast morphology. Although a decrease in the relative cerebellar volume has been previously observed in limbless squamates, we were not able to find a similar correlation here, likely due to difficulties in accurately determining the limits of the cerebellum in squamate endocasts. This first large-scale comparative study demonstrates that the loss of limbs in squamates cannot be predicted from endocast morphology alone, having implications for the interpretation of isolated crania in the fossil record. However, this provides the first elements of a framework to investigate the form-function relationships in endocasts that do not reflect the brain morphology alone, demonstrating that both phylogenetic and ecological effects are driving their morphology.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

BUCCAL TOOTH DEVELOPMENT, REPLACEMENT RATE, AND MICROSTRUCTURE IN PARKSOSAURIDAE (DINOSAURIA: NEORNITHISCHIA)

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The highly specialized dental characteristics and tooth replacement rates of herbivorous cerapodans exhibiting complex dental batteries (i.e., Ceratopsia and Ornithopoda) have been the focus of intense study; however dental evolution within the sister-taxon of Cerapoda-- Parksosauridae--remains largely enigmatic. In order to better characterize dental evolution within parksosaurs, we investigated tooth growth and microstructure for representative members of its two subclades--the Maastrichtian thescelosaurine Thescelosaurus neglectus (NCSM 15728) and a new undescribed species of orodromine (MM15-MT) from Cenomanian-aged deposits in western North America. Buccal dentition of both taxa is diminutive. A dislodged buccal tooth prepared from the articulated skull of NCSM 15728 measures 4.18 mm in crown height (CH) and 6.32 mm in maximum crown mediodistal width (CW), whereas the isolated buccal tooth from the new orodromine measures 3.47 mm (CH) and 4.52 mm (CW). Both teeth were sectioned longitudinally. Incremental growth lines in the dentine (Von Ebner lines, VELs) were largely obscured along the apicobasal plane in both samples, yet clearly visible and distinct ventral to this plane. We calculated a mean increment width of 28.5 µm for T. neglectus and 20.72 µm for the new orodromine. These values were used to derive tooth formation times for functional teeth (132 days and 137 days, respectively). Additionally, µCT reconstructions of associated dentaries were used to estimate generations of replacement teeth in parksosaurids (only one generation of replacement teeth was evident in both taxa) and calculate tooth replacement rates. These values were approximately 70 days for T. neglectus (range 45-95 days) and 76 days for the new orodromine. Uncertainty in tooth replacement rate within T. neglectus largely stems from poor resolution of the apex of the pulp cavity in these teeth within CT scan data and a high degree of tooth wear. The orodromine tooth exhibited thinner enamel (mean enamel thickness 13 µm). Whereas, enamel was >6x thicker in the thescelosaurine (mean enamel thickness 81 µm (range: 65-92 µm). Based on these data, we hypothesize that tooth formation times and replacement rates are relatively conserved among parksosaurid neornitischians.

Grant Information:
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Technical Session XI (Friday, October 11, 2019, 10:30 AM)

A WAY TO ACCOUNT FOR BIOGEOGRAPHIC BIAS IN ESTIMATING THE SPECIES RICHNESS OF NORTH AMERICAN CENOZOIC MAMMALS

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Withdrawn

Paleontological diversity curves are plagued by biases that go far beyond variation in sample size. Richness interpolators and extrapolators, such as rarefaction, quorum subsampling, and Chao 2, are all weakly to moderately biased by variation in the evenness of species counts, and they underestimate when there is high biogeographic provincialism (the presence of many endemics). The evenness bias is not fully resolvable and not dealt with here. However, an approach to the provincialism problem can be suggested. The first and key step is to order the fossil samples into a line based on their spatial coordinates using one or another algorithm that minimizes the [illegible] resulting trail. The trail is then scanned from one [illegible] samples are encountered, one records the number of [illegible] to that point. This count is summed across all [illegible] product of [illegible] and [illegible] factor. The [illegible] plogging [illegible] of [illegible] species count and [illegible] scan is reversed, and the two [illegible] are averaged. Simulations assuming random [illegible] that this method produces values that are highly [illegible] almost insensitive to sample size. Analyses of empirical sample [illegible] various vertebrate groups that are drawn from the Ecological Register show the same thing. The method is applied to published Cenozoic mammal data for North America, which are often strongly spatially clustered. Samples are binned into time intervals of equal lengths. The trail-based extrapolations are also largely insensitive to sample size. They yield a diversity curve that is remarkably flat, with a plateau around 400 species throughout almost the entire Cenozoic. There are crashes in the Oligocene and Pliocene that seem biologically plausible because they coincide with times of major global climate change, but few other excursions. Similar patterns are obtained with interval lengths of 2, 2.5, and 3 myr. These results confirm that there is a hard limit to species richness in mammals and that the limit was reached almost immediately after the Cretaceous-Paleogene mass extinction. Tetrapod diversity curves at all scales that show large swings are presumably strongly compromised by sampling overprints. Because mammal fossils are both highly diagnostic and physically robust and this is not true of most other tetrapod fossils, low tetrapod diversity in the Mesozoic may prove to be a taphonomic artifact.

Technical Session VI (Thursday, October 10, 2019, 8:30 AM)

A MORPHOMETRIC ASSESSMENT OF MODERN AND EXTINCT *MACRONYCTERIS* SPP. (CHIROPTERA: HIPPOSIDERIDAE) ON MADAGASCAR

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Extant *Macronycteris* spp. bats are broadly distributed across Madagascar, and vary in size with respect to their sex, biogeographic origin and genetic clade. An extinct member of the genus, *Macronycteris besaoka*, was identified from ≤ 10,000 year-old breccias from Anjohibe Cave in northwestern Madagascar. Since its description, taxonomic and phylogenetic revisions of living *Macronycteris* spp. have reshaped our understanding of the genus. This includes the discovery of a new cryptic species, *M. cryptovalorona*, and two

clades within *M. commersoni.* Furthermore, augmentation of well-documented museum collections has permitted more comprehensive assessment of the morphological trends within the extant Malagasy species, and of the validity of *M. besaoka*. Herein, we investigate the variation within modern and extinct *Macronycteris* spp. through PCA and non-parametric multivariate methods (e.g., PERMDISP, PERMANOVA). Living species are sexually dimorphic and display different trends in size and morphological dispersion. When separated by latitude and bioclimate, modern *Macronycteris* spp. were found to differ by location along the western portion of the island. These new assessments validate the recognition of the extinct species *M. besaoka*, and support the original assertion that it possesses wider molars than modern *Macronycteris* spp. in Madagascar. *Macronycteris besaoka* may have adapted to preying on larger insects, and inhabited a more stable, mesic environment compared to modern conditions at Anjohibe Cave.

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 3:15 PM)

LATE PLEISTOCENE TO MID-HOLOCENE PALEOECOLOGY OF EAST JAVA: EVIDENCE FROM CAVE SITES IN THE GUNUNG SEWU REGION

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The climatic shifts during the Pleistocene to Holocene transition in Island Southeast Asia resulted to dramatic changes in landscape configurations and paleoenvironments which are presumed to have had greatly impacted vertebrate community composition, including the extinction/extirpation of several mammalian taxa. In the island of Java, paleoenvironmental proxies point to a drastic change from the predominance of open, grasslands to closed, dense rainforests. How this environmental change shaped animal distributions/interactions remains to be fully elucidated. Here we looked at least 20,000 animal bone fragments from archaeological layers dated to the last 30,000 years in three cave sites in East Java's Gunung Sewu (Thousand Hills') region: Song Terus, Goa Braholo and Song Gupuh. The Late Pleistocene layers of the sites were dominated by large-sized ungulates mostly adapted to open environments, albeit intermediate-sized forest-adapted mammals are also present. The onset of the Holocene, in contrast, coincided with the predominance of small, forest-adapted taxa not dissimilar to the current fauna in the area. However, we identified three closed-canopy rainforest-adapted murid taxa that are now extirpated in East Java. In addition to zooarchaeological analyses, we also looked at the stable isotope from dental enamel of selected taxa as well as dental mesowear and microwear in ungulate specimens. Although the presence of forest-dependent taxa, including stenotopic species, clearly indicates the presence of dense, closed-canopy rainforest in the area during the onset of the Holocene, taxa usually adapted to open environments persisted until this period. Dental wear and stable isotope analyses reveal that this could be attributed to both the presence of grassland-forest mosaics in the region during this period and a change in the ecological preference of some species, or at least tolerance of the shift in environmental conditions. The results of our analyses provide important insights on the paleoecology of East Java during times of climatic and environmental change.

Technical Session IX (Thursday, October 10, 2019, 1:45 PM)

CRANIAL BONE INNER STRUCTURE AND FOSSORIALITY IN LEPIDOSAURIA

AMSON, Eli, Museum fuer Naturkunde, Berlin, Germany; EBEL, Roy, Museum fuer Naturkunde, Berlin, Germany; MUELLER, Johannes, Museum fuer Naturkunde, Berlin, Germany

Fossoriality has been acquired repeatedly in the evolutionary history of squamates (e.g., worm lizards, sand skinks, hog-nosed snakes). Related to this case of convergent evolution, the gross morphology of the skull in the corresponding fossorial clades has been subject of numerous studies. Indeed, these clades mostly comprise head-first-burrowers, a digging style that can be expected to influence cranial anatomy. However, to our knowledge, the inner structure of the cranial bones has never been quantified. Because some lifestyles have been clearly associated with bone microanatomical phenotypes, we here test whether the convergent acquisition of fossoriality in squamates is associated with skull roof structural features.
We employed micro-CT-scans and the image analysis software ImageJ to generate a comprehensive data set including thickness and compactness of premaxilla, nasal, frontal and parietal in all extant fossorial non-Serpentes lepidosaur clades, as well as their respective sister-clades. We have also sampled five extinct amphisbaenians, for which well-preserved cranial material is known. Taking into account the different positions of homologous bones along the anteroposterior skull axis, we were able to plot the distribution of these parameters over a cranial profile. These profiles differ consistently in amplitude, slope, and position of maxima according to fossoriality, with for instance the fully fossorial amphisbaenians (worm lizards) showing a greater thickness and compactness in the anterior region of the skull than their surface-terrestrial sister-group, the lacertids (true lizards). Mapping of these traits on a time-calibrated phylogenetic tree clearly shows the convergent evolution of cranial bone structure across non-Serpentes lepidosaurs. The extreme condition observed in extinct amphisbaenians, such as the Eocene *Cryptolacerta*, confirms that they likely were fossorial, as previously inferred based on gross-morphology. It is planned to extend the sampling to surface-terrestrial as well as fossorial snakes, in order to understand the evolution of cranial bone structure in relation to fossoriality across Lepidosauria as a whole.

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EA: German Research Council (DFG AM 517/1-1)
RE: Studienstiftung des deutschen Volkes

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

DIAGNOSIS OF THE PRINCIPAL TAXA OF TERATORNITHIDAE (AVES: ACCIPITRIFORMES), INCLUDING *TERATORNIS* MILLER 1909 AND ITS SPECIES *T. MERRIAMI* AND *T. WOODBURNENSIS*

ANDERSON, Julia N., University of California, Berkeley, Berkeley, CA, United States of America; STIDHAM, Tom, Chinese Academy of Sciences, Beijing, China; PADIAN, Kevin, University of California Berkeley, Berkeley, CA, United States of America

The teratorns, large condor-like birds of prey, are among the most important discoveries of the Pleistocene La Brea Tar Pit deposits, because their enormous size and their ecological role. The holotype specimen of the first and most abundant teratorn species described, *Teratornis merriami* (UCMP no. 12101), is an isolated partial skull. The family Teratornithidae is diagnosed on four cranial features: the compression and vaulting of the beak, the lateral and backward extension of the post-auditory prominences, the reduced, dome-shaped occipital region, and the flatness of the skull. The genus *Teratornis*is diagnosed on three autapomorphies: the angular distal portions of the post-auditory prominences, the elliptical shape of the foramen magnum, and the large, fungiform basipterygoid processes. The holotype contains two referred specimens, a partial beak and quadrate, both of which cannot belong to specimen no. 12101. Although a large quantity of referred material has been found since 1909, no post-cranial specimens have been associated with described cranial material. Of the seven species and six genera within Teratornithidae, only two species, *T. merriami and T. woodburnensis*, are contained within the holotype genus, *Teratornis*. *Teratornis woodburnensis* is diagnosed on the facies articularis basipterygoidea, a feature not present on the holotype of *T. merriami*. Further taxa cannot be referred to *Teratornis* until a full morphometric study of post-cranial material is conducted.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

POSTCRANIAL ANATOMY OF THE LUANGWA BASIN CISTECEPHALID (THERAPSIDA, ANOMODONTIA): PHYLOGENETIC AND FUNCTIONAL IMPLICATIONS

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Cistecephalidae is a clade of Lopingian dicynodonts from southern Africa and India whose skulls and postcrania are modified for a fossorial lifestyle. There are four named cistecephalid species, along with a fifth new species from the Lopingian Upper Madumabisa Mudstone Formation of the Luangwa Basin (Zambia), which is currently under description. It is diagnosed by the presence of tusks, a trough on the ventral surface of the vomer, and an interparietal with a pair of dorsal processes that extend onto the skull roof. A newly prepared specimen (NHCC LB820) preserves the skull and mandible, most presacral vertebrae, pectoral girdle, forelimbs, and a distal hindlimb. When combined with other specimens, nearly the entire skeleton of the Luangwa Basin form can be described. Like other cistecephalids, the scapula lacks an acromion process. The dorsal end of the scapula possesses a short, posterior process, although it is not as prominent as in *Kawingasaurus*. The humeral head is well-ossified and weakly set off from the humerus by an incipient neck. The

insertion of *M. subcoracoscapularis* on the humerus is developed into a distinct process, a strong supinator crest is present, and the deltopectoral crest is proportionally the longest of any cistecephalid. The olecranon process of the ulna is large and well ossified, and the manus is robust. Three sacral vertebrae are present. Little of the femur is preserved, but the tibia and fibula are present and gracile. Phylogenetic analysis of a matrix including new postcranial data places *Cistecephalus* and the Luangwa Basin species on the stem leading to a clade comprised of *Sauroscaptor*, *Cistecephaloides*, and *Kawingasaurus.* Cistecephalidae receives strong branch support, however relationships within the clade are weakly supported. The pectoral girdle and forelimb morphology of the Luangwa Basin form are generally consistent with specialization for scratch digging, but differ in detail from *Cistecephalus* and *Kawingasaurus*. The mosaic of functional traits displayed by cistecephalids indicate that a more nuanced approach to their functional morphology and ecology may be warranted.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

TOWARDS A MORE COST-EFFECTIVE, TRANSPARENT AND OPEN PUBLICATION WORKFLOW: PEER COMMUNITY IN PALEONTOLOGY (PCI PALEO), A COMMUNITY-DRIVEN PEER REVIEW PLATFORM FOR PALEONTOLOGY

ANQUETIN, Jérémy, Jurassica Museum, Porrentruy, Switzerland; BILLET, Guillaume, MNHN, Sorbonne Université, Paris, France

Over the years, academic publishing has become increasingly costly for users, institutions, funders, and ultimately the taxpayer. Billions of US dollars of public money are spent every year on subscriptions and article processing charges. Scientists were long blind to these costs, but there is now a growing realization that these are no longer justified. Open Access is also having a profound impact on the landscape of academic publishing, and this is likely to accelerate as funders worldwide issue Open Access mandates. Finally, science in general is facing a confidence crisis in which the lack of transparency of the peer review process and the over-reliance on perceived impact of research results undoubtedly have a responsibility.
A more transparent, completely open access, and cost-effective academic publishing system is now possible thanks to modern digital technologies. Preprints notably have been successfully used for more than 25 years by physicists, mathematicians, astronomers, and computer scientists as a way to rapidly diffuse research results and to promote early feedback from a wider audience. In these disciplines, articles commonly remain as preprints, and are cited as such, for months or even years, before eventually being published by a journal. Preprints have more recently penetrated the field of biological sciences, including paleontology, but some justifiably criticize their non-peer-reviewed status.
The peer review process is currently managed by journals, but it is in fact a voluntary service provided by the community. A more transparent and cost-effective evaluation system can be organized by decoupling peer review from publishing. Peer Community in Paleontology (PCI Paleo) is a non-profit, community-driven peer review platform backed up by an international Managing Board and a growing group of editors. Peer review at PCI Paleo is very similar to that of conventional journals. Manuscripts are evaluated by an editor and at least two external referees. Revised versions are posted online after each round of peer review. If the paper is accepted, a final version is uploaded and permanently linked to a recommendation text (written by the editor) and the peer-review reports, which are published by PCI Paleo. Articles recommended by PCI Paleo are therefore peer-reviewed, fully citable (DOI) and Open Access.
Publishing an article on an open online archive and having it peer reviewed by PCI Paleo is entirely free of charge, opening the way to a more cost-effective, transparent, and open publication workflow.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 10:45 AM)

NEW CENOZOIC ACROBATID POSSUMS FROM THE RIVERSLEIGH WORLD HERITAGE FOSSIL DEPOSITS, AUSTRALIA, AND INVESTIGATION OF THEIR BIZARRE MIDDLE EAR STRUCTURE

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Until now, no extinct species referable to the Acrobatidae have been named. Recent assessment of small possum fossils from the Late Oligocene and Early and Middle Miocene deposits of the Riversleigh World Heritage Area in northwestern Queensland has revealed a minimum of four new taxa, two referable to *Acrobates*, a genus that contains the living, open-forest, Feathertail Glider (*A. pygmaeus*) of Australia, and two referable to *Distoechurus*, a genus that contains the living rainforest, non-gliding Pen-tailed Possum (*D. pennatus*) of New Guinea. The closed forest paleohabitats of the Riversleigh fossil species suggest that the living *D. pennatus* exhibits the relatively plesiomorphic life-style of the common ancestor of these small, omnivorous possums. The presence of species of both genera in Riversleigh's Late Oligocene deposits provides a minimal estimate of divergence time for these lineages of at least 23 million years.

Examination of the middle ear of the two living acrobatid species reveals a bony process that arises and expands up from the ventral rim of the ectotympanic ring to obstruct most of the passage of the external auditory canal immediately adjacent and lateral to the tympanic membrane. No other mammal known has a similar structure. Given the fact that one of the two living species is a glider in open forests and the other a non-glider in rainforests, there is no obvious reason known to us for why this structure would be a beneficial adaptation relating specifically to mobility or type of habitat occupied. We also report that this structure is correlated in both living species with an unusual hypertrophy of the lateral lobe of the brain. We support an earlier suggestion that this structure may be operating as a 'Helmholtz resonator' modulating the frequency of incoming sounds. Although the actual reasons why evolution of this structure would have been sufficiently important to offset any potentially related loss in auditory acuity remain unclear, we suggest a potential explanation based on the paleoecology of Riversleigh's Oligocene/Miocene faunal assemblages.

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Technical Session X (Friday, October 11, 2019, 9:30 AM)

NEW FINS OR OLD FINS? SKULL AND PECTORAL GIRDLE OF EARLY TRIASSIC '*PERLEIDUS*' *WOODWARDI* REVISITED USING µCT

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Despite decades of research, the deep-time origins and ancestral morphologies of crown actinopterygian evolutionary lineages remain obscure, with the membership of late Paleozoic-Triassic taxa being particularly fluid with respect to the actinopterygian crown group. Lack of data on the endoskeleton of important fossil groups, and a disjunction among phylogenetic matrices aimed at resolving different branches of the actinopterygian tree of life, are the major causes of this gap of knowledge. The Triassic 'perleidids' have been historically viewed as early members of Neopterygii, the most successful group of modern actinopterygians. Yet, recent research has cast doubts not only on their evolutionary affinities, but also their monophyly, though no stable phylogenetic alternatives have been provided. Based on previously undescribed material in museum collections in Paris and Zurich, we reappraise '*Perleidus*' *woodwardi*, from the early Olenekian (Early Triassic) of Spitsbergen. Exquisitely preserved exoskeletons provide novel data on the osseus constituents of the ethmoid region, and the anatomy of the tail fin, which is now shown to lack obvious epaxial rays. In addition, using µCT, we studied a recently collected, three-dimensionally preserved cranium and pectoral girdle, which revealed a wealth of phylogenetically important information. The braincase and endocast of '*P'. woodwardi* broadly resemble those of *Australosomus*, with the presence of a posteriorly elongate parasphenoid in the former being a notable difference between the two. Contrasting primitive actinopterygians, '*P'. woodwardi* shows an increased separation between maxilla and palate, which are loosely connected by a posterolateral palatal process. Uniquely amongst actinopterygians, '*P'. woodwardi* exhibits perforate anterior pharyngobranchials. The pectoral girdle and fin of '*P'. woodwardi*, show a unique combination of primitive and derived characters, including: an anterodorsally–posteroventrally expanding coracoid arch; a ventral coracoid ridge; the lack of anterodorsal, or posterodorsal coracoid processes; and the presence of a propterygium fused with the first ray. Our study of *Perleidus* acts as a vehicle for greatly expanding existing phylogenetic matrices, and reformulating traditionally

used characters, like those pertaining to the maxilla and the pectoral girdle. Furthermore, it allows for testing the monophyly and proposed crown group affinities of this salient lineage of Triassic ray-fins within a more informed phylogenetic context.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 11:30 AM)

INHERENT DIETARY FLEXIBILITY WAS KEY TO THE EVOLUTIONARY SUCCESS OF KANGAROOS

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Kangaroos and kin (Macropodidae) diversified through the later Neogene, becoming the Australian equivalent of ungulates elsewhere. Differences in craniodental morphology between clades have long suggested that diet was an important determinant of observed diversification and extinction patterns. Previous morphological work has suggested that kangaroos radiated following the late Pliocene expansion of grasslands and arid shrublands, culminating in a dietary dichotomy where macropodines became mostly grazers and sthenurines largely browsers. Morphology, though, only points to what an animal may be adapted to eat, rather than actual diet. One means of inferring the diet of individuals is dental microwear texture analysis, which I applied here to further elucidate dietary patterns in kangaroos. In doing so I address a number of technical challenges, ultimately refining microwear methodologies with applications well beyond kangaroos.
A multi-taxon dataset was used to appraise how dietary change through the Neogene and to map dietary variation within a diverse assemblage from the middle Pleistocene, the interval during which kangaroo diversity peaked. Microwear trends from the early Miocene indicate predominantly browsing diets across numerous clades until the late Pliocene, during which grass becomes a significant dietary component, as reflected by prior studies of dental morphology and macrowear patterns. Pleistocene microwear data show that the sthenurine–macropodine browser–grazer dichotomy is oversimplified. Both groups consume a mix of browse and grass, though differences are evident between species, with some more strict browsers and others mixed feeders. When combined with morphological and stable-isotopic evidence, specialist diets are revealed for a number of species. Moreover, some species clearly shifted diets through time.
The current sum of evidence suggests that dietary flexibility allowed kangaroos to adapt to changes in vegetation over both the short and long term. Craniodental morphology defines the endpoints of dietary adaptation; actual diet is more linked to availability of foods. One implication is that it is highly unlikely that the reduction of any single vegetation type in the late Pleistocene could have resulted in the continent-wide extinction of the diverse sthenurine radiation.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

P4 SIZE VERSUS SHAPE IN DISCRIMINATING SPECIES OF *MESODMA* AND *NEOPLAGIAULAX* (MAMMALIA, MULTITUBERCULATA): DOES SIZE MATTER?

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Our understanding of North American Late Cretaceous and Paleocene mammalian faunas is based in large part on the taxonomic identification of poorly preserved fossils, most often incomplete jaws and teeth. Multituberculates—although often the most abundantly represented mammals in any given fauna—are notoriously difficult to identify, particularly in fossil assemblages where they are frequently represented by isolated teeth. Historically, the most useful tooth for discriminating species of multituberculates has been the blade-like lower fourth premolar (p4). The size, lateral profile, and morphological detail of p4s have been used not only for recognizing multituberculate taxa, but also in better understanding multituberculate feeding biomechanics, in assessing their paleoecology, and in reconstructing their phylogeny. A recent analysis of co-occurring species of the neoplagiaulacid *Mesodma* concluded that size more reliably identified individual p4s to species than did shape alone; based on these results, the study further concluded that all species of *Mesodma* may be better discriminated on the basis of p4 size. In order to test this hypothesis, we replicated the study, but supplemented the sample with specimens of other species of *Mesodma*, including several from the Judithian of North America, as well as the Paleocene species *Mesodma pygmaea*. Further, we examined the fidelity of shape over size among multituberculate genera with the addition of p4s from several Paleocene species of *Neoplagiaulax*. Size assessment included principal component analysis (PCA) of p4 lateral profiles (centroid included) and PCA using a set of three linear measurements of the blade typically used in species identification (height, length, length1). Shape was assessed using PCA of p4 lateral profiles (centroid excluded). All data sets were analyzed using canonical variate analysis (CVA) to determine discrimination accuracy for the size versus shape analyses. Our preliminary results suggest that p4 size alone may be important in distinguishing multituberculate genera, but shape and size may provide similar levels of accuracy at the species level. These findings suggest that a correct taxonomic referral of multituberculate p4s could in principle be based on both shape and size, depending on the level of taxonomic resolution required in a given study.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

A NEW SPECIES OF *PARATOMARCTUS* (CARNIVORA, CANIDAE) FROM THE MIDDLE MIOCENE OF MONTANA

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Anceney is a middle Miocene fossil locality in southwest Montana that has yielded a range of taxa characteristic of the Barstovian North American Land Mammal Age (NALMA). Herein we describe a new species of *Paratomarctus* (Carnivora, Canidae, Borophaginae) from Anceney and constrain the absolute age of the Anceney locality using detrital zircon U-Pb maximum depositional age analysis. The new species of *Paratomarctus*, MOR 8673, is represented by a complete skull and mandible. This genus is the stem taxon of the Borophagina subtribe, and as such this new species shares the following derived characters: dorsally enlarged frontal sinus and the absence of a tubular auditory meatus. Phylogenetic analyses place MOR 8673 in the *Paratomarctus* clade. MOR 8673 has premolars that are uniformly reduced, an autapomorphy of this clade. The new species is distinguished from the two previously recognized species of *Paratomarctus* (*P. temerarius and P. euthos*) by its relatively greater height of the ramus of the lower jaw and by the larger size in most cranial and dental measurements. It is distinguished from *P. temerarius* in having a moderately widened palate and from *P. euthos* by lacking a symphyseal flange on the ramus.
Despite the Barstovian character of the mammalian fauna, the absolute age of the Anceney locality has not been previously determined. Sixty-eight zircon grains were collected from a tuffaceous sandstone unit that overlies the strata that contained MOR 8673 for U-Pb ages and were analyzed with laser ablation inductively coupled plasma mass spectrometry. Our detrital zircon U-Pb maximum depositional age analysis yields an age of 15.31 +/- 0.24 Ma. The new species and absolute age presented here provide resolution for the age of the fossil-bearing Anceney locality, as well as contributing a better characterization of the early Barstovian NALMA on a broader, continental level.

Technical Session II (Wednesday, October 9, 2019, 10:15 AM)

PALEOHISTOLOGY OF A NEW ORODROMINE FROM THE UPPER CRETACEOUS (CENOMANIAN) MUSSENTUCHIT MEMBER OF THE CEDAR MOUNTAIN FORMATION, UTAH; HISTOLOGICAL IMPLICATIONS FOR BURROWING BEHAVIOR

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Orodrominae is a clade of neornithischian dinosaurs known from Aptian to Campanian deposits of western North America and Asia. Exceptional preservation of the orodromine *Oryctodromeus* within preserved burrow structures coupled with gross anatomical traits linked to digging behavior, suggest that fossoriality may have characterized most if not all orodromines. The recent discovery of a new orodromine from the Mussentuchit Member of the Cedar Mountain Formation, Utah, raises intriguing questions about fossoriality in this species. At least four individuals of different size classes and presumably varied ontogenetic stages were recovered from a single locality. Two of these individuals are represented by partially articulated, tightly overlapping skeletons compacted into a square meter, suggesting the possibility of cohabitation within a burrow structure; however, no

sedimentological evidence is preserved. Given the rarity of vertebrate burrow preservation, other indicators are needed to understand the prevalence of fossoriality among orodromine species and bone histology offers a possible proxy. Several extant fossorial mammal taxa exhibit a high degree of compacted coarse cancellous bone (CCCB) within limb elements. CCCB is formed early in ontogeny and its widespread presence in the limb bones of mature individuals is associated with biomechanical adaptations for fossorial behavior. In order to investigate potential histological correlates of fossoriality in the Mussentuchit orodromine, we sampled multiple hind limb bones of different size classes. The smallest femur (NCSM 33545, 11.6 cm long) derives from a juvenile; it is highly vascularized with a cortex dominated by fibrolamellar bone and exhibits a small amount of CCCB localized near the endosteal margin. In contrast, regions of the largest femur (NCSM 33547; 21.5 cm long) are composed of ~70% CCCB, which extends from the endosteal surface to the periosteal surface in some areas. CCCB was not observed in a subadult tibia (NCSM 33548), which bears a compact cortex with radially oriented longitudinal vascular canals and multiple growth marks. The presence of CCCB in the femora of this new species bolsters a hypothesis of fossorial behavior; however, its use as a paleobiological indicator is likely complex. CCCB is also documented in the iguanodontians *Dysalotosaurus* and *Dryosaurus*, as well as birds, pterosaurs, and pseudosuchians. Greater study is needed to understand the relationship between this tissue type and fossoriality in extinct vertebrates.

Preparators' Session (Thursday, October 10, 2019, 3:30 PM)

PREPARATION OF INDURATED CAVE DEPOSITS FROM BARROW ISLAND, WESTERN AUSTRALIA

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In 1995, E. L. Lundelius, A. Baynes, and K. Aplin traveled to Barrow Island, Western Australia, to prospect the abundant Plio-Pleistocene fissure-fill deposits in the Miocene Trealla Limestone for vertebrate fossils. One fissure-fill, labeled Y1, is a breccia consisting of limestone clasts within a calcite-cemented red siltstone. Abundant disarticulated microvertebrate remains were present in the siltstone and visible on the surface of the fill. During excavation, this deposit was broken into cobble- to boulder-sized blocks and shipped to The University of Texas at Austin for preparation. Initial mechanical and chemical preparation proved to be time-consuming and challenging. Difficulties included poor separation between soft bone and hard matrix, high density of overlapping bone fragments, and calcite infilling of bones that reacted strongly with acid. As a result, the project was temporarily postponed.
The project was revisited after advances in high-resolution X-ray CT scanning (HRXCT) allowed for the assessment of individual blocks of matrix for mechanical preparation. Two scans were performed on a block of matrix: a lower resolution data set of the entire block (voxel size = 0.1061 mm), and a higher-resolution scan (voxel size = 0.0219 mm) focusing on two tooth-bearing elements observed in the lower resolution data. The calcite-cemented matrix of the block has similar X-ray attenuation to preserved enamel on teeth, but is considerably more dense than bone. Nevertheless, the scans reveal abundant bone throughout the sample, except within large clasts presumed to be derived from the cave walls. The higher resolution data reveal two mandibles representing a marsupial and a rodent, as well as isolated teeth and other skeletal elements.
Digital segmentation of the mandibles shows extensively fractured bone, suggesting additional physical preparation of the bone may not be advisable. However, due to the difficulty of digital separation of the enamel from the matrix, mechanical preparation of the teeth is necessary for identification. Experiments with chemical preparation were yet inconclusive, therefore fine-detailed micropreparation was completed with a sharp carbide needle in a pin vice under high magnification using HRXCT as a roadmap. These results underscore the utility of CT data for both identifying candidates for mechanical preparation and for documenting the distribution and abundance of fossils in samples that are otherwise extremely difficult to physically prepare.

Technical Session XI (Friday, October 11, 2019, 10:45 AM)

LANDSCAPE PROCESSES AND DIVERSITY DYNAMICS OF NORTH AMERICAN MAMMALS

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Mountain ranges are home to biodiversity hotspots for many kinds of plants and animals today. Living mammals show a topographic diversity gradient on all of the ice-free continents. However, the fossil record presents a different picture. In the North American record, mammal diversity over the past 30 Myr was often higher on the Great Plains than in the intermontane west. Notably, the topographic diversity gradient was high in the Middle Miocene during an interval of global warming and rapid tectonic extension in the Basin and Range. Similar to today, nearly twice as many mammal species inhabited the Basin and Range as the Great Plains at 15 Ma.
We attempted to disentangle the potentially interacting influences of tectonic activity, climate change, and basin sediment accumulation on the record of mammal diversity in western North America. We used the PyRate program for Bayesian modeling of macroevolutionary rates to infer origination, extinction and preservation rates from rodent fossil-occurrence data compiled in the MioMap database. We used a geophysical model of tectonic activity to estimate changes in area, elevation, and barriers to dispersal; the marine global temperature record; and basin-fill records to evaluate whether diversification rates were influenced by tectonic, climatic, or preservation history. We found high rates of origination (speciation, immigration) from 20 to 15 Ma and low, variable extinction (true extinction, range shift) rates over the Neogene. Using the multivariate birth-death model implemented in PyRate, origination rates were positively correlated with rates of tectonic extension. In contrast, extinction rates were negatively correlated with temperature. The number of fossiliferous sedimentary units in the Basin and Range increased steadily between 25 and 10 Ma, implying that the timing of basin fill was not the major control on the record of species richness across the region.
These results suggest that the dominant drivers of macroevolutionary dynamics changed over time. Tectonic extension generated a pulse of origination in the Middle Miocene, whereas global cooling at the end of the Miocene Climatic Optimum caused a loss of mammal species in the Basin and Range as species richness rose on the Great Plains. The integration of dynamic landscape and climate history with diversification processes expands our understanding of interactions between landscape and life today and in the past. The fossil record is critically important in revealing different biogeographic patterns than those of today.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

CHARACTERIZING MESOCARNIVORE DISTRIBUTIONS AT RANCHO LA BREA

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Major environmental disturbances may precipitate the rise of novel communities. This was seen at the end of the last Ice Age following the megafaunal extinctions, which on most continents occurred during a time of climatic change and human impacts. As the large carnivores and their large prey disappeared, so did the interactions that likely exerted cascading trophic effects on ecological communities. Most carnivores today are of small to medium body size: mesocarnivores.
North American mesocarnivores before and after the end-Pleistocene present a natural laboratory to track the effects of large-scale disturbance on a faunal community. In the first stage of a three-year project to assess mesocarnivore assemblages from pre- to post-disturbance, we surveyed fossil mesocarnivores preserved at the Rancho La Brea (RLB) asphalt seeps in Los Angeles, southern California, U.S.A. . While RLB is known for trapping megafauna, the asphalt also ensnared smaller carnivores, which we comprehensively evaluate here for the first time.
Taphonomic histories likely differed between smaller and larger mammals, as did historical practices of excavation, collection, and curation. Excluding coyotes, five mesocarnivore species are represented by >10 individuals at RLB: badger (*Taxidea taxus*, minimum number of individuals (MNI) = 20), bobcat (*Lynx rufus*, MNI = 13), grey fox (*Urocyon cinereoargenteus*, MNI = 23), striped skunk (*Mephitis mephitis*, MNI = 37), and weasels (*Mustela* spp., MNI = 22). These species were found in 33 deposits (“pits”) with dates spanning at least 44,650–5,270 radiocarbon years before present. Five deposits each have yielded >100 identified mesocarnivore specimens. All mesocarnivore-bearing deposits have produced badger, grey fox, and striped skunk. Weasels occur mainly in deposits that have undergone systematic

excavation (Pit 91, Project 23), suggesting that their small body size hindered recovery in earlier megafauna-focused excavations. About one-fifth of mesocarnivore specimens are juvenile, on par with the proportion of juvenile individuals for megafaunal carnivores. Two hundred mustelid specimens are unidentified to species or genus, necessitating morphometric identification. Raccoon (*Procyon*), ringtail (*Bassariscus*), and spotted skunk (*Spilogale*) also are present but, like weasels, tend to be from systematically excavated deposits. Future analyses will develop radiocarbon chronologies and stable-isotope and morphological data in order to quantify mesocarnivore ecological response to Late Pleistocene disturbance.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

THE BASAL SAUROPODOMORPH *THECODONTOSAURUS* FROM THE LATE TRIASSIC OF BRITAIN: OSTEOLOGICAL RE-DESCRIPTION, LIMB MUSCULATURE RECONSTRUCTION AND LOCOMOTION

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Thecondontosaurus was the first sauropodomorph dinosaur ever named and one of the most basal members of this clade, making it crucial for the understanding of the early evolution of the group. Its fossils have been found in different fissure fill localities of southwestern Britain, although the holotype and the material that served to describe the type species *T. antiquus* come from the early Rhaetian deposits of Durdham Down in Bristol, United Kingdom. Specimens found in the south Wales locality of Pant-y-ffynnon were assigned to a new species, *T. caducus*, that was later given its own genus, *Pantydraco*. Here, we describe for the first time the numerous and well-preserved remains from Tytherington, Southwestern England, found in 1975. We find these specimens can be assigned to *T. antiquus*. The osteology of *Thecodontosaurus* is updated and new anatomical information of previously poorly preserved or missing bones is added. We provide a revised diagnosis of the species and discuss its phylogenetic position. Comparing the anatomy of *Thecodontosaurus* and *Pantydraco*, we propose that the possibility of the latter being a juvenile of the former cannot be ruled out. We also reconstruct limb muscle attachment sites from osteological correlates and inferences based on the extant phylogenetic bracket. From this we find that *Thecodontosaurus* possessed a plesiomorphic limb musculature arrangement for sauropodomorphs. Muscle attachment sites and functional morphology of the limb bones indicate that it was a biped with crouched hindlimbs and partially supinated forelimbs. Further biomechanical investigation is required to test whether it was an obligate or facultative biped, and more detailed aspects of locomotion.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

STABLE ISOTOPIC SIGNATURES OF FOSSILISED RODENT TEETH: FAUNAL RESPONSE TO CLIMATE CHANGE IN SOUTH-EASTERN AUSTRALIA DURING THE LATE QUATERNARY

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An understanding of how past climate and environmental change has influenced faunal communities over time is important for understand how future climate change may affect ecosystems. Stable isotopic analysis of bioapatite from fossilised mammalian tooth material is a well-established proxy for reconstructing past climate and vegetation. The use of small mammals, in particular rodents, has been overlooked in the past for such studies. Owl-accumulated deposits preserved in caves in the Naracoorte Caves World Heritage Area (NCWHA), yield abundant assemblages of fossilised rodent remains providing large samples from which a temporal scale of climate and vegetation change can be reconstructed. In this study, stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopic composition of bioapatite from the incisors of three Australian rodent species was used as a proxy to reconstruct the paleoclimate and paleovegetation of the Naracoorte region.
$\delta^{18}O$ and $\delta^{13}C$ analyses were performed on crushed incisors of three species of *Pseudomys (P. auritus, P. australis and P. shortridgei)* across the upper 27 sedimentary layers from a paleontological excavation in Blanche Cave (NCWHA). The layers were aggregated into climatic-stratigraphic units: pre-glaciation (layers 27-25, ≈ 49 to 35 ka), early-glaciation (layers 24-20, ≈ 32 to 25 ka), Last Glacial Maximum (layers 19-15, ≈ 22 to 19 ka) and deglaciation (layers 13-1, ≈ 17 to 14 ka). Relative abundances and isotopic values for the three species were calculated for each unit. The carbonate bound component of the bioapatite was analysed for $\delta^{13}C$ and $\delta^{18}O_{CO3,}$ as well as the additional analysis of phosphate bound oxygen ($\delta^{18}O_{PO4}$) using isotope ratio mass spectrometry. Isotopic signatures from $\delta^{13}C$ and $\delta^{18}O$ were used to reconstruct paleoclimate and paleovegetation over the four climatic-stratigraphic units, which were compared to existing paleoclimate studies. Through these units there were changes in the dominance between C_3 and C_4 plants, as well as changes in the water regime, form cool, wet to warm, dry environments.
As rodents are commonly abundant in fossil deposits globally, they have the potential of being used to determine climatic and vegetation change associated with extinction events, such as the megafauna extinction in Australia. This study also has the potential to extend to larger mammals, such as the megafauna, to understand how large mammal communities have reacted to changes in climate and vegetation.

Grant Information:
This study was funded by the University of Adelaide, Department of Earth Sciences.

Technical Session XV (Saturday, October 12, 2019, 8:15 AM)

HIGH-DENSITY MORPHOMETRIC ANALYSIS OF MACROEVOLUTION AND PHENOTYPIC INTEGRATION OF THE ANURAN (FROG) CRANIUM

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Anurans (frogs) are the most speciose amphibian clade (numbering over 7000 species), and they exhibit astonishing cranial diversity, creating a significant challenge for quantifying cranial morphology across the clade. Consequently, studies of morphological evolution and modularity (the division of a structure into subsets of integrated/correlated traits) are limited in taxonomic breadth, or density of shape data, for frogs. Here we quantify anuran cranial morphology using high-density semilandmarks for 173 anuran species sampling every extant anuran family and including the Eocene species *Thaumastosaurus gezei*. We define 19 cranial regions with 58 landmarks, 59 curves, and 527 surface points. The complex morphology of the frog skull is thus represented by a total of 995 (semi)landmarks, making this the most comprehensive dataset of anuran cranial morphology to date, in terms of both taxonomic sampling and density of shape data. With these shape data we identify the best-supported modular structure using maximum likelihood ('EMMLi') and Covariance Ratio analysis. We investigate phylogenetic, allometric and ecological influences on cranial morphology, as well as determining the disparity and evolutionary rate of each cranial module.
Anuran crania are highly modular and more integrated posteriorly, with highest support for a 13-module model including multi-region 'suspensorium' and 'occipital' modules. This pattern is strikingly similar to the pattern of integration identified in caecilians, suggesting conservation of modularity across these two amphibian clades. Anuran crania exhibit significant influences of phylogeny (K_{mult} = 0.66, p = 1e-04), evolutionary allometry (R^2 = 0.12, p = 1e-04), and ecology (R^2 = 0.16, p = 0.003). Fossorial and aquatic species occupy distinct areas of cranial morphospace, with fossorial species associated with dorsoventrally taller skulls. Of the 13 cranial modules, the ventral sphenethmoid is the most disparate, and the parasphenoid the least (Procrustes variance = 1.95 x10-5, 6.00 x10-6 respectively), with earlier ossifying bones generally less disparate. Evolutionary rate is fastest in the stapes and suspensorium modules, and lowest in the parasphenoid (σ^2_{mult} = 5.99e-08, 5.26e-08, 1.70e-08 respectively). We find no significant relationship between integration and disparity (R^2 = 0.05, p = 0.48), or between integration and rate (R^2 = 0.02, p = 0.68), suggesting strong integration variably promotes or constrains (or has little effect on) morphological evolution of anuran cranial modules.

Grant Information:
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Technical Session XIV (Friday, October 11, 2019, 3:30 PM)

PHYLOGENY REPETITIVELY CONSTRAINS BIRD MORPHOLOGY

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Avian wing shape has been extensively studied, with high aspect ratio wings are typically attributed to large soaring birds, while low aspect ratio wings are attributed to birds which continually flap and are more agile in the air. Recent studies have shown a high phylogenetic signal in wing shape morphometrics but a low ecological signal. While it is expected that evolutionary history would play a big part in the shape of a bird wing, it seems surprising that ecology seems to play such a small role in predicting wing shape.
Previous metrics for avian ecology have generally been limited to flight style (i.e., gliding, flapping). These capture flight through open air but may not fully encompass how they interact with their environment, looking for food. Here we test a behavior metric that is more holistic (i.e., plunge diving, ground foraging, dabbling) to determine whether that metric is able to tease out more information regarding the correlation between ecology, phylogeny, and wing shape.
We collected two-dimensional geometric morphometric data from a diverse group of 138 "water bird" wings. The wing and dorsal covert outlines were digitized using thirteen homologous landmarks and 300 semi-landmarks. We then used a principle component analysis (PCA) to visualize the data and a canonical variate analysis (CVA) to determine how well the data separates into groups by foraging behavior and then by clade.
Overall, the wings plot along axes featuring aspect ratio and wing-tip shape – low aspect ratio wings with rounded tips on one side of the plot, and high aspect ratio wings with pointed tips on the opposite end. Some behaviors like stalkers and plunge divers have tight clusters, while other behaviors like surface diving and probing have a wide diversity of wing shape. Clades cluster out much more clearly. Charadriiformes, for example, have generally higher aspect ratio wings, though a few converge with lower aspect ratio wings. The CVA shows that bird wings can be accurately classified by clade 82.3% of the time, while classification by behavior is only 63.7% accurate. These results suggest that wing shape is much more divergent in terms of foraging behavior than it is in terms of clade, and that other factors may be at play with regards to wing shape. Combined with other studies indicating bird beak shape is not as influenced by ecology as expected, this work emphasizes the importance of evolutionary history in constraining form and divergence in function is a very recent trend in evolution.

Technical Session X (Friday, October 11, 2019, 11:30 AM)

BIOTIC AND ABIOTIC DRIVERS OF SELACHIAN EVOLUTION THROUGHOUT THE CENOZOIC

BAZZI, Mohamad, Uppsala University, Uppsala, Sweden; CAMPIONE, Nicolás, University of New England, Armidale, Australia; KEAR, Benjamin, Uppsala University, Uppsala, Sweden; BLOM, Henning, Uppsala University, Uppsala, Sweden; AHLBERG, Per E., Uppsala University, Uppsala, Sweden

Sharks (Selachii) have a long evolutionary history that spans almost all the Phanerozoic mass extinctions and, throughout the Mesozoic and Cenozoic, they shared marine habitats with a number of tetrapods. As a result, sharks represent a unique opportunity to assess the relationship between the Red Queen (biotic processes) and the Court Jester (abiotic processes), on a broad scale. The K/Pg mass extinction appears to have been a pivotal event in modern shark evolution, given its differential ecological effect. The Late Cretaceous was a time of peak diversity for lamniforms, which subsequently underwent widespread extinctions across the K/Pg boundary, whereas post-extinction ecological restructuring favored carcharhiniforms resulting in the most speciose shark radiation today (N>280). Although the transition between lamniform- to carcharhiniform-dominated communities was recently documented, prolonged extinction effects, the influence of changing environmental conditions, and the impact of competition and predation imposed by the advent of whales remains poorly understood.
Here we reconstruct the morphological succession of lamniform and carcharhiniform sharks across the last 83 million years. Based on a data set of 3400 teeth, we apply a geometric morphometric approach along with morphospace, disparity, and time-series analyses. Lamniform and carcharhiniform tooth disparities peaked during the Late Cretaceous, but noticeably declined in lamniforms during the Mid-Miocene Climatic Optimum. The previously noted shift from cutting- to clutching-type dentitions in lamniforms across the K/Pg boundary was maintained throughout the Cenozoic, suggesting a sustained influence of the mass extinction to this day. In contrast, the dental disparity of coeval carcharhiniforms increased across the optimum. Large-bodied predatory sharks (eg. *Carcharocles megalodon*) also appeared during this timeframe, coincident with climate-related changes in ocean productivity and the diversification of whales and larger ray-finned fishes. Ocean productivity may have also played a role in the success of carcharhiniforms, along with their generalist feeding strategies and ability to utilize intermittently available food resources at a time of environmental stress. However, climatic effects, whether direct or indirect, were likely episodic and magnitude-dependent given that no general relationship was recovered between sea-level estimates and paleotemperature proxies and the disparity of either lamniforms or carcharhiniforms.

Technical Session X (Friday, October 11, 2019, 9:45 AM)

OUTSTANDING MORPHOLOGY OF SOME MESOZOIC GONDWANAN FISH CONFLICTING PREVIOUS TAXONOMIC AND PHYLOGENETIC INTERPRETATIONS.

BEAN, Lynne B., Australian National University, Canberra, Australia; ARRATIA, Gloria, Kansas University, Lawrence, KS, United States of America

Waldmanichthys koonwarri is an Aptian freshwater fossil fish from the Koonwarra Fossil Beds in Victoria, (Australia) and *Cavenderichthys talbragarensis* is also a freshwater fish from the Tithonian Talbragar Fossil Fish Bed in New South Wales, (Australia). Recently, these two species, together with *Luisiella feruglioi* from the Oxfordian-Tithonian of Patagonia, (Argentina), were included in a new teleostean family, Luisiellidae. This new family was interpreted as a stem teleost group, closer to *Leptolepis coryphaenoides* than to the crown-group Teleostei.
Examination of 46 previously undescribed specimens of *W. koonwarri*, from Museum Victoria, has resulted in the discovery of new morphological characters. For example, the special configuration of the jaws and the position of the quadrate-mandibular articulation; the special vertebral pattern at the level of the abdominal/caudal regions; a stegural-like uroneural in the caudal skeleton; and the structure of the scales. This inspired a re-examination of the morphology of *Cavenderichthys* and *Luisiella.* Hence the systematic position of the Gondwanan taxa was re-evaluated using a pre-existing data matrix including about 240 characters and 57 taxa. The new results give a very different scenario, with the three taxa now included in the crown-group Teleostei. Luisiellidae is restricted to its type-species, *L. feruglioi*. In contrast, the two Australian species cluster together with the Late Jurassic European genera *Leptolepides* and *Orthogonikleithrus* emphasizing the role of the Tethys Ocean and the position of South America and Australia at the time of the break-up of Gondwana.

Grant Information:
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Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 8:00 AM)

MACROEVOLUTIONARY DYNAMICS OF SOUTH AMERICAN AND AUSTRALIAN FAUNIVOROUS MARSUPIALS DURING THE NEOGENE

BECK, Robin M., University of Salford, Manchester, United Kingdom; ENGELMAN, Russell K., Case Western Reserve University, Chagrin Falls, OH, United States of America; TRAVOUILLON, Kenny, Western Australian Museum, Welshpool, WA, Australia

South America and Australia are the only major landmasses where the dominant faunivorous mammals for most of the Cenozoic were metatherians (marsupials and their fossil relatives), most notably microbiotherians, paucituberculatans, sparassodonts and didelphimorphians in South America, and peramelemorphians and dasyuromorphians (dasyurids and thylacinids) in Australia. There has been considerable controversy as to the extent to which these clades competed with each other and filled similar ecological niches. Analyses of the diversification of extant lineages provides only limited insight into the evolution of these clades, because the known modern diversity of Microbiotheria (one species), Paucituberculata (seven species) and Thylacinidae (one species) is relictual compared to their known fossil diversity, and Sparassodonta is entirely extinct. Here we use a combination of phylogenetic analyses including fossil and extant taxa (including the first tip-dating analyses of microbiotherians, paucituberculatans and sparassodonts using Bayesian morphological clock models), fossil occurrence data, and quantitative analyses of body size and tooth shape to infer the macroevolutionary dynamics of these clades during the Neogene. There is support for broadly synchronous faunal turnover among these groups during the middle-to-late Miocene in both South America and Australia, suggesting a common abiotic (probably climatic) driver. There appears to be a distinct lag of several million years before didelphids and dasyurids evolved to fill the

medium-sized (>300 g) predatory niches, again suggesting passive rather than active replacement. Dental morphology within these clades shows clear phylogenetic signal, making ecomorphological comparisons difficult, but dasyurids and thylacinids overlap in dental morphospace, suggesting that they are indeed ecologically similar, and early Miocene peramelemorphians fall between modern peramelemorphians and dasyuromorphians.

Grant Information:
Australian Research Council (DE120100957)
Santander Travel Grant

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

BONE PATHOLOGIES IN THE EARLY CRETACEOUS THERIZINOSAURIAN *FALCARIUS UTAHENSIS*

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Paleopathologies provide key information on evolution and epidemiology of disease, and behavior in extinct animals. We describe osteopathologies observed in the right metatarsus II (NCSM 27412) and left humerus (UMNH VP 14661) of the early diverging therizinosaurian, *Falcarius utahensis*, recovered from a paucispecific bonebed in the Lower Cretaceous Cedar Mountain Formation of eastern Utah. The two specimens were collected approximately 52 meters apart, making it unlikely the metatarsus and humerus are from the same individual. Morphologic diagnoses are based on macroscopic and histologic examination of the fossilized lesions, and comparative pattern recognition analysis of histomorphologic features in vertebrate pathologic processes. Macroscopically, both the right metatarsus II and left humerus exhibit irregular nearly circumferential bulbous expansion in the mid-diaphyseal region. Histologic lesions in the right metatarsus II are most consistent with healing fractures stabilized by a chronic callus encasing a large fragment of necrotic bone (sequestrum) that is lined by a peripheral layer of reactive bone (involucrum). Large sequestra have been well-documented to complicate fractures and delay healing by causing instability at the fracture ends, thereby inhibiting the normal development of a callus. Histomorphologic features in the metatarsal fossilized lesion provide evidence that this was a complicated fracture in the pes of a subadult individual with delayed healing. Histologic examination of the left humerus reveals lesions most consistent with chronic osteomyelitis with abscess/microabscess formation, osteonecrosis and lysis, and both subperiosteal and endosteal reactive bone formation. The pattern and distribution of these lesions are suggestive of an infectious etiology that likely initiated in the corticomedullary junction and extended to the subperiosteal periphery of the humerus. A minimum estimation of 300 individuals are represented in this Lower Cretaceous Cedar Mountain Formation, and preliminary analysis of the bonebed suggest these individuals succumbed to a mass mortality event. Further research is required to evaluate the prevalence of additional osteopathologies, and if these pathologies have any correlation with the mass mortality event.

Technical Session VI (Thursday, October 10, 2019, 11:15 AM)

***NAKALIPITHECUS* AND HOMININE ORIGINS**

BEGUN, David R., University of Toronto, Toronto, ON, Canada

Several samples of the late Miocene fossil apes from Africa are said to “fill the gap” both chronologically and phylogenetically between middle Miocene African stem hominids and the earliest hominins. These samples, attributed to *Nakalipithecus*, *Samburupithecus* and *Chororapithecus*, have been interpreted as having closer affinities with African apes and humans than do Eurasian Miocene apes, despite small samples, poor preservation and no formal cladistic analysis. To test this conclusion, I carried out the first formal numerical phylogenetic analysis to include *Nakalipithecus* and other middle and late Miocene apes from Europe and Africa. The data were analyzed using TNT. Character states were unordered. The outgroup was *Ekembo* from the early Miocene of Kenya. The sample was limited to mandibular and dental remains, given the preservation of *Nakalipitheus.* The results were inconclusive, with low CI and RI values (0.25-0.37) and multiple polychotomies. This is not surprising given the restriction to mandibular and dental characters (those available for *Nakalipithecus*.) However, none of these phylogenies support the prevailing hypothesis that *Nakalipithecus*, *Samburupithecus* or *Chororapithecus* are hominines. They fall out as either stem hominids or stem hominoids. The low RI and CI values suggest that the data are insufficient to conclude, despite claims to the contrary, that there is convincing evidence of the presence of hominines in the late Miocene of Africa before *Sahelanthropus*. In contrast, the presence of hominines in Europe is more strongly supported based on more comprehensive analysis including characters not known for *Nakalipithecus*, *Samburupithecus* and *Chororapithecus*. These three late Miocene African fossil apes are simply too poorly known to place them in a phylogeny with any confidence.

Grant Information:
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Technical Session VII (Thursday, October 10, 2019, 11:45 AM)

TAPHONOMY AND PALEOCOMMUNITY RECONSTRUCTION OF A PTEROSAUR-BEARING FOSSIL ASSEMBLAGE IN THE UPPER TRIASSIC OF ARIZONA

BEHRENSMEYER, Anna K., Smithsonian Institution, Washington, DC, United States of America; WHATLEY, Robin L., Columbia College Chicago, Chicago, IL, United States of America; FITCH, Adam J., University of Wisconsin, Madison, WI, United States of America; PARKER, William, Petrified Forest National Park, Petrified Forest National Park, AZ, United States of America; MCINTIRE, Suzanne, Smithsonian Institution, Washington, DC, United States of America; PRITCHARD, Adam C., Smithsonian Institution, Washington, DC, United States of America; KLIGMAN, Ben, Virginia Tech, Blacksburg, VA, United States of America; CLINE, Richard G., Smithsonian Institution, Washington, DC, United States of America

The paleoecology of pterosaurs and other members of late Triassic vertebrate communities has been inferred primarily using functional anatomy and association with specific environments. The RLW11-56 quarry in the upper Chinle Fm. of Petrified Forest National Park provides new evidence for the ecology of Late Triassic vertebrates. Uranium-Lead dating of detrital zircons from the quarry place its age at 209.16±0.08 Ma, making this the most precise date available for a Triassic pterosaur and associated fauna. Microscope-assisted excavation of matrix blocks has yielded >1300 catalogued specimens, most of which are smaller than 2 cm diameter and represent diverse taxa, body parts, and preservation states. Bones generally are disassociated and fragmentary but include well-preserved, delicate elements. Isolated teeth are abundant, limb elements uncommon, and cranial and dentary elements rare. Remains were buried together in poorly sorted conglomerate that filled a local depression in a small fluvial channel cut into floodplain deposits. The fauna includes: actinopterygian, metoposaur, chelonian, anuran, phytosaur, aetosaur, *Revueltosaurus*, pterosaur, stem-archosaur, rhynchocephalian, and theropod, along with possible trilophosaur and cynodont. Notably absent are molluscs and dipnoans, which are common elsewhere in the Chinle Fm., and mammaliaforms. Micro-excavation provides an unbiased assemblage that can be used to examine paleocommunity structure and taphonomic history. From geological and taphonomic evidence, we infer that the fossil-bearing unit was formed by a flood that entrained sediment and skeletal debris from the channel bed and deposited it rapidly, with minimal sorting and reworking. The most complete fossils, including a partial pterosaur jaw, fish scales, delicate frog and turtle elements, represent “first cycle” remains that experienced limited taphonomic damage prior to final burial. These were mixed with previously reworked bones and teeth, resulting in some degree of temporal and spatial averaging. However, the identifiable subset of the quarry sample likely represents a relatively short period of time, on the order of years to centuries. The RLW11-56 assemblage shows that pterosaurs, *Revueltosaurus,* fish, frogs, turtles, and other taxa co-existed in a fluvial ecosystem during the latest Triassic in SW North America. The exceptional variety of teeth, many of which cannot be identified using available apomorphies, suggests a higher level of functional diversity than most other Chinle Fm. localities.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

DIAGNOSTIC EFFICACY OF PUBLISHED MORPHOLOGICAL CHARACTERISTICS OF NORTH AMERICAN SAND LIZARDS

BELL, Christopher J., University of Texas at Austin, Austin, TX, United States of America; SCARPETTA, Simon G., University of Texas at Austin, Austin, TX, United States of America; ANDERSON, Danny, Brown University, Providence, RI, United States of America

We present results of our effort to assess the reliability of published morphological features of the skeleton that reportedly have power to

discriminate among taxa in the monophyletic clade of iguanian lizards colloquially known as 'sand lizards.' These include species within the genera *Callisaurus*, *Cophosaurus*, *Holbrookia*, and *Uma*. Phylogenetic analyses based on morphology and molecular data recover these taxa as a monophyletic clade that is sister to the horned lizards of the genus *Phrynosoma*, but there is no consensus about relationships among the sand lizard genera. Although there is no currently published fossil record for *Uma*, the other three genera all have a published fossil record. We reviewed the primary literature of the Neogene and Quaternary fossil record for published reports of sand lizards that were identified at least to generic level. We found 32 publications that document the fossil record for the group. Of those, only 12 documented morphological features to support taxonomic identification; the others simply included taxa in a faunal list without meaningful comment. We discretized 15 morphological features so that they could be scored in a matrix format to facilitate ease of comparison among and between specimens and taxa. We then scored morphological features for 114 specimens of sand lizards, representing all four genera and eight species. Our goal was to test the reliability of each published morphological feature to discriminate among taxa *independent*of geographic data. Only one published feature, the shape of the ventrolateral edges of the frontal, consistently allowed identification of *Callisaurusdraconoides*to the exclusion of the other taxa. No other published features serve to discriminate among the taxa. These data emphasize the need for additional morphological work, and especially a search for apomorphic characters, before the late Cenozoic fossil record of North American sand lizards can be reliably interpreted. In our experience, this holds true for other groups of squamates as well, and marks a critical need for additional research on the evolutionary morphology of the group.

Technical Session XIX (Saturday, October 12, 2019, 2:00 PM)

MID-CRETACEOUS ENDEMICITY OF EASTERN AUSTRALIAN VERTEBRATE FAUNAS

BELL, Phil R., University of New England, Armidale, Australia; CAMPIONE, Nicolas E., University of New England, Armidale, Australia; SMITH, Elizabeth T., Australian Opal Centre, Lightning Ridge, Australia; MILAN, Luke, University of New England, Armidale, Australia

The Cenomanian-aged Griman Creek Formation (GCF) in eastern Australia preserves one of the most diverse vertebrate fossil assemblages from the mid-Cretaceous in eastern Gondwana. The GCF is therefore a crucial, yet largely unexplored, datum for examining paleobiogeographic connections within Australia's limited Cretaceous terrestrial record and across Gondwana more broadly. To date, vertebrates in the GCF include a diversity of fishes, plesiosaurs, turtles, pterosaurs, crocodylomorphs, ankylosaurians ornithopods, sauropods, theropods (including birds), and mammals. Given this diversity, we ask: how does the inclusion of often-overlooked Australian faunas contribute to our understanding of global paleobiogeography during the Mesozoic? Here we combine non-metric multidimensional scaling (NMDS) and minimum spanning trees to characterise potential connections between 15 mid-Cretaceous (Aptian–Cenomanian) formations from Africa, Australia, and South America. The data set includes 257 taxon-level entries of aquatic and terrestrial vertebrates from the Paleobiology Database supplemented by the recent literature. Our analyses were carried out at a high taxonomic resolution (family or above), as high levels of specific endemicity will mask potential connections. However, various taxonomic schemes were tested. Results reveal: 1) high levels of endemicity overall *via* a significant positive correlation between geographic distances between formations and their faunal dissimilarity ($r=0.51$, $p<<0.001$) and 2) strong connectivity between Australian formations to the exclusion of those from Africa and South America. Endemicity, especially among Australian faunas (NMDS axis 1), is driven by occurrences of australosphenid mammals, certain dinosaurs (ankylosaurs, ornithopods), plesiosaurs, temnospondyls, and certain osteichthyans (albuliforms, crossognathiforms, pachychormiform) along with a dearth of many carnivorous dinosaurs (alvarezsauroids, carcharodontosaurids, coelurosaurians), dryolestoid mammals, and polypteriform and salmoniform osteichthyans. Our results indicate that, by the mid-Cretaceous, endemicity of Australia's fauna was established, whilst Africa and South America continued to share faunal similarities into the Late Cretaceous. These findings are congruent with current tectonic models, which place the physical break up between West (Africa and South America) and East Gondwana (Australia, Indian, Antarctica) in the latest Jurassic.

Grant Information:

Funding provided by an Australian Research Council Discovery Early Career Researcher Award to PRB.

Technical Session XV (Saturday, October 12, 2019, 10:15 AM)

STERNAL EVOLUTION IN SYNAPSIDA AND THE ORIGIN OF THE MAMMALIAN STERNUM

BENDEL, Eva-Maria, Museum für Naturkunde, Berlin, Germany; KAMMERER, Christian F., North Carolina Museum of Natural Sciences, Raleigh, NC, United States of America; FRÖBISCH, Jörg, Museum für Naturkunde, Berlin, Germany

The sternum is a functionally important thoracic bone in extant birds and mammals, where it helps protect the chest cavity and serves as an attachment site for ribs and pectoral muscles. The sternal morphology of mammals is unique among amniotes: a multipartite structure consisting of the anterior manubrium, several sternebrae, and a posterior xiphoid process. In birds, the sternum is a single keeled element, whereas in other amniotes it is poorly-developed, being cartilaginous or absent entirely in many extant reptiles and rarely preserved in the reptilian fossil record. Because of its poor record outside the mammal crown, the origins and evolution of the mammalian sternum are not well understood. Previously, the earliest record of a multipartite sternum was in the Triassic cynodont *Diademodon*, although problematically, comparable structures are not known in more crownward non-mammalian cynodonts. Here, we provide new insight into mammalian sternal evolution through an investigation of synapsid pectoral morphology, and present the first evidence for a mammal-style sternum among Permian synapsids.

In early synapsids ('pelycosaurs' and dinocephalians) there is no evidence for an ossified sternum; its earliest record is in dicynodonts, where it is a single, plate-like element. Historically, gorgonopsians were thought also to have a single sternal element. However, our study of postcranial material referable to *Gorgonops* (late Permian) demonstrates that its sternum (attached to a large oval interclavicle) was divided into a larger anterior manubrium and three smaller posterior sternebrae. The metameric sternebrae resemble the configuration seen in Theria, making this the earliest record of a mammal-like sternum and indicating a deep evolutionary origin of this feature. However, there is no evidence it was multipartite in the more crownward Therocephalia. Our examination of numerous well-preserved specimens representing most therocephalian subclades indicates that sterna in the group consist of a single, rounded plate. Ossified sterna are not known in the earliest cynodonts, but the interclavicles of these taxa are narrower and more elongate than those of therocephalians, indicating they did not support a comparably broad, rounded sternum. We propose an origin of the multipartite sternum at the base of Theriodontia, with probable loss within Therocephalia. The absence in most gorgonopsians and cynodonts is likely attributable to the sternum remaining cartilaginous in small taxa and historic poor preservation/preparation.

Grant Information:
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Technical Session XIV (Friday, October 11, 2019, 2:45 PM)

NEW *ICHTHYORNIS* SPECIMENS: SHEDDING NEW LIGHT ON MODERN BIRD ORIGINS

BENITO, Juan, University of Bath, Bath, United Kingdom; BHULLAR, Bhart-Anjan, Yale University, New Haven, CT, United States of America; BURNHAM, David, University of Kansas, Lawrence, KS, United States of America; WILSON, Laura E., Fort Hays State University, Hays, KS, United States of America; FIELD, Daniel, University of Cambridge, Cambridge, United Kingdom

The origin of crown birds is poorly understood and the study of their early evolution must incorporate data from their closest relatives among Mesozoic stem birds. The postcranial morphology of the Late Cretaceous toothed bird *Ichthyornis dispar* may be more representative of the ancestral condition of crown birds than that of any other known Mesozoic avialan, and its study has crucial implications for understanding morphological evolution prior to the great radiation of the avian crown group.

Here we present high resolution scans of new, exquisitely preserved three-dimensional specimens of *Ichthyornis* from the Late Cretaceous of Kansas. These correspond to a partial skeleton from a single individual, more complete and in better condition than the classic material known since the 19th Century. The new material includes a complete sternum and shoulder girdle with evidence of extensive pneumatization. This new skeleton shows certain morphological differences from the classic material, including the absence of some previously proposed autapomorphies of *I. dispar*. Thus, the new material may represent a previously unknown species, or it could indicate that morphological variation within *I. dispar* was greater than previously appreciated.

Phylogenetic analyses incorporating our new morphological data corroborate recent results and recover a grade of predominantly marine taxa close to the origin of crown birds. *I. dispar* is recovered stemward of Hesperornithes and *Iaceornis marshi*, which is recovered as the sister taxon to all crown birds. Additional information on the crownward-most portion of the avian stem group will help confirm these results and provide critical information on the ancestral ecology of the crown bird radiation.

Technical Session VIII (Thursday, October 10, 2019, 1:45 PM)

THE INFRAORBITAL FORAMEN IN CYNODONTS AND MAMMALS: ORIGIN OF WHISKERS AND HOMOLOGY

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In mammals, the infraorbital foramen (IOF) and canal are located in the maxilla rostral and ventral to the orbit and provide a passage for the infraorbital nerve (a branch of the maxillary division of the trigeminal nerve). The infraorbital nerve (ION) ensures sensitivity of the upper teeth and face between the eye and upper lip including facial vibrissae (whiskers). Homology of the IOF across mammals is based on the fact that it gives passage to the ION. In most non-mammalian synapsids the IOF is replaced by the maxillary canal, which completely encloses the ION and its branches. Remarkably, the pattern of ramification of the branches of the maxillary canal can be homologized with that of the ION in modern mammals, which strongly supports the idea that the two structures are homologous. In contrast, a conspicuous foramen present below the orbit on the maxillolacrimal suture in Probainognathia (the non-mammalian Cynodontia more closely related to mammals than to *Cynognathus*) and early Mammaliaformes (e.g., *Morganucodon*), has in the past been homologized to the IOF by most authors. Using µCT-scanning and 3D modelling to reconstruct the evolution of the maxillary canal from the primitive synapsid condition to the modern mammalian condition in Probainognathia, it is here suggested that this foramen did not provide a passage for the ION. According to our observations, this pseudo-IOF might, in fact, have been for the zygomatic nerve and/or a blood vessel. In addition, this study shows that the transition from a maxillary canal to a mammal-like IOF was gradual, and that a mammalien IOF evolved in the last common ancestor of *Probainognathus* and more derived cynodonts. This suggests that whisking movements and associated whiskers evolved in the mammalian lineage before the very origin of Mammaliaformes, some 241 million years ago.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

SHARKS' TEETH, SHELLS AND CITIZEN SCIENCE

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Abbey Wood is a famous Early Eocene fossil locality situated in south-east London, U.K. The fossils come from a particularly rich shell lens within the Blackheath Formation. It is mainly composed of broken mollusc shells and flint pebbles and fine sand but does have some perfectly preserved sharks' teeth and shells along with rare mammal, bird and reptile remains.
The site was first recorded in 1872 when sharks' teeth and shells were seen in rabbit holes, but not exploited until the 1920's when two amateur collectors, F. J. Epps and St. J. Marriott, made a large collection from this locality, enlarging the rabbit burrows into a small pit.
In 1969 the Tertiary Research Group (TRG) and the Natural History Museum, London (NHMUK) started a series of small annual excavations, mapping the extent of the deposit and extracting the fossils using wet sieving. Since then many significant finds have been made that have been deposited in scientific institutions and resulted in many important scientific papers.
In 2005 the NHMUK expanded the project to allow members of the public to engage with paleontologists and help sort some of the fossil material. This was done at the Lyme Regis Fossil Festival (LRFF), a large science festival in the U.K. which is held in Dorset every May. The citizen science project which developed was simple. The aim was to explain to members of the public, usually children, the concept of deep time; the process of fossilization; how to identify fossils; why common and scientific names are used and the importance of properly labelled specimens. The most important thing was to pass on our enthusiasm for paleontology.
During the activity, the participants screen the sediment through different sized sieves, then carefully pick out fossils and identify what they have found using an ID guide. They may keep what they have found, predominately shark and ray teeth and shells if they identify them. If any rare specimens are found, such as mammal remains, the NHMUK gratefully accepts them, however the participant is told about the significance of their find. In our experience, they are always pleased to have found something important and many come back to repeat the activity and show off some of their own finds.
Over the last 50 years, approximately 400 people have been involved in the excavations and since 2005 we have participated at the LRFF where we have engaged with more than 8500 people, sieving just short of 4 tonnes of shell bed.
This year the project was nominated for the prestigious Pal. Ass. Gertrude Elles Award for high quality public engagement in the field of paleontology.

Grant Information:
The Tertiary Research Group and The Sylvester Bradley Grand Fund of the Paleontological Association.

Technical Session X (Friday, October 11, 2019, 11:45 AM)

ENVIRONMENTAL EFFECTS ON BODY SIZE IN LATE CRETACEOUS LAMNIFORM SHARKS FROM THE ENGLISH CHALK: UNLOCKING HIDDEN DATA IN HISTORIC COLLECTIONS TO ADDRESS KEY SCIENTIFIC QUESTIONS.

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The environmental effects of global warming, such as higher seawater temperatures and reduced levels of dissolved oxygen in the world's oceans, are predicted to cause a reduction in the sizes of marine fish, with wide-ranging implications for marine ecosystem structure and function. This hypothesis is mainly based on theoretical considerations and short-term experimental studies on small-bodied ectotherms, such as benthic marine invertebrates. The fossil record of past global change events provides an archive of data that can be used to test this hypothesis in taxa that cannot be studied *in vivo*, such as sharks and other apex marine predators, and over much longer timescales.
In this study, we analysed size change in Late Cretaceous lamniform sharks from the English Chalk to test whether they became smaller in response to global environmental change during the Cenomanian-Turonian anoxic event (OAE 2) and Cretaceous Thermal Maximum. Due to their cartilaginous skeletons, often only the teeth of sharks are preserved in the fossil record. However, tooth size can be used as a proxy for body size. Shark teeth have been collected from the Chalk Group of England for more than 200 years and the museums of southern England, in particular The Natural History Museum, London, which houses one of the most important collections of Late Cretaceous fish worldwide, contain substantial archives of potential data. Unfortunately, many museum specimens were collected more than 100 years ago and the very sparse stratigraphic data associated with them limits their usefulness. In order to improve this, we extracted nannofossils from the associated matrix of selected specimens with poor stratigraphic control in order to better constrain their relative ages and thus increase our dataset.
Key morphometric variables were measured from 761 fossil teeth spanning 14 lamniform genera. Overall, tooth size decreased significantly as temperatures warmed during the Cenomanian, and particularly during OAE2, in the whole assemblage. However, assemblage-scale changes may simply be due to differences in the composition of the fauna. One genus (*Scapanorhynchus*) was sufficiently abundant for individual analysis. Our results show that *Scapanorhynchus* teeth became smaller as temperatures rose during the Cenomanian, with a significant reduction in tooth size during OAE 2. Our results are consistent with the hypothesis that environmental changes, such as reduced oxygen concentration in seawater, caused a substantial decrease in the body size of lamniform sharks during OAE 2.

Grant Information:
Commonwealth Scholarship Commission, United Kingdom and Department of Ocean and Earth Sciences, University of Southampton, United Kingdom.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

REVISION OF *DUGALDIA EMMILTA* (TELEOSTEI; ICHTHYODECTIFORMES) FROM THE EARLY CRETACEOUS OF AUSTRALIA.

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The Australian record of Ichthyodectiform fishes is restricted to the Early – 'mid' Cretaceous, marine – brackish deposits of the Eromanga Basin of Central West and North West Queensland, Australia (*Cooyoo australis* and *Cladocyclus geddesi*). *Dugaldia Emmilta* was originally described by Lees in 1990 from a specimen discovered near the town of Cloncurry, Queensland, Australia. In the original description the specimen (the only one in existence at the time) it was attributed to the Neoteleostei because of the presence of a tripartite occipital condyle and placed in a basal position among neoteleosteans because of the presence of several plesiomorphic characters. Two new specimens were recently recovered from the Early Cretaceous Toolebuc Formation (Albian) that indicate that *Dugaldia emmilta* is, in fact, an ichthyodectiform fish. The combination of features such as well-ossified ethmoid massif with a probable ethmopalatine ossification, a disc-like articular had of the autopalatine, a saber-shaped maxilla with two deep supramaxillae, large infraorbitals with elongated diverticula of the infraorbital sensory canal, a participation of the exoccipital in the occipital condyle, the coronoid probably in contact with its counterpart, wide and elongated ribs with a groove along their length and articulating with their corresponding centrum via a complex parapophysis, elongated epineurals and deeper than long ovoid scales support the placement of this fish within Ichthyodectiformes and not as a basal neoteleosts as suggested in the original study.
The ichthyodectiforms present several specialised features of the jaw apparatus and *Dugaldia* possesses several of them (freely movable head of the palatine, strong autosphenotic spine, loose symphysis.) This fish, however, also possesses very derived characters (articular process of the maxilla which is well-developed and allows the maxilla to switch laterally in an almost horizontal position, lateral face of the mandible with a large triangular fossa for the infralabial ligament and a row of teeth oriented horizontally along the oral margin of the mandible) indicating a very special jaw mechanics. It is likely that the fish was able to greatly enlarge its gape by lateral motion of the jaws. This characteristic was probably related to its mode of feeding – a possible ram-feeder on plankton – or for social interactions as in the Sarcastic Fringhead (*Neoclinus blanchardi*). This indicates Australia had a high diversity of Ichthyodectiforms fishes comparable to the Western Interior Seaway of North America.

Technical Session XVIII (Saturday, October 12, 2019, 3:45 PM)

FIRST VIRTUAL ENDOCASTS OF TWO PALEOCENE ARCTOCYONIDS: A GLIMPSE INTO THE BEHAVIOR OF EARLY PLACENTAL MAMMALS AFTER THE END-CRETACEOUS EXTINCTION

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Placentals are by far the most diverse group of mammals today, with 6,111 species. They occupy a plethora of ecological niches worldwide and display a broad range of body masses. The vacant niches left by non-avian dinosaurs and other vertebrates after the end-Cretaceous mass extinction provided a crucial opportunity for placentals to diversify; however, intrinsic factors also may have played a role. The general neurosensory organization exhibited by extant mammals has been maintained since the early Mesozoic. Much later, early members of extant placental groups from the Eocene and Oligocene—including rodents, primates and artiodactyls—display neurosensory innovations such as a proportionally larger neocortex and higher encephalization quotient compared to their Mesozoic ancestors. However, between these two well-known intervals of mammalian neurosensory evolution, there is a gap: few studies have focused on the brains of the oldest placentals living during the early Paleogene, in the Paleocene.
We focus on the 'Arctocyonidae', a likely polyphyletic group of 'condylarths', including species potentially implicated in the origins of some extant orders. 'Arctocyonids' were among the first placentals to diversify after the end-Cretaceous extinction. They have been reconstructed as small-to-medium sized, mainly omnivorous and terrestrial. We obtained cranial and bony labyrinth endocasts for *Chriacus baldwini* and *C. pelvidens* from the lower Paleocene of the San Juan Basin, New Mexico, and *Arctocyon primaevus* from the upper Paleocene of the Paris Basin, France, via high-resolution computed tomography. Both share plesiomorphic brain features with previously described early Paleocene mammals. They have small lissencephalic brains with an EQ range of 0.12-0.43 and 0.16-0.31, respectively. The olfactory bulbs and the paraflocculi represent 6% and less than 1% of the total endocranial volume, respectively and the neocortical height ratio represents ~25% of the total endocranial height. Based on cochlear measurements, both taxa had hearing capabilities similar to those of extant wild boars. Agility scores between 2 and 3 were obtained for both taxa, similar to the modern American badger and crab-eating raccoon, suggesting that *C. pelvidens* and *A. primaevus* were ambulatory.
These results support growing evidence that early placentals had lower EQs and less expanded neocortices compared to Eocene and later taxa, potentially indicating that high intelligence was not key to the placental radiation after the End-Cretaceous extinction.

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Technical Session II (Wednesday, October 9, 2019, 8:00 AM)

NEW HIGH-PRECISION U-PB GEOCHRONOLOGY FOR THE WAHWEAP FORMATION, SOUTHERN UTAH AND IMPLICATIONS FOR LATE CRETACEOUS DINOSAUR EVOLUTION IN NORTH AMERICA

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High precision temporal calibration of terrestrial vertebrate faunas by the U-Pb geochronology method has advanced significantly in the last decade. Bentonite marker horizons can be dated at 95% confidence level precision that now approaches 0.02%. This improved temporal constraint has significant implications for Late Cretaceous fossil localities that represent the height of dinosaur diversity in North America. The Kaiparowits Plateau in southern Utah has yielded plentiful new vertebrate taxa in the last two decades with a high concentration of discoveries coming from the Wahweap Formation in the Grand Staircase – Escalante National Monument. Important discoveries include early members of Tyrannosauridae and Ceratopsidae. In this study, we systematically contextualised key taxa from the Wahweap Formation using high-precision geochronology and improved intraformational correlations.
Here we present the first high precision U-Pb ages for the Campanian Wahweap Formation using the chemical abrasion isotope dilution thermal ionisation mass spectrometry (CA ID TIMS) method. The findings of this study provide the basis for a revised temporal framework of the Wahweap Formation and taxa within. The Star Seep Bentonite (one of two Wahweap Fm. bentonites with published Ar-Ar geochronology [CF05-B]) was used as a distinctive horizon traceable across the formation. A northern and southern sample of the Star Seep Bentonite (B2-07B and WLS-R respectively) were collected and volcanic zircons from each were analysed using the CA ID TIMS approach. The two samples yielded statistically indistinguishable U-Pb dates thus confirming the correlation across 38 km and, most significantly, the results indicate a U-Pb date nearly 1.5 million years older than the previously published Ar-Ar date. This shift in the temporal framework has substantial implications for taxa from the Wahweap Formation. The type locality for the oldest known tyrannosaurid in North America, *Lythronax argestes*, is two metres below the southern Star Seep Bentonite sample locality. Another basal ancestor of significance is the oldest known ceratopsian *Diabloceratops eatoni*, identified from its type locality approx. 50 m stratigraphically higher than the newly dated bentonite. The new early Campanian age for the lower Wahweap Formation is considerably older than previously thought and has significant implications for understanding the timing and drivers of a major dinosaur diversification interval in the Santonian to early Campanian of the Western Interior Basin.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE LARGEST LAGERPETIDS: EVIDENCE FROM A NEWLY IDENTIFIED OTISCHALKIAN ASSEMBLAGE FROM THE LOS ESTEROS MEMBER (SANTA ROSA FORMATION) OF NEW MEXICO

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The Triassic strata of the American Southwest, especially the Chinle Formation and Dockum Group, are critical to our understanding of Late Triassic faunal diversity and evolution. In recent decades, these strata have been informative regarding the evolution of close dinosaur relatives, which remain poorly sampled and enigmatic in their geographical distribution. Here, we describe and discuss a new non-dinosaurian dinosauromorph assemblage from the Los Esteros Member of the Santa Rosa Formation at the base of the Dockum Group in east-central New Mexico. This assemblage includes hindlimb fragments assignable to Silesauridae and Lagerpetidae. Much of the lagerpetid material is assignable to *Dromomeron* and has unusually large size. Based on a dataset of complete lagerpetid femora, we estimate a femoral length of 221.9 mm for one partial femur, making it the largest reported individual. In addition to the dinosauromorph specimens, we present biochronologic support that at least a portion of the Los Esteros Member corresponds to the Otischalkian LVF through the identification of non-Mystriosuchinae phytosaurs. Resultantly, we question the presence of a bifurcated lateral ridge on the squamosal of all phytosaurs currently assigned to *Parasuchus*. This is the first Otischalkian fauna identified from New Mexico, and it reveals lagerpetids achieved large body size earlier than previously known. Our identifications expand the geographical and temporal range of non-dinosaurian dinosauromorphs in the American Southwest. The material presented here, as well as an increasing number of *Dromomeron* specimens, demonstrate that non-dinosauriform dinosauromorphs could match or exceed the body size of many coeval dinosaurs.

Technical Session XVIII (Saturday, October 12, 2019, 2:00 PM)

THE EARLY CRETACEOUS EUTHERIAN *AMBOLESTES* AND ITS IMPLICATIONS FOR THE EUTHERIAN-METATHERIAN DICHOTOMY

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Extant placental and marsupial mammals are the dominant vertebrates in many ecosystems, which makes the placental-marsupial dichotomy a significant event in Earth's history. Molecular estimates of the divergence of placentals and marsupials (and their broader clades Eutheria and Metatheria) fall primarily in the Jurassic. In support, the oldest purported eutherian, *Juramaia*, is reported to be from the early Late Jurassic (160 million-years ago) of Liaoning Province, northeastern China. The oldest purported metatherian, *Sinodelphys*, is 35 million-years younger from the Early Cretaceous Jehol Biota also in Liaoning Province, northeastern China. In 2018, we reported a new eutherian, *Ambolestes zhoui*, also from the Jehol Biota. The fossil, a nearly complete skeleton, preserves anatomical detail unknown from contemporaneous eutherians including the hyoid apparatus and ectotympanic. The complete hyoid is the first known for any Mesozoic mammaliaform, and the ectotympanic resembles that in some extant didelphid marsupials.
In our phylogenetic analysis concentrating on the eutherian-metatherian dichotomy, the closest relative of *Ambolestes* was *Sinodelphys*, and both fell within Eutheria. With *Sinodelphys* as a eutherian, postcranial differences formerly thought to indicate different invasions of a scansorial niche by meta- and eutherians in Jehol are only variations among the early members of the placental lineage. Additionally, the earliest known metatherians are approximately 15 million years younger than previously thought and their fossils, isolated teeth and fragmentary jaws, are from North America. Our tree results in a 50 million-year ghost lineage for Metatheria, accepting the 160 million-years age for *Juramaia*. A possibility raised elsewhere is that the age of *Juramaia* is incorrect; rather than Late Jurassic, perhaps it is from the Early Cretaceous Jehol Biota. In our study, *Juramaia* is in a clade with Albian/Aptian *Prokennalestes* and Late Cretaceous eutherians by having a more molariform ultimate upper premolar. In contrast, *Ambolestes*, as in the outgroups, has a non-molariform ultimate upper premolar. Although resolution of this intriguing debate is not currently possible, our understanding of the issues has been furthered by the discovery of *Ambolestes*.

Grant Information:
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Technical Session XX (Saturday, October 12, 2019, 3:00 PM)

USING DYNAMIC OPTIMIZATION TO SIMULATE LOCOMOTION IN EXTANT AND EXTINCT ARCHOSAURS

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Archosaurs have displayed a wide array of locomotor habits throughout their 250 million year evolutionary history, including quadrupedal and bipedal terrestrial species, semiaquatic and marine forms, and two instances of powered flight. Understanding their history of locomotor specialization and innovation may therefore provide important insight into the patterns and processes of archosaur evolution. Computational biomechanical models of the musculoskeletal system provide a unique avenue to understand, simulate and recreate locomotion in extant and extinct archosaur species. In particular, *in silico* predictive simulations can explore musculoskeletal function and organismal performance under a range of conditions, beyond those that are measurable in experimental settings, enabling investigation of 'what if' questions. Under the assumption that a given behaviour maximizes some performance objective, dynamic optimization can be used to generate simulations of behaviours *de novo*, including maximal performance behaviours. Here, we explore the ability of direct collocation approaches to generating various maximum performance simulations in the fastest extant terrestrial archosaur, the ostrich. Direct collocation approximates the system dynamics over a series of short time intervals, obviating the need for explicit numerical integration, and the states (e.g., limb kinematics) and controls (e.g., muscle activations) throughout the entire behaviour are optimized simultaneously. By avoiding forward integration, the optimization problem can be solved very quickly using standard computing hardware. We have conducted simulations for running, walking and vertical jumping with an 18 degree-of-freedom, 68 muscle model, and these can generally be solved in under an hour. Our running simulation reaches a maximum speed of 15 m/s, comparable to that reported for wild ostriches. However, we have found that simulation performance and results are highly sensitive to how well 'tuned' the musculotendon parameters are, suggesting that certain simplifications may be necessary, particularly for modelling extinct species, such as using an ideal muscle model (i.e., independent of length or velocity effects) over the more traditional Hill-type model. Framed with circumspect caution and suitable sensitivity analysis, direct collocation dynamic optimization has great promise in enabling simulation of locomotor behaviours in extinct archosaurs.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ENGAGING AND EXCITING PRE-UNIVERSITY STUDENTS IN STEM VIA 3D MODELLING OF DINOSAUR ANATOMY AND BIOMECHANICS

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Dinosaur paleontology is well-known for its capability to engage students of all ages, and provides a strong basis for increasing understanding and interest in STEM (Science, Technology, Engineering, and Mathematics) topics. Likewise, three-dimensional digital and physical modelling appeals to students for its visually intuitive and technological aspects, and it can convey a wide variety of concepts of varying degrees of complexity. Combining these approaches can help maximize the scope and impact of STEM outreach work. Here we present a multi-faceted, multi-disciplinary approach that we have refined in local secondary schools with substantial numbers of underrepresented demographics. This approach spans the full breadth of our current research into archosaurian evolutionary biomechanics, using this diversity of topics to reach students with different interests. Our school-based "dinosaur club" sessions run across a series of consecutive weeks, and cover:

(1) Triassic–Jurassic paleontology, ecosystems, macroevolution and extinction; (2) osteology and limb proportions; (3) joint morphology, muscular anatomy and mechanical advantage; (4) body dimensions and computer models of centre of mass and (5) dynamic computer simulations of locomotor balance. Here we explain our approach, the rationale behind each topic covered, and the lessons we have learned from testing it with students. In particular, we have found that framing lessons in the context of group-based games can help inspire interest in concepts and topics that some students may otherwise find abstract or uninteresting, such as Earth history and Newtonian mechanics. Our approach introduces students to major concepts in morphology, showing how morphology is central to the study of organisms, biomechanics, behaviour, ecosystems and evolution, as well as how it can be fascinating in its own right.

Grant Information:
Supported by an ERC Horizon 2020 Advanced Investigator Grant (695517, to JRH)

Technical Session XI (Friday, October 11, 2019, 11:00 AM)

NETWORK ANALYSIS UNVEILS THE FUNCTIONAL SUCCESSION OF IBERIAN MAMMALIAN FAUNAS OVER THE LAST 20MY

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One potential conservation strategy in the context of current environmental crisis is to preserve functional diversity with the hope that ecosystems and species pools will increase their chances against future environmental disturbances. To complement neontological perspectives, an interesting approach is to track functional faunas over deep timescale and to evaluate the resilience of functional-diverse systems during past events of ecological disturbance. To do so, we investigated functional morphology trends of Iberian peninsula macromammals during the last 20 my. Our dataset includes functional information for 386 species grouped in 102 functional entities (i.e., unique combinations of functional traits). We use network analysis framework to assess the functional evolution of these faunas. Besides, we estimate changes in functional disparity, functional redundancy and functional vulnerability, and compare these trends with speciation and extinction dynamics over the analyses interval. Using network analysis community detection algorithms we identified 11 “functional communities”, defined as groups of localities that harbor similar functional entities (FE) over time. We observe the substitution of these communities during the studied time interval in relation to changes in functional diversity. Functional redundancy peaks were followed by accelerating extinction and a marked species lost, typically extirpating species with the same functional ecology. The resulting system show low functional redundancy, and eventually would rebound its resilience by gaining species with existing ecological roles. In terms of FE, the recovery after episodes of functional depletion were followed by a stasis or slow recovery. In particular, we observe periods of sustained positive and moderate diversification rates, fueled by a progressive increase in FE and broadening of the multivariate functional space (a pattern observed between 14-9, and 6-1Ma). Coinciding with these patterns we observed the replacement of highly diverse functional communities by less diverse ones. After the extinction event around 9 Ma, the system underwent an increase in functional disparity and richness at the expense of increasing its functional vulnerability (many ecological roles played by just one species), which enhanced the biotic collapse of the Iberian faunas during the Messinian Salinity Crisis. We show that the use of network analysis in paleobiology is not limited to taxonomic entities, but can also be successfully applied to functional units.

Grant Information:
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Technical Session XX (Saturday, October 12, 2019, 2:00 PM)

BIOMECHANICAL RELEASE: LOADING REDUCTION AS A PATHWAY FOR MORPHOFUNCTIONAL CHANGE IN THE SKELETONS OF VERTEBRATES ACROSS EVOLUTIONARY TRANSITIONS IN HABITAT

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The relationship between structure and function is a central paradigm for understanding the diversity of biological form. For the skeletons of vertebrates, one of the main required functions is bearing the loads imposed by the actions of muscles and support of body weight. Differences in such loads across species are often viewed as a factor that contributes to differences in the shapes of their skeletal elements. One of the main sources of variation in loading across taxa is differences in the physical conditions imposed by how organisms move through different habitats. During evolutionary habitat transitions, changes in loading conditions might impose selection that could favor corresponding changes in skeletal morphology. For example, the limb bones of modern sprawling tetrapods are exposed to high torsional loads during walking on land. In this context, evolutionary changes in limb bone shape during the invasion of land by tetrapods, from a blocky to a tubular morphology, could be viewed as changes that improve resistance to torsion. However, as a counterpoint to transitions in which *increases* in particular loading regimes favor specific changes in skeletal morphology, the invasion of habitats in which loads *decrease* might allow a “biomechanical release” from demands, providing an opportunity for skeletal structure to diversify. We tested this possibility by recording limb bone strains from swimming and walking turtles and using X-ray Reconstruction of Moving Morphology (XROMM) to evaluate long axis rotation of the proximal limb bones. These recordings showed much lower torsion during swimming than during terrestrial walking. Thus, release from the biomechanical demand of resisting torsion may have led to conditions that enabled the evolution of limb bone shapes other than tubes suited to resist torsion, such as the flat limbs found in flapping lineages like sea turtles. However, some shape changes in new habitats might evolve despite disadvantageous changes in loading. For example, the limbs of arboreal taxa are often longer than those of terrestrial relatives, and longer bones typically have a greater risk of failure during running over level ground. Our data show this risk is not reduced by loading changes in arboreal habitats: strain data from the femur of green iguanas show higher, not lower, loads during climbing behaviors. Thus, although loading may have mediated the evolution of bone shape during some transitions, tradeoffs with functional demands other than loading may also have shaped bone design in other environments.

Technical Session IX (Thursday, October 10, 2019, 3:45 PM)

NEW TERRESTRIAL VERTEBRATES FROM THE PALEOGENE OF INDONESIA

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Wallace’s Line today demarcates the separation between an Asian biotic province in northern Oceanic Southeast Asia (OSEA) and an Australian biotic province in southern OSEA, thought to have resulted from northward movement of the Indo-Australian plate towards and along the Sunda Shelf. Terrestrial Paleogene vertebrates from OSEA have been largely unknown, limiting our ability to understand the timing of the development of this biogeographic pattern. Recent fieldwork (2012-2014) in West Sumatra has resulted in recovery of a diverse array of terrestrial Paleogene vertebrates contemporary with the initial emergence of the Sunda Shelf Islands. Fossils come from the Ombiliin Basin in the Barisan Mountain Range at Tanahsirah Village Road Cut locality. The fossil bearing layer is in the lower part of the late Eocene/early Oligocene Sawahlunto Formation characterized by thin coal

seams in a rooted siltstone, mudstone and limestone succession interpreted as marginal lacustrine.
Fossil turtles are the first known from the Paleogene of Indonesia and include: Geoemydidae (old world pond turtles); Testudinidae (land tortoises); and Trionychidae (soft-shelled turtles), the latter with a finely pitted and posteriorly multi-keeled carapace similar to forms found in Asia today. Crocodyliform fossils include a partial braincase, postcrania, osteoderms, and teeth of at least one crocodyloid and several teeth with serrations similar to those of ziphodont planocraniids, which are also known from the Paleogene of Asia. A single precloacal vertebra represents the oldest record of anilioid snakes in Southeast Asia. Although incomplete, the specimen appears to be anatomically distinct from extant *Cylindrophis*, and demonstrates that the wet tropical soil habitats of extant taxa were present on the emerging Sunda Shelf during the Paleogene. The first definitive mammal, a single rodent incisor, was recovered in 2014. The enamel microstructure has a unique combination of characteristics that suggest possible affinities to a ctenodactyloid-hystricognath clade. We also found a podocnemidid pleurodire (side-necked turtle), the first record from OSEA, from the middle to late Eocene Tanjung Formation in southwestern Kalimantan indicating that further exploration in the Paleogene of Indonesia is likely to be successful.
Discovery of a Paleogene terrestrial vertebrate fauna with Asian affinities is consistent with tectonic reconstructions that suggest a later Oligocene contact between the Sunda Shelf and Australia.

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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

A PATHOLOGIC TURTLE SHELL FROM THE PALEOGENE UPPER HORNERSTOWN FORMATION AT THE EDELMAN FOSSIL PARK, GLASSBORO, NEW JERSEY

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Shell lesions and other pathologies are not uncommon in extant turtles, especially aquatic species. Pathologies have also been noted in several fossil turtles, although more in-depth studies and descriptions are lacking. Recently, an associated skeleton of the sea turtle, *Catapleura repanda*, was excavated from the Upper Hornerstown Formation at the Edelman Fossil Park in Glassboro, New Jersey. The specimen consists of at least six costals, six peripherals, plastron elements, pubes, ilia, a limb bone, and other bone fragments. Pathologic pitting, holes, and excess bone growth are present in several of the costals and are restricted to the medial one-third of the elements. Some lesions present as smooth-walled depressions on the dorsal surface of the costals. The nearly circular pits range in size from 12 to 20 mm in diameter and approximately 9 mm deep. On the ventral surfaces of these bones, there is a complimentary ‘bulge’ directly beneath the pits. In other instances, the bone has been completely resorbed, resulting in a hole in the bone. The edges of these holes are smooth and intact indicating that they are not taphonomic artifacts. A slightly raised rim is present around portions of the holes on the dorsal surface. On another costal, there is a cluster of two large ovoid pits and a small circular pit. The smaller lesion is ~5 mm in diameter whereas the larger ovoid lesions are between 14 and 20 mm in maximum diameter. On the ventral surface of this costal, there is excess bone growth, giving the bone a roughened or filigree texture.
The etiology of turtle shell lesions is highly debated, and a confident identification may only be possible in living turtles in clinical settings. Consequently, this specimen is identified as having shell disease, a broad term that describes various types of damage to the shell of turtles. Possible causes include bacterial, algal, or fungal infections or healed bite-marks from failed predation attempts. The location and distribution of the lesions seems to rule bite-marks or scrapes from rocky substrates. The filigree texture seen on the ventral surface of the one costal is consistent with osteomyelitis and suggests that the lesions are the result of some type of infection.

Technical Session IX (Thursday, October 10, 2019, 2:15 PM)

NEW INSIGHTS ON LEPIDOSAUR EVOLUTION AS INFORMED FROM EVOLUTIONARY RATES AND DISPARITY ANALYSIS

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Lepidosaurs (squamates and rhynchocephalians) form one of the most speciose clades of tetrapods. Despite their success in terms of both taxonomic and morphological diversity, the early evolutionary history of lepidosaurs and timings of morphological expansions are poorly understood. Here, we provide new insights on the evolutionary history of lepidosaurs from a macroevolutionary perspective. For this, we performed multiple evolutionary rates and disparity analyses using morphological data matrices as the source of information. Despite a very poor Middle and Late Jurassic fossil record for squamates (which is even more underrepresented in morphological matrices, where complete and informative specimens are favored), our results suggest there was a notable evolutionary radiation during this time. Disparity analyses show that there was a great expansion of morphospace among lepidosaurs in the Middle-Late Jurassic, coinciding with the confluence of all major morphotypes. This morphospace does not undergo great modifications in subsequent times, only slightly expanding and becoming more densely populated. Some metrics of relative disparity through time point to the Middle-Late Jurassic as the interval of maximal disparity, or, alternatively, show this time as an inflection point initiating steadily rising disparity towards the present. Evolutionary rate analyses record a first spike of high rates in the Late Jurassic, and a second in the Late Cretaceous. Despite the appearance of several new clades in the Late Cretaceous, we regard this second spike as more problematic, as denser sampling can result in inflated rates because of the associated shortening of branches. In summary, a sudden increase in morphospace, a spike representing high rates of morphological evolution, and the presence of the earliest fossil occurrences of many crown groups, all point to a great adaptive radiation occurring no later than the Middle-Late Jurassic. Signals for a great evolutionary radiation persist when rhynchocephalians are removed, suggesting that it is highly related to the evolution of squamates. A Jurassic squamate radiation had been suggested only on the basis of the crude analysis of the composition of the fossil record, but we provide further support for this interpretation from analyses that need fewer a priori assumptions. Despite the recovered high rates in the Late Cretaceous, our results do not support an adaptive radiation of squamates linked to the Cretaceous Terrestrial Revolution.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW EMBRYOLOGICAL AND PALEONTOLOGICAL EVIDENCE SHEDS LIGHT ON THE EVOLUTION OF THE ARCHOSAUROMORPH ANKLE

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The homology and evolution of the archosaur ankle is a controversial topic that has been deeply studied using both fossil and extant evidences. In stem-archosaurs, the astragalus and calcaneum form the ancestral proximal tarsus and a single ossification composes the centrale series. In more recent stem-archosaurs, the centrale is incorporated to the proximal row contacting laterally the astragalus. This bone is subsequently lost as an independent ossification before the split between birds and crocodyles, but the evolutionary fate of this element remains mostly unexplored. Here, we combine embryological and paleontological data and morphogeometric analyses to test the hypothesis of loss of the centrale or, alternatively, its incorporation into the archosaurian astragalus. Our results support that the centrale has been incorporated into the archosaur astragalus and contradict the presence of a tibiale in bird embryos. The latter bolsters previous embryological studies that have concluded that the tibiale never develops in amniotes.

Grant Information:
Préstamo BID-PICT 2019-0159 (PB)

Technical Session IX (Thursday, October 10, 2019, 3:15 PM)

EXPLORING ELBOW KINEMATICS OF THE CENTRAL BEARDED DRAGON (*POGONA VITTICEPS*) USING XROMM: IMPLICATIONS FOR ANCESTRAL AMNIOTE ELBOW FUNCTIONAL MORPHOLOGY

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Lizards are a successful group of squamate reptiles that retain the non-erect limb posture of the ancestral amniote. Thus, understanding lizard locomotion has far-reaching implications for inferring ancestral limb posture and range of movement in both reptiles and mammals. Despite decades of research on lizard locomotion, the mechanics of the elbow joint and its relationship to manus orientation remain understudied. Previous studies on monitor lizards have inferred from dissection and X-ray cine that manus pronation is dictated by long-axis rotation of both the radius and ulna relative to the humerus. To further explore the kinematics of the lizard elbow, we used XROMM (X-ray Reconstruction of Moving Morphology) to explore elbow movements in the central bearded dragon, *Pogona vitticeps*, a docile and hardy lizard native to Australia. Lizards were trained to walk on a trackway, and videofluoroscopes captured their movements from two calibrated perspectives. Tantalum markers were affixed to the forelimb and body axis with medical tape to improve accuracy and semi-automate the reconstructions. Our results show that during stance (the portion of the step cycle when the manus is in contact with the ground and the forelimb is retracted), the radius and ulna both rotate laterally on their long-axes relative to the humerus, especially during elbow flexion. Given that the radial and ulnar condyles of the humerus have different morphologies, the antebrachial bones follow different paths at the elbow, resulting in their distal ends moving in opposite directions. Collectively, these movements of the radius and ulna maintain palmar contact of the manus with the ground during stance in what can be described as the squamate equivalent of pronation. At the end of stance and the beginning of swing (the portion of the step cycle where the manus is lifted off the ground and the forelimb is protracted), the long-axis rotations of the radius and ulna reverse, rotating medially relative to the humerus, allowing the manus to supinate. Our data are in agreement with previous work on the elbows of montior lizards which showed a similar pattern of antebrachial movements. We find it significant that manus pronation is maintained in part through movements of the radius and ulna (lateral long axis rotation) typically associated with supination in birds and (at least for the radius) in mammals. Our data suggest that we need more models and examples of elbow kinematics across reptiles and mammals to enhance our understanding of the ancestral mechanism for amniote pronation and supination.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

LIFE HISTORY PATTERNS IN EARLY JURASSIC DINOSAURS FROM SOUTH AFRICA

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The end-Triassic mass extinction (ETE) was one of the five most catastrophic mass extinction events in Earth's history, witnessing the loss of non-crocodylomorph pseudosuchians, phytosaurs, and most non-mammalian therapsids. The radiation of Late Triassic and Early Jurassic dinosaurs suggests that they were not negatively affected by the extinction event, but the difficulty in finding body fossils in a complete or near-complete sequence containing the ETE has hampered our understanding of ecosystem reorganization during this time. The Elliot Formation in South Africa contains an excellent continental record of uppermost Triassic and lowermost Jurassic strata with abundant dinosaur fossils, providing an opportunity to examine the life histories of dinosaur taxa that lived during the earliest Jurassic post-extinction environment. Osteohistology in vertebrates can be used to assess life histories because it is known to reflect growth rates and patterns, ontogenetic stages, reproductive maturity, biomechanical adaptations, lifestyles and potentially the effects of significant environmental perturbation on growth. High mortality rates affect populations in unstable, resource-limited environments such as those that form during mass extinction events, and species exhibiting different life history strategies might be expected to respond differently to critical biotic or abiotic factors. We examined the osteohistology of several dinosaur taxa from the earliest Jurassic Elliot Formation including ornithischians, theropods and the abundant sauropodomorph *Massospondylus* to assess their life history patterns. All taxa reveal rapidly forming, highly vascularized fibrolamellar bone tissues intermittently interrupted by temporary decreases (annuli) or cessations (Lines of Arrested of Growth) in growth. However, *Massospondylus* and the ornithischian *Lesothosaurus* reveal a degree of developmental plasticity in the form of irregularly spaced growth marks showing inconsistent periods of rapid growth throughout ontogeny. Ontogenetic plasticity may have been a key feature in allowing these dinosaurs to have had a high rate of survival during the post-extinction earliest Jurassic environment following the ETE.

Grant Information:

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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NASAL PASSAGE GROWTH THROUGH ONTOGENY IN THE LAMBEOSAURINE PARASAUROLOPHUS (ORNITHOPODA: DINOSAURIA)

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The cranial crest of *Parasaurolophus* is a signature feature of the genus. As with all lambeosaurines, this crest housed remarkably elongate nasal passages at least twice the length of the crest itself. Published CT scans of the ontogenetically youngest known *Parasaurolophus* skull (RAM 14000; Raymond M. Alf Museum of Paleontology at the Webb Schools, Claremont, California, U.S.A.) from the Late Cretaceous Kaiparowits Formation (Grand Staircase-Escalante National Monument, Utah) indicated that the crest originated in juveniles as a modest expansion of the cranium with some of the initial airway shape already present. However, incomplete preservation left some anatomical details uncertain. To better determine airway shape in juveniles of the genus, we constructed a composite crest from several subadult to adult *Parasaurolophus* specimens recovered from the Kaiparowits Formation. Using geometric-morphometric-based landmarking of the overlying cranial bones, we digitally morphed the crest of the more mature individuals to fit the juvenile shape of RAM 14000. The morphed cranial bones were used as guides for the underlying airway, resulting in equal morphing of the nasal passage. Our results show a much-reduced nasal passage that retains the signature curves of the genus, with prevalent dorsal ascending and ventral ascending tracts. Our morphed nasal passage differs slightly from previous interpretations of RAM 14000, with the extensive lateral diverticulum now a continuation of the dorsal and ventral ascending tracts. An extra nasal loop deep within the cranium of the composite adult specimen was retained in the morphed juvenile airway. Poor preservation in this region of the RAM 14000 cranium makes it difficult to determine if this loop was osteologically bounded or if this was an artifact of the morphing process. Resonance calculations of this longer, juvenile nasal passage resulted in slightly lower harmonic frequencies than originally estimated for RAM 14000, albeit still higher than the harmonic frequencies calculated for the adults. Our revised interpretation suggests that the basic shape of the nasal passage in *Parasaurolophus* was in place prior to hatching, and that regional nasal passage length change occurred through ontogeny.

Technical Session XVIII (Saturday, October 12, 2019, 2:30 PM)

EXPLORING LATE CRETACEOUS PATTERNS OF TAXONOMIC AND ECOLOGICAL DIVERSIFICATION AMONG NORTH AMERICAN STEM MARSUPIALS (PEDIOMYIDS AND ALPHADONTIDS)

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Metatherians (the clade that includes marsupials and their closest therian relatives) exceeded eutherians (the clade that includes placentals and their closest therian relatives) in taxonomic richness prior to the Cretaceous-Paleogene mass extinction. In North America, metatherians underwent a Cretaceous taxonomic radiation, in which five major lineages diverged by the Albian-Cenomanian–late Santonian (100–85 Ma). However, in contrast to their taxonomic diversity, North American Cretaceous metatherians have been conventionally viewed as having little dietary diversity and have been seen as mostly insectivorous. To assess the amount of ecological expansion metatherians underwent during the Cretaceous, as well as how patterns of dietary diversification relate to patterns of taxonomic richness through time, we analyzed metatherian dental morphology and function within a temporal and phylogenetic framework.
We generated 3D digital elevation models (DEMs) from microCT data of extant and fossil metatherian molars to characterize dietary ecology. We focused this pilot study on only pediomyid and alphadontid metatherians; we sampled upper third molar specimens of eight pediomyid species and 12 alphadontid species from the Santonian- to Maastrichtian. Our extant sample consists of 25 mammalian species that span a variety of dietary ecologies. Extant sampling included both marsupial and placental taxa, as the methods

used to assess dietary ecology are assumed to be homology-free. From the 3D DEMs of the sampled fossil specimens, we quantified morphological disparity and inferred diet from dental topographical measures (DTM), including relief index, Dirichlet normal energy, and orientation patch count—all of which have been shown to correlate with diet in extant mammalian taxa. Preliminary results show that pediomyids have higher values of disparity—calculated as the variance of each DTM—than present in alphadontids. This dietary expansion of pediomyids may be related to the broadly concurrent ecological radiation of angiosperms. Increased ecological richness of angiosperms may have provided new dietary niches for these metatherians to exploit. Because dietary expansion appears to coincide with taxonomic diversification, our results may imply that dietary ecology expansion may be a driving factor behind the taxonomic diversification seen in at least pediomyids.

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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

INSIGHTS INTO DINOSAUR TRACKING IN THE 21ST CENTURY USING PHOTOGRAMMETRIC ICHNOLOGY AND NEOICHNOLOGY OF EMUS

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Over the course of the past 20 years, Middle Jurassic (Bathonian) dinosaur tracks have been intensively documented in the northern Bighorn Basin of Wyoming. Evolving state-of–the-art geospatial techniques were used to capture 3D data for scientific, interpretive, and management purposes. Close-range photogrammetry was used for the proper documentation, preservation, and assessment of ichnologicalresources in this region, as stereo images have the quality, reliability, and authenticity necessary for scientific use. To better understand the taphonomic, ontogenetic, and behavioral implications of these fossil footprint data, neoichnologicstudies were undertaken.
In particular, field observations of modern emus (*Dromaius novaehollandiae*) making tracks and trackways, provided direct comparison of the actions and activities of trackmakers with the traces they leave. To that end, various ichnological datawere collected from Australia's national bird (i.e., emu) of various ages, sothat track formation could be better understood and footprint growth curvesdeveloped. Footprint length scaled well with age, weight, and other variables. Inaddition, observations of modern ground birds provide insight into thecomplexities associated with gaits. Although most theropod trackways representwalking gaits, it is apparent that trackways may not always representcontinuous movement, as some animals may stop midstride (e.g., "start-stopwalking"), which is not preserved in ichnite morphology. Also, puzzling trackways, such as those with pace angulations greater than 180 degrees (e.g., crossovers) and seemingly random orientations in dinoturbated areas, relate to those of modernratites observing and interacting with their environment (e.g., "observationaldirectionality and crossover stepping"). These studies assist in the understandingof spacing, movement patterns, age distributions, and community dynamics, representedby footprints. The Middle Jurassic Sundance Formation Vertebrate IchnofaunalProvince of the Bighorn Basin (where thousands of *Carmelopodus* undertracks are arranged into hundreds of trackways) provides evidence for a monotaxonomic population of tetanuran theropods travelingin gregarious family groups. Here and other places around the world, neoichnologicaland photogrammetric ichnological studies are being used to help unravelnumerous ichnological complexities and provide a unique glimpse of the paleoecology, paleobiology, and paleoethology of dinosaur communities.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 8:15 AM)

DIETARY NICHE SEPARATION IN LATE MIOCENE TO RECENT HYPSELODONT WOMBATS

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Hypselodont (euhypsodont) teeth have evolved multiple times in distantly related mammals. New dental material is continuously added to the base of hypselodont teeth during life to compensate for high rates of wear at the occlusal surface. There is a positive correlation between the presence of hypselodont cheek teeth and a grazing diet (i.e., monocotyledonous plants forming >90% of food intake) owing to the abrasive nature of ingested phytoliths and/or grit.
Wombats (Vombatidae, Diprotodontia) are the only Australian marsupials to have evolved hypselodont cheek teeth and all three extant species are grazers. Hypselodonty evolved in wombats in the Tortonian (late Miocene) and from the beginning of the Pliocene all known wombats have hypselodont cheek teeth. As a result of this all Plio-Pleistocene wombat species are assumed to have been grazers; however, this has never been explicitly tested and the alternative explanation, that one or more taxa incorporated significant amounts of browse in their diet, is tested here.
Mesowear is a technique that evaluates the relative degree of abrasive and attritional tooth wear using cusp height and sharpness. The resultant mesowear score can be used as a proxy for the relative degree of browse and graze in the diet of herbivorous mammals. The shape of the muzzle of many herbivores is also correlated with the relative amounts of browse/graze in the diet. These proxies are used here to see if a mixed feeding signal (<90% graze and >10% browse) can be detected in living and fossil hypselodont wombat taxa.
The results show that significant ($p<0.05$) differences in mesowear scores and muzzle shape exist between wombat taxa. In extant wombats, taxa which consumed a greater proportion of young leafy growth in the diet had lower mesowear scores (less abrasion) overall than those which incorporated a greater proportion of stems, roots and old growth (reinforcing the results of an earlier study using a broader taxonomic data set). Muzzle shape was only weakly correlated with diet. Molars of the late Miocene to Pleistocene plesiomorphic wombat, *Warendja*, have a strong attritional signal; whereas molar wear in living wombats is strongly abrasive. Extension of the analysis to other Plio-Pleistocene wombats results in a series of hypotheses which can now be tested using additional techniques such as microwear. Potential correlation between occurrences of these taxa in the fossil record and climate change is discussed.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 8:00 AM)

TRENDS IN SOFT TISSUE PRESERVATION AND ITS ROLE IN REVEALING THE HISTORY OF LIFE

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The common perception of the vertebrate fossil record is bones, scales and teeth and, more rarely, eggshell. Associated biomolecules and their potential significance have received relatively little attention with the exception of ancient DNA and its celebrated applications. In this respect research on fossil vertebrates differs from that on invertebrates and plants where organic cuticles, for example, are a much more significant component of the fossil record. Analyses of fossil samples and experiments have shown how lipids in arthropod cuticles and leaves are transformed into longer chain hydrocarbons with a higher preservation potential. Conodont elements have long been used both in biostratigraphy and as an indicator of thermal maturity based on diagenetic color change in their organic components but without the realization that organics in familiar vertebrate hard tissues are similarly affected. The neglect of biomolecules in fossil vertebrates was a result, at least in part, of a poor understanding of taphonomy – what settings favor biomolecular preservation in vertebrate tissues and what processes are involved – and limited analytical approaches. Recent discoveries have transformed the potential utility of biomolecules in vertebrate fossils. The pigment melanin has been shown to be one of the most degradation resistant biomolecules, which can survive largely intact at least as far back as the Jurassic. Fossilized melanin has provided a method for reconstructing color in fossil vertebrates both within and outside melanosomes (the organelles preserved in fossil fur and feathers). Just as significant is the demonstration that vertebrate hard tissues in particular sedimentary settings sequester soft tissue remains. The composition of this material (protein, lipid, and polysaccharide fossilization products) retains a chemosystematic signal that is diagnostic of particular taxa and reflects affinities and metabolic rate. Such data can enhance paleoecological reconstructions, inform phylogenies, and assist in the placement of problematic taxa. Combined with new analytical approaches, ancient biomolecules in vertebrate hard tissues have the potential to provide increasingly powerful complementary evidence to fossil remains in revealing the history of vertebrate life.

Technical Session IV (Wednesday, October 9, 2019, 2:30 PM)

TOOTH REPLACEMENT RATES IN HETERODONT REPTILES

BRINK, Kirstin, University of British Columbia, Vancouver, BC, Canada; RICHMAN, Joy, University of British Columbia, Vancouver, BC, Canada

Tooth replacement frequency in polyphyodont animals is tightly correlated with tooth function, diet, and dental evolution. The tooth replacement process involves perfect timing between initiation, development, eruption, and shedding. A common method used to calculate replacement rates in fossils is the examination of histological sections or high resolution microCT scans to count lines of von Ebner in the dentine of sequential teeth at one tooth position, which gives an estimate of the time between the initiation of each tooth. The rate calculated for that tooth position is often averaged to get an estimate of tooth replacement rates for the whole mouth. This is generally not a problem for animals with homodont dentitions, where teeth are the same size and shape around the mouth. However, this could be problematic for animals with heterodont dentitions, where teeth of different sizes may have different developmental times, and therefore estimates of tooth replacement rates based on one tooth position may not be an accurate representation of the whole mouth.

To test whether animals with heterodont dentitions have different tooth replacement rates based on position in the mouth, a dataset of X-rays collected in the 1950s and '60s at the Royal Ontario Museum, Toronto, was examined. X-rays from *Dracaena* (n=2), *Varanus* (n=2), *Teius* (n=2), and *Alligator* (n=2) were collected monthly or bimonthly for up to two years. For this study, the X-rays were examined for presence or absence of replacement teeth, and shedding events were scored over the data collection interval. Results show that larger teeth have longer development times than smaller teeth, however, eruption and shedding times are uniform between positions around the mouth. For example, in *Dracaena* and *Alligator*, a tooth at each position is shed once a year, however, the large molariform and caniniform teeth take eight months to develop while the smaller conical teeth take two months. These data suggest that, surprisingly, calculations of tooth replacement in heterodont animals based on one tooth position might in fact be accurate, as it is actually the timing of tooth development that differs between tooth positions while shedding frequencies are consistent. These differences in tooth development times may be key to understanding how variation in tooth morphology arises over evolutionary timescales, such as the differences between premaxillary and maxillary teeth in homodont animals, or more pronounced tooth modules, such as incisors, canines, and molars in mammals.

Grant Information:
NSERC Banting Postdoctoral Fellowship and American Association of Anatomists Short-Term Visiting Scholarship to KSB

Technical Session XIII (Friday, October 11, 2019, 2:15 PM)

STILL STRANGER THINGS: MICRO CT IMAGING OF 3D DREPANOSAUR SKULLS AND SKELETONS (SAINTS & SINNERS QUARRY, LATE TRIASSIC, EOLIAN/INTERDUNAL NUGGET FORMATION) REVEALS BIZARRE AND NOVEL MORPHOLOGIES INCLUDING A BEAK COMBINED WITH TRANSVERSELY WIDE TEETH, SAUROPOD-LIKE PNEUMATIC DORSAL VERTEBRAE, A CHEVRON THAT ARTICULATES WITH THE PELVIS, AND TRIPODAL ADAPTATIONS

BRITT, Brooks B., Brigham Young University, Provo, UT, United States of America; PRITCHARD, Adam C., National Museum of Natural History, Washington, DC, United States of America; CHURE, Daniel J., Retired, Jensen, UT, United States of America; ENGELMANN, George F., University of Nebraska, Omaha, Omaha, NE, United States of America; SCHEETZ, Rodney D., Brigham Young University, Provo, UT, United States of America; THEURER, Brandon C., Brigham Young University, Provo, UT, United States of America; ESPLIN, Rebecca B., Brigham Young University, Provo, UT, United States of America

With a bird-like head, mole-like arms, and a "claw" at the end of the tail, derived drepanosaurs (lizard-sized neodiapsids) are highly enigmatic. Multiple 3D skeletons of a new drepanosaur taxon from Utah provides insights into this clade, previously known from flattened skeletons and isolated 3D elements.

The rostrum of the skull is edentulous with elongate nares (>50% of rostrum). Teeth are transversely broad. Upper tooth rows are offset medially with the posteriormost upper teeth separated from the jugal by a broad suborbital fenestra. Mandibular rami are fused and rostrally edentulous. The dentary teeth extend nearly to the posterior end of the mandible, and the tooth row is rotated medially along its long axis. The jaw joint is ventral to the tooth row. The quadrate tapers dorsally, lacks a cephalic condyle articulation with the squamosal, and lacks a posterior concavity, indicating the absence of an external ear. The frontal and parietal are large and their endocranial contributions dorsally inflated.

Dorsal vertebrae are lightly built. The ventral portion of the anterior cotyle of the centrum is absent, perhaps facilitating hyperflexion. Dorsal vertebrae are convergent with sauropod vertebrae in having proportionally large, pneumatic ventrolateral fossae on the centrum and elongate fossae and thin laminae on the neural arch. The apices of the neural spines of dorsals 2-3 are anteroposteriorly elongated, transversely thick, and fused into a "notarium" with a sulcus on each side of the elongated spine of 2 that receives the tip of the rod-like scapulae.

Contra other drepanosaurs, the ilium has large anterior and posterior blades and chevron 1 is elongate, extending ventrally to the level of the ischia. Anteriorly, it is laterally wide and posteriorly bladiform terminating ventrally in a plate. When the tail is ventroflexed (and the tail "claw" in a substrate) this plate abuts the elongate ischia, firmly bracing the tail to the pelvis to form, along with the large feet, a tripod stabilizing the rigid tubular trunk during scratch digging with the arms. This tripodal stance is further facilitated by large iliac blades that act as the origins of large muscles to bridge the body and tail.

The Utah taxon inhabited playa flats in an enormous dunefield. Such finds increasingly show that although drepanosaurs were highly specialized they were ecologically diverse, geographically widely distributed, and were common constituents of Late Triassic faunas.

Grant Information:
Smithsonian Peter Buck Fellowship to Adam Pritchard

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

GIANT DWARF CROCODILES – A NEW CLADE OF OSTEOLAEMINE CROCODYLIDS FROM THE MIOCENE OF KENYA

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Crocodiles are commonly found in late Cenozoic fluviolacustrine deposits throughout the East African Rift Valley System, but until recently, they were often assumed to be closely related to the Nile crocodile (*Crocodylus niloticus*) currently living in the region. Here, we describe an assemblage of crocodylids from several early to middle Miocene sites in Kenya. The specimens are housed the Department of Earth Sciences, National Museums of Kenya.

The most completely known of these is based on a skull and lower jaws from Maboko (Serravallian, Lake Victoria Basin). The snout is comparatively short and deep, broadly resembling those of the modern mugger (*C. palustris*) and Morelet's crocodile (*C. moreletii*). New species with somewhat longer snouts are known from Karungu (Lake Victoria Basin) and Loperot (Turkana Basin), both of putative Burdigalian age. The largest known specimens of each derive from 3.5 to 4 m long individuals. These forms lack features diagnostic of *Crocodylus*, such as a derived arrangement of the medial and lateral Eustachian openings and basisphenoid in posterior view. They do, however, share derived characters with the modern African dwarf crocodiles (*Osteolaemus*), such as a thin crest circumscribing the internal choana. Phylogenetic analysis supports a close relationship between these forms and a closer relationship to *Osteolaemus* (which rarely exceeds 2 m in length) than to *Crocodylus*.

This new clade of osteolaemines disappears shortly after the Middle Miocene Climatic Optimum and the early transition from continuous forest to grassland-savannah biomes in the region. Another osteolaemine, *Brochuchus*, disappears at approximately the same time. The only crocodylians found throughout the Miocene in the area are longirostine forms (gharials and *Euthecodon*). Modern *Osteolaemus* is restricted forested wetlands, suggesting the contraction of osteolaemine diversity in East Africa was driven by changes in vegetation. This is consistent with the presence of a possible close relative in the late Miocene of western Uganda, where forested conditions persisted. The appearance of *Crocodylus* in the late Miocene might reflect its more relaxed environmental preferences.

US National Science Foundation DEB 1257786-125748
Research on East African Catarrhine and Hominoid Evolution (REACHE)

Romer Prize Session (Thursday, October 10, 2019, 10:45 AM)

ON THIN AIR: VENTILATION MECHANICS IN LIVING AND FOSSIL BIRDS

BROCKLEHURST, Robert J., University of Manchester, Manchester, United Kingdom

Modern birds have a highly modified ribcage associated with both a uniquely efficient respiratory system and powered flight. The avian fossil record preserves the sequence of transformations in ribcage anatomy related to the origin of flight, but how these changes affected respiration & ventilation mechanics remains unclear. Reconstructing the evolution of breathing requires integration of anatomical, kinematic and physiological data. Here, I combine these multiple data streams to create multi-body dynamics musculoskeletal models, and use evolutionary robotics optimization approaches to estimate muscle activation patterns, ventilatory movements and – for the first time in a simulation study – the energetic cost of breathing. I started by constructing a model of an extant bird (wild turkey, *Meleagris gallopavo*); musculoskeletal anatomy was taken from CT scan and dissection data, and joint behaviour & ranges of motion were characterised using XROMM (X-ray reconstruction of moving morphology). Model predictions for muscle activation and skeletal kinematics were validated against *in vivo* electromyography and XROMM data, and costs of ventilation from the model fell broadly in-line with experimental results. Next, I altered the validated model to reflect morphologies seen in the early bird fossil record e.g., by removing the sternal keel or shortening the sternum posteriorly. This let me test how the anatomical transformations of the ribcage and sternum associated with flight might have affected breathing mechanics along the avian stem. The evolution of a keeled sternum and increased flight muscle mass increased the cost of breathing, but other features of the ribcage acted as compensatory mechanisms, e.g., the presence of uncinate processes. Although the locomotor demands of flight on the skeleton constrain ventilation performance, birds have managed to maintain effective, low-cost ventilation even as they became increasingly specialised for flight. Integrating the results of these dynamic models with other means of reconstructing ventilation in fossils (e.g., "scientific motion transfer" of breathing kinematics from extant archosaurs), I aim to provide a holistic view of respiratory evolution during a major ecological radiation, across the dinosaur-bird transition.

Grant Information:
This work was supported by a U.K. Biotechnology and Biological Sciences Research Council Doctoral Training Partnership (BBSRC DTP).

Technical Session XII (Friday, October 11, 2019, 8:45 AM)

BODY SIZE CORRELATES WITH DISCRETE CHARACTER MORPHOLOGICAL PROXIES IN DINOSAURS

BROUGHAM, Tom, University of New England, Armidale, Australia; CAMPIONE, Nicolas E., University of New England, Armidale, Australia

The application of statistical ordination techniques, primarily Principal Coordinate Analysis (PCoA), to morphology-based phylogenetic character-taxon matrices has become an increasing popular method in morphospace and disparity studies. However, to date little effort has been invested in testing whether traits extrinsic to these matrices, such as body size, are related to the ordinated morphospaces used to interpret the evolution of major body plans. We present evidence from a re-analysis of independently-compiled character-taxon matrices across a wide range of different dinosaurian clades that body size (obtained from a comprehensive database of body mass estimates) displays a previously unrecognised significant relationship with the principal axis of variation (PCoA1). Of the nine re-analysed matrices, seven returned a positive statistically significant ($p<0.05$) correlation between the first principal coordinate axis and body size. This correlation appears to be independent of coding strategy (i.e., contingent vs. multistate) employed in the construction of the cladistic datasets. In addition, the statistical significance of this relationship is inversely related to the size (i.e., number of characters and taxa) of the cladistic matrix. This indicates that large clades appear to be more prone to the effects of 'hidden' confounding factors, and that these effects may be inherent to the data used to generate morphology-based phylogenies. We extended this study to critically re-examine a recently proposed macroevolutionary hypothesis: that a strong directional shift in morphospace in the hypothetical theropod ancestors of modern birds documents a period of accelerated accumulation of avian-type traits. A re-analysis of the character-taxon matrix used to derive this hypothesis demonstrates that over 80 percent of the morphological variation along the avian stem lineage could be attributed to the reconstructed body sizes of each ancestor. Furthermore, when the effects of body size are accounted for, the strong directional change in morphology within the hypothetical avian stem lineage is effectively removed. Our results indicate that life-history traits extrinsic to character-taxon matrices can nonetheless have a significant effect on morphological proxies derived from PCoA ordination. Future studies using PCoA-based cladistic morphospaces should therefore explore and account for potential correlations with body size to ensure that no confounding factors are influencing perceived macroevolutionary patterns.

Grant Information:
TB was supported by a Research Training Program scholarship administered by the Australian Government.

Technical Session XII (Friday, October 11, 2019, 11:15 AM)

VARIATION IN BRAINCASE MORPHOLOGY AND PALEONEUROLOGY WITHIN CERATOPSIA.

BULLAR, Claire, University of Bristol, Bristol, United Kingdom; BENTON, Michael J., University of Bristol, Bristol, United Kingdom; ZHAO, Qi, Institute of Paleontology and Paleoanthropology, Beijing, China; RYAN, Michael, Carleton University, Ottawa, ON, Canada

In recent years the study of braincase anatomy and paleoneurology in dinosaurs and other extinct vertebrates has been transformed by high-resolution CT scanning and 3D reconstruction. The paleoneurology and development of cognitive abilities is of particular interest in Ceratopsia, a group of non-avian dinosaurs for which many behavioural theories have previously been posited. Ceratopsian braincases, however, have often been neglected because of the high level of bone fusion and consequent obscurity of sutures.

Here we use several taxa from across Ceratopsia to study morphological disparity levels in ceratopsian paleoneurological architecture. Through the examination and segmentation of high-resolution CT scans of taxa across the clade, we find that, while general braincase arrangement remained the same, the morphology of individual elements altered significantly as the group evolved. The paroccipital processes are long and thin in basal forms and become taller and distally flared to accommodate the large frills of ceratopsids. These changes also increase the area of attachment for neck muscles such as *m. obliquus capitis magnus*. Similarly, the basal tubera of the basioccipital grow and develop, which increases the size of neck muscle attachment sites. On the ventral surface of the braincase, the morphology and orientation of the basipterygoid processes change dramatically leading to an overall transformation in appearance of the basisphenoid. The processes project anteroventrally in basal taxa and move caudally through evolution of the clade, so that ceratopsids have caudoventrally projecting basipterygoid processes. There are some exceptions to this rule, which is possibly a result of geographic separation and allopatric speciation. On the dorsal surface of the braincase, the frontal and parietal undergo drastic change, in part due to the development and expansion of supracranial sinuses, brow horns and the parietosquamosal frill. Additionally, we explore semi-circular canal plasticity and find that there is a decrease in the size of the anterior semicircular canal relative to the posterior semicircular canal.

This project has provided a suitable basis to collect synapomorphic braincase characters to complement previous phylogenetic research. In further work, these characters will be added to a grand ceratopsian phylogeny and will supplement the current sparse selection of paleoneurological characters.

Grant Information:
We thank the Paleontological Association, Geological Society of London, Neoceratopsian Scholarship, and Bristol University Alumni Foundation for funding assistance.

Preparators' Session (Thursday, October 10, 2019, 2:45 PM)

TECHNIQUES FOR SUCCESSFUL COLLECTION OF PLEISTOCENE MEGAFAUNA MATERIAL FROM LAKE CALLABONNA FOSSIL RESERVE, SOUTH AUSTRALIA.

BURKE, Carey J., Flinders University, Adelaide, Australia; WORTHY, Trevor H., Flinders University, Adelaide, Australia; CAMENS, Aaron B., Adelaide, Australia

The Pleistocene megafauna fossil deposits of Lake Callabonna have been known for over a century. The many challenges that arise from working in this inhospitable terrain continue to test paleontologists. Fossils usually consist of articulated skeletons entombed in damp, hypersaline clays with localised concretions. There is a history of rapid deterioration of specimens after collection and aborted attempts to reach the fossil sites. The abundance and quality of fossil material at Lake Callabonna make it an enticing prospect for researchers. The integration of logistic, collection and preparation techniques have enabled Flinders University researchers to recover exceptional fossil material from this site.

Logistics- Lake Callabonna is extremely remote, desolate and difficult to traverse. The use of quad bikes and small ATVs to navigate the landscape is essential as standard four-wheel drive vehicles cannot access the lake surface without becoming bogged. These extra vehicles restrict the number of people and amount of supplies/equipment that can be transported to the site. The remote, desolate nature of the lake prevents supplementation of resources. Field workers require experience or training in all aspects of remote area hazards.

Collection- Standard plaster jacketing techniques are supplemented by a layer of plastic pallet wrap within the jacket to prevent desiccation. Sediments surrounding bones can harbour integument impressions. Multiple sites are worked simultaneously as shifting sand can make excavation impossible in some areas. Regular prospecting ensures that new skeletons are noted as they become exposed by erosional winds.

Preparation- Lake Callabonna fossils do not store well. Desiccating specimens results in shrinking and cracking of the dense clay matrix, destroying bone in the process. Best results are obtained while the clays are still wet. Standard mechanical removal of clay matrix followed by cleaning and consolidation with acetone and Paraloid B72 as the bones slowly dry will halt the extrusion of halite crystals from the exposed surfaces and prevent the specimen from becoming brittle. Microjacks are employed to remove localised concretions. Funding and space resources for the prompt preparation of Lake Callabonna fossil material must be considered before the expedition can proceed.

Grant Information:
ARC Discovery Project DP180101913

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

CHEIRACANTHUS (ACANTHODII, ACANTHODIFORMES) FROM THE MIDDLE DEVONIAN OF SCOTLAND: NEW ANATOMICAL DATA AND NEW SPECIES

BURROW, Carole, Queensland Museum, Brisbane, Australia; NEWMAN, Michael J., First Group, Johnston, Haverfordwest, United Kingdom; DEN BLAAUWEN, Jan L., University of Amsterdam, Amsterdam, Netherlands

Articulated specimens of three species of *Cheiracanthus*, *C. murchisoni*, *C. latus* and *C. grandispinus*, have been known from the Orcadian Basin of northern Scotland since the mid-19th century. Although their gross morphology has been reasonably well described, the histology of much of their exo- and endoskeleton and the variation in scale morphology have not. We have addressed this lack of information by serial sectioning specimens of each species to determine the structure of scales, fin spines, and endoskeletal elements, and using scanning electron and light microscopy to examine scale variation over the body. Our investigations support the validity of the three species, and the sinking of junior synonyms in the 19th century.

We can also report that other species of *Cheiracanthus* also occur in the Orcadian Basin, with several of these also found as isolated scales in the Baltic region. At least one new species *C. peachi* has been identified from both Scotland and the Baltic. The co-occurrence of the same species in both the Main Devonian Field/Baltic region and Scotland during the Middle Devonian indicates that there was at least a short-term connection between the lacustrine Orcadian Basin and the marine environment.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 11:00 AM)

FANGAROOS AND KANGAROOS: PHYLOGENY, PALEOECOLOGY, DIVERSIFICATION AND EXTINCTION OF EARLY KANGAROOS (MARSUPIALIA: MACROPODIFORMES) FROM THE RIVERSLEIGH WORLD HERITAGE AREA

BUTLER, Kaylene, The University of Queensland, St Lucia, Australia; TRAVOUILLON, Kenny, Western Australian Museum, Welshpool, WA, Australia; WEISBECKER, Vera, The University of Queensland, Brisbane, Australia; EVANS, Alistair R., Monash University, Monash University, Australia; MURPHY, Laura, Monash University, Victoria, Australia; PRICE, Gilbert, The University of Queensland, St Lucia, Australia; ARCHER, Michael, University of New South Wales, Maroubra, Australia; HAND, Suzanne J., University of New South Wales, Sydney, Australia

Kangaroos are one of Australia's most iconic faunal groups. The suborder Macropodiformes (kangaroo and allies) includes at least three families: Hypsiprymnodontidae (musky rat-kangaroos), Macropodidae (rat-kangaroos, kangaroos and wallabies) and an extinct family of fanged kangaroos (Balbaridae). Fossil evidence of all three families extends back to the late Oligocene. One fossil kangaroo-bearing locality which contains numerous early representatives of all three families is the Riversleigh World Heritage Area, northwestern Queensland, Australia. Riversleigh's numerous fossil sites which range from Oligo-Miocene to Pleistocene in age make it an ideal place to trace the evolution of kangaroos.

The timing and potential drivers behind the decline, and eventual extinction, of Balbaridae remains unresolved. Previous research suggests that, at Riversleigh, macropodids were more diverse than balbarids throughout most of the Oligo-Miocene with balbarids becoming extinct by the end of the middle Miocene. Here, we present new data based on more recent taxonomic descriptions and analyses of species diversity, trends in body mass and skull shape. Our results indicate that macropodids were in fact more diverse than balbarids throughout most of the Oligo-Miocene. The presence of two balbarid specimens in late Miocene deposits at Riversleigh extends the temporal range of balbarids, indicating that their extinction was more recent than previously thought.

Furthermore, previous interpretations of diet of Oligo-Miocene macropodiforms (kangaroos and allies) from Riversleigh suggest that, in contrast to many modern macropodiform communities, extinct representatives of Macropodidae and Balbaridae were predominantly folivorous browsers or fungivores. We use 3D geometric morphometric analyses to investigate the probable diet of early macropodiforms by examining the relationship between skull shape and diet in macropodiforms. Using principal component analysis of shape variation for crania, Riversleigh macropodids and balbarids generally cluster closest to extant folivorous browsers, providing support for previous interpretations of these species as browsers. Further, despite representing taxonomically distinct families, balbarids and early macropodids exhibit similar overall cranial shapes.

Grant Information:
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Technical Session XII (Friday, October 11, 2019, 9:15 AM)

USING BIOMECHANICAL MODELLING TO INVESTIGATE AN ADAPTIVE RADIATION: A CASE STUDY IN DINOSAURIA

BUTTON, David J., Natural History Museum, London, United Kingdom; PORRO, Laura B., UCL, University College London, London, United Kingdom; JONES, Marc E., UCL, University College London, London, United Kingdom; BARRETT, Paul M., The Natural History Museum, London, United Kingdom

Adaptive radiations – rapid diversifications of clades colonizing new ecospace – are central to understanding the history of life, as they unite concepts from ecology and evolutionary theory. Information from the fossil record is critical, but paleontological studies of adaptive radiations have often been restricted to qualitative comparison of characters of presumed mechanical and ecological significance. Empirical case studies comparing direct measures of performance through clade history have been lacking, precluding a comprehensive perspective of the dynamics of an adaptive radiation. Early dinosaur evolution, between 240–190 Ma, provide such a case study. During this interval dinosaurs greatly increased in size, diversity and abundance. Their varied craniodental morphologies have fueled hypotheses linking this radiation to innovations in the feeding apparatus and feeding ecology. However, anatomy alone can be a poor indicator of functional performance, and biomechanical studies of dinosaur crania have been restricted to deeply-nested taxa. Consequently, the functional morphology and feeding behavior of early dinosaurs remains poorly understood.

Here, we virtually restore the cranial osteology of four early dinosaur taxa (*Coelophysis*, *Heterodontosaurus*, *Plateosaurus* and *Melanorosaurus*), including representatives of Theropoda, Ornithischia and Sauropodomorpha, from CT scan data. Scans were imported into *Avizo* to execute retrodeformation procedures, repairing taphonomic damage, and reconstruct jaw adductor musculature from osteological correlates. This then allowed the performance of finite-element analyses within *Strand7*, quantifying functional performance during simulated feeding behaviors. Results demonstrate systematic differences between theropods and ornithischians consistent with early specializations towards carnivory and herbivory, with a greater emphasis on jaw closure speed versus mechanical stability, respectively. However, early sauropodomorph taxa exhibit mechanical compromises leading to more generalized performance. This suggests the rapid diversification of sauropodomorphs in the Late Triassic may have linked with dietary flexibility, rather than specialization. These data permit quantitative comparison between functional performance and diversity dynamics through the early evolution of Dinosauria, illuminating the processes underpinning an exemplar adaptive radiation.

Grant Information:
This research was supported by NERC grant NE/R000077/1, awarded to PMB and LBP.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

VIRTUAL 3D-RECONSTRUCTION OF INCLUSIONS FROM THREE LARGE COPROLITES FROM AN EARLY TOURNAISIAN LAKE DEPOSIT

BYRNE, Hannah M., Uppsala University, Sweden; BLOM, Henning, Uppsala University, Sweden; NIEDZWIEDZKI, Gregorz, Uppsala University, Sweden; KEAR, Benjamin P., Uppsala University, Sweden; AHLBERG, Per E., Uppsala University, Sweden

The Devonian-Carboniferous (D-C) strata from East Greenland form one of the best successions of low latitude sediments from that time. The Obrutschew Bjerg Formation represents a deep permanent lake from the earliest Tournaisian, and this black shale deposit can be linked to the famous Hangenberg extinction event. The deposit contains an abundance of actinopterygian remains believed to belong solely to the species *Cuneognathus gardineri,* along with a smaller number of acanthodian and chondrichthyan specimens. There is also an abundance of coprolites (over 100 collected) of various morphologies. There are large, non-spiral coprolites present which are suspected to be tetrapod in origin, however tetrapod body fossils do not occur in this assemblage; only in the late Devonian Aina Dal and Britta Dal formations. However, large non-spiral coprolites may be tetrapod in origin, thus placing tetrapods in the vicinity of the lake. Here we present the modelled inclusions of three large coprolites, which have been imaged using Synchrotron phase-contrast microtomography at the European Synchrotron Radiation Facility (ESRF). The coprolite intrusions were modelled via masking using the imaging software Materialise Mimics 19. Both coprolites contain a similar assemblage of elements; partly articulated fish, multiple cleithra, clavicles and dental elements of actinopterygian origin, and acanthodian spines. The vast abundance of actinopterygian inclusions within the coprolites show that actinopterygians were the preferred choose of prey and could suggest that *Cueneognathus gardneri* were schooling fish. It also indicates that the coprolite producer was a proficient swimmer. The actinopterygian inclusions have excellent 3D preservation, and so have the potential to aid in furthering our understanding of changes in actinopterygians across the D-C boundary.

Grant Information:
This work was supported by grants from the Wallenberg Scholarship, from the Knut and Alice Wallenberg Foundation.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

FIRST EVIDENCE OF CHAMPSOSAURS (DIAPSIDA: NEOCHORISTODERA) FROM THE LATE CRETACEOUS OF THE ATLANTIC COASTAL PLAIN

CALLAHAN, Wayne R., New Jersey State Museum, Trenton, NJ, United States of America; MEHLING, Carl M., American Museum of Natural History, New York, NY, United States of America; BALLWANZ, Steven, New Jersey State Museum, Trenton, NJ, United States of America; DUDGEON, Thomas W., Carleton University, Ottawa, ON, Canada

Fossils recovered from the Late Cretaceous Brook Sites of Monmouth County, New Jersey have yielded a tantalizing look at the marine, nearshore, and terrestrial vertebrate fauna of Appalachia. In spite of urban sprawl and dwindling access to natural areas, new discoveries are made on a fairly regular basis due in part to cooperative agreements between the Monmouth County Park Service and the Natural History Bureau of the New Jersey State Museum. Three vertebral centra, recovered from the Late Campanian/Early Maastrichtian boundary interval, are identified as the first reported evidence of champsosaurs from the East Coast of North America. With the exception of specimens from the Turonian/Coniacian of Axel Heiberg Island of the high Canadian Arctic, these are the only choristodere fossils known from Appalachia. The first of the three was recovered in-situ from the base of the Navesink Formation along a stream bed in the area of Holmdel, New Jersey. This locality has been well studied and is interpreted as representing a mix of marine, fluvial and terrestrial environments. The other two specimens were recovered as float, along the same streambed, approximately 1.2 and 2.8 kilometers to the southeast respectively. The first of the vertebrae measures approximately 30 mm in length and 29 mm in width and height. The second is slightly smaller at 29 mm long, 25 mm in width and 22 mm in height. The third is considerably smaller at 7.5 mm long by 6 mm in width and height. All vertebrae are worn to some degree due likely to post-mortem transport. All three vertebrae are spool-shaped, with amphiplatyan to slightly amphicoelous centra. On the ventral floor of the neural canal there is a strong midline ridge, bordered laterally by hourglass-shaped longitudinal grooves characteristic of choristodere vertebrae. Two of the vertebrae, including the smallest, have a strong midventral keel indicative of champsosaur cervical vertebrae. Both of these also display saddle-shaped depressions where the neural arch pedicles were attached at a point slightly anterior of the mid-line of the centrum. The other specimen has a rounded ventral surface and is possibly a dorsal or proximal caudal vertebra. The ventral portion of one broken neural arch pedicle can be observed on one side of the vertebra with a clear indication of the suture.
It is hoped that continued recovery of material from these localities, and a review of both institutional and private paleontological collections made from the area, will provide additional specimens of this allusive taxon in eastern North America.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 11:45 AM)

WALK LIKE A KANGAROO: NEW FOSSIL TRACKWAYS REVEAL A BIPEDALLY STRIDING MACROPODID IN THE PLIOCENE OF CENTRAL AUSTRALIA

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Vertebrate trace fossils can provide information relating to manual and pedal soft-tissue morphology, foraging patterns, the way in which a taxon interacts with other organisms and even novel locomotory repertoires. Although Mesozoic vertebrate traces have been documented from multiple areas of Australia, Cenozoic traces have received comparatively little attention. Published sites are largely restricted to the south-eastern part of the continent and are mainly of Pleistocene age. Recent investigations into the Pliocene lacustrine sediments of the Tirari Formation in the Lake Eyre Basin have revealed significant potential for the preservation of vertebrate trace fossils including flamingos, waders and large herbivorous marsupials. Here we report the discovery of two remarkable trackways in Tirari Fm. sediments (3.5-4 Ma) that appear to represent a bipedally striding kangaroo. Kangaroos are widely recognised for their hopping (ricochetal) gait and this represents the first direct evidence that any macropodoid routinely employed a bipedal stride during terrestrial locomotion. The two trackways (one, 19 consecutive steps and the other, nine) both display a footprint with a single elongate digit, indicating that the track-maker was a small sthenurine kangaroo. Based on trackway parameters and species known from the skeletal fossil record for this time period, the taxon responsible was most probably either *Sthenurus tindalei* or a species of *Archaeosimos*. An analysis of the bending stresses in the tails of sthenurines for which sufficient material is known indicates that *S. tindalei* was using its tail differently to all other macropodids studied. The lack of tail-drag marks in the trackways indicates that the tail was held off the ground and it is suggested that the track-maker employed a head-down, tail-up posture similar to that hypothesised to have been used by theropod dinosaurs. These trackways provide support for the hypothesis that some sthenurine kangaroos included bipedal striding in their locomotory repertoire and that they may not have used the pentapedal bounding seen in large extant macropodids.

Grant Information:
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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ANALYSIS OF SOUTHERN AFRICAN PLEISTOCENE RODENT HUMERI FROM SWARTKRANS: MEMBERS 1-3

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Rodent remains found in many southern African Plio-Pleistocene fossil-bearing deposits are commonly used to reconstruct paleoenvironments using a taxonomic framework. In these studies, craniodental remains are the primary material used to reconstruct rodent paleocommunities. Postcranial elements are generally not considered. In this study, we extract the suprageneric taxonomic signal present in modern rodent humeri and apply these results to fossil specimens from the Pleistocene hominin-bearing site of Swartkrans, Members 1-3 (~2.0 –0.62 Ma). High resolution images of the extensor surface of 241 modern specimens representing 5 families (Muridae, Bathyergidae, Nesomyidae, Sciuridae, Gliridae), and 126 fossil specimens were used to digitize humeral outlines. Due to sample size issues, the latter two families were grouped at the subordinal level (Sciuromorpha) in statistical analyses. Outlines were then subjected to elliptic Fourier analysis from which 120 harmonic coefficients were calculated to represent shape information invariant to size, location, rotation, and outline origin. Harmonics of known specimens were then subjected to principal components (PC) analysis.

Swartkrans specimens were rotated to the PC axes as well, placing them in the same shape space as the known subjects. The 19 largest PC axes accounted for 98% of shape variance among the known specimens, and specimen scores for these variables were retained. Modern shape differences were tested using multivariate analysis of variance (MANOVA) on PC scores, and classification success was calculated using linear discriminant function analysis (LDA). Results from the LDA on modern specimens were used to classify the unknown fossil specimens. Modern specimens were found to differ strongly in shape ($\eta^2 = 0.82$; $P < 0.01$) with 91% correctly classified using posterior probabilities, and 88% using cross-validation. All misclassifications occurred between the Muridae and the Nesomyidae families. Finally, to explore potential family level signal within the Sciuromorpha a follow-up PCA was run on modern specimens using linear measurements of humeral length and epicondylar breadth, with the fossil specimens classified to this group rotated to the PC axes. Examination of the PC plot shows that the fossil specimens cluster closest to the glirids and suggests that they should be classified as such. This study demonstrates that higher level taxonomic signals are present in southern African rodent humeri, and suggests that similar studies of additional elements are warranted.

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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

ON THE POTENTIAL TO RECONSTRUCT A DIETARY CONTINUUM IN DINOSAURS

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Paleontologists of the past 200 years investigated much about the anatomy and diversity of Mesozoic dinosaurs. Dinosaur evolutionary paleoecology, however, has been particularly challenging to reconstruct, given the rarity with which direct evidence of interactions between species are preserved. For instance, dinosaur diets remain broadly categorized (herbivore vs. carnivore) and lacking in nuance. Large data sets of ecologically-relevant anatomical measures (ecometrics or functional traits) provide a means to reconstruct ecology of many species, allowing in-depth macroevolutionary studies of dietary and ecological evolution spanning the entire evolutionary history of dinosaurs.
We propose the use of 3D dental surface quantification techniques to generate an ecomorphological proxy for diet. Metrics such as orientation patch count rotated (OPCr) have already evinced their ecomorphological potential as dietary metrics in modern mammals and reptiles. These have substantial potential, but have not yet been applied to dinosaurs. Here we apply OPCr, a measure of dental complexity, to an initial data set of four phylogenetically disparate dinosaurs: *Albertosaurus*, *Stegoceras*, *Leaellynasaura*, and *Chasmosaurus*. OPCr was calculated for individual teeth via the traditional 2.5D approach. *Albertosaurus* (OPCr=8) occurs near the upper extreme of modern carnivorous reptiles, due to its oval profile in occlusal view, which likely reflects the potential for bone-crushing hypothesized for tyrannosaurids. *Stegoceras* (OPCr=9) occurs within a broad range of dietary values, including those of herbivorous, omnivorous, and insectivorous reptiles and it is possible that such OPCr values reflect dietary versatility among pachycephalosaurs. Both *Leaellynasaura* (OPCr=10.9) and *Chasmosaurus* (OPCr=13.9) occur well within the range of herbivorous reptiles, the latter closer to the upper extreme of all extant reptiles.
Although preliminary, these results reveal the potential of such an approach to generate a dietary continuum from dinosaur teeth spanning carnivorous to exceedingly more herbivorous ecologies. Recent attempts to reconstruct the evolution of dinosaur body size hypothesized shifts in diet as a mechanism for rapid adaptive dynamics at the origin of dinosaurs along with many tendencies towards certain adaptive body size peaks. The patterns recovered here, therefore, presents the possibly of testing the role of diet in instigating and maintaining the terrestrial dominance of dinosaurs during the Mesozoic.

Grant Information:
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Technical Session XIV (Friday, October 11, 2019, 3:45 PM)

DO FEMALE PENGUINS RESORT TO MEDULLARY BONE AS A SOURCE OF CALCIUM FOR THE EGGSHELL?

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Until recently the phylogenetic distribution of medullary bone (MB), an ephemeral reservoir of calcium used by female birds for eggshell production, was largely unknown. New studies revealed that MB is widespread among Neornithes, yet it is still unclear whether this specialization is ubiquitous to all extant birds as past observations suggested that some species might resort to an alternative source for mobilizing calcium.
MB has not yet been unambiguously reported in Spheniscidae, which are of particular interest to assess this question. Indeed, the dense bone microstructure of most penguins, which is an adaptation to their flightless, diving lifestyle, does not leave many voids in the medulla for the endosteal deposition of MB. Moreover, the clutch size of all penguins is small (1-2 eggs) and species laying two eggs have relatively long laying intervals. Their momentary calcium requirement to form eggshell is thus probably lower than in most other birds. Finally, adult penguins often exhibit cortices formed of a dense Haversian system, indicative of intense bone remodeling and mineral homeostasis. From these observations, we hypothesized that female penguins could resort in part or exclusively to the calcium contained in their thick bone cortices, without having to form large amounts of MB during egg-laying (H1). Using nano computed-tomography (CT) and histochemical staining, we investigate the long bone microstructure of females of six penguin species that died during the egg-laying cycle, as well as conspecific males as controls, in order to i) test our H1 hypothesis, ii) assess whether different species resort to different sources of calcium to form eggshell (MB *vs* cortical bone), and iii) advance our overall understanding of MB use and phylogenetic distribution in Neornithes.
Our preliminary results reveal that some species likely metabolize cortical bone tissue to form eggshell, thereby supporting H1. Indeed, a female *Pygoscelis adaliae* that died with an unshelled egg in its oviduct shows extensive resorption cavities throughout the hindlimb cortices, yet no signs of MB deposition. However, nano-CT data and histochemical analyses suggest that some species, such as *Spheniscus magellanicus* and *Spheniscus humboldti*, deposit MB in the marrow cavity of their femur and tibiotarsus. Further analyses will be aimed at understanding the differences observed.

Grant Information:
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Technical Session VI (Thursday, October 10, 2019, 11:45 AM)

ECOLOGICAL FUNCTION AND MACROEVOLUTIONARY PATTERNS IN PROBOSCIDEANS

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With only three living species, today's proboscideans represent but a tiny fraction of their Cenozoic diversity. During their 60 myr of evolution, proboscideans dispersed over Africa, Eurasia and America, they evolved into remarkable diversity of body sizes and dental adaptations, and have been common constituents of Cenozoic mammalian communities. Which factors drove the rise and fall of this iconic lineage? Despite their cosmopolitanism and relevant ecologic role (most of the largest Cenozoic terrestrial mammals were proboscideans), we lack comprehensive quantitative approaches that assess the large-scale processes that shaped their diversity trends: speciation, extinction and the potential role of ecological adaptation in species selection. We present preliminary results based on an up-to-date paleobiological database of proboscideans that includes 2300 occurrences for 196 species, and 12 ecomorphological traits. The early proboscideans fossil record (57 to 40 Ma) is scarce, and yet we recover the signal of a sustained high turnover during this interval (high speciation and extinction). From 40 to 2.5 Ma the clade shows a steady increase in diversity rendered by an overall-constant, moderate net diversification (0.1 species Myr^{-1}). In the earliest Miocene we

recover a sudden increase in ecological disparity, which has plateaued out since then. Even though diversity and ecomorphs increase through the Neogene, these new ecomorphs do not represent large innovations, being added to already-opened regions of the ecological space. The diversity trend peaks in the early Pleistocene, when we estimate a global species richness of around 30 species. Speciation through the Neogene was mainly clustered in the ecological space, whereas extinction has shifted in its ecological scope, being generally clustered within ecological niches until Pleistocene times. Since 15 to 6 Ma, the increase in functional diversity, which may have fueled the steady net diversification rates, was maintained at the expense of increasing functional vulnerability (higher frequency of unique ecomorphs). The Pleistocene, specially the last 1.5 myr, brought about a very severe extinction pulse that hit a wide array of ecological niches, wiping off two thirds of the species by the end of this period and a significant part of the functional disparity too.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

ECOLOGICAL NICHES AMONG PTEROSAURS FROM THE SOLNHOFEN ARCHIPELAGO

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The Solnhofen Limestones of southern Germany are one of the most important deposits for studying pterosaurs, and the most relevant Jurassic one in terms of diversity, disparity, and abundance. Recent taxonomic reviews suggest that up to twelve genera of pterosaurs might have been present there. Even though many have been recovered from different chronostratigraphic units, the high taxonomic diversity and morphological disparity still suggest specializations that reflect distinct ecological roles. An endocast analysis of *Pterodactylus antiquus*, together with a literature review of the anatomy and ecology of these taxa, suggest interesting niche partitions. *Pterodactylus*, *Scaphognathus*, and *Rhamphorhynchus* were generalist taxa that lived on coastal areas and fed on fishes and small invertebrates. Their niche, however, did not overlap completely: our analysis corroborates a previous study that *Pterodactylus* had photopic vision, in contrast to the scotopic type of *Rhamphorhynchus. Scaphognathus* was also photopic, but the different dentition indicates it was not preying on the same items as *Pterodactylus*. Other taxa have been regarded as more specialists. *Germanodactylus* has been proposed as a durophage, based mostly on the lack of teeth on the tips of the rostrum and mandible, and therefore also likely preyed on different items than *Pterodactylus*. *Anurognathus*, *Ctenochasma*, *Gnathosaurus*, and *Cycnorhamphus* represent highly specialized taxa. *Anurognathus* was probably an aerial insectivore, with moderately curved unguals that are consistent with a scansorial habit, thus suggesting it inhabited forested areas. *Ctenochasma* and *Gnathosaurus* were filter feeders and their different sizes might have prevented, at least to some extent, niche overlap. The diet of *Cycnorhamphus* is more disputed: it has been proposed as a durophage, a jellyfish specialist, or a generalist feeding on fishes and insects. In any case, its uniquely curved mandible with teeth only on the distal tip implies a different feeding niche from Solnhofen generalist pterosaurs. Lastly, the endocast of *Diopecephalus kochi*, a taxon that has been proposed as synonymous with *Pterodactylus*, was analyzed but poor preservation prevented adequate assumptions on niche specializations. Our preliminary analyses suggest that, although the Solnhofen archipelago was a rich pterosaur site, these taxa were not in direct competition, separated either by functional anatomy or time. More data on paleoneurology is still needed to better understand niche occupation by *Pterodactylus*.

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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

BIRDS OF A FEATHER: CALAMUS CORROBORATES IDENTITY OF *ARCHAEOPTERYX* WING COVERT

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Previously, we reinterpreted the iconic fossil feather (MB.Av.100) as an upper major primary covert, based on the relatively long calamus originally present. A recent study has confirmed the existence and morphology of this calamus, implicitly corroborating our interpretation of the Jurassic "Urfeder." Nonetheless, that study challenged the feather's identity, based on a lack of an S-shaped centerline purportedly observed for the first time in upper major primary coverts of some modern birds. However, there are errors in the results presented, and the interpretations conflate the feather's anatomical and taxonomic identities. Here we present further evidence that the feather is a primary covert, based on seven morphological characteristics. Critically, this hypothesis is independently supported by evidence of similar primary coverts in multiple fossils of *Archaeopteryx*, particularly the 11th, Berlin, and London specimens. Based on an updated statistical analysis of melanosome morphology, the original colour of the isolated feather was matte black, with 90% probability. Furthermore, this feather may have moulted from a left wing similar in size to that of the 11th specimen. Given the isolated nature of the fossil feather, we will never know the anatomical and taxonomic provenance with 100% certainty. However, based on the positive evidence herein, the most empirical and parsimonious conclusion is that the feather represents a primary covert from the ancient wing of *Archaeopteryx*.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW CENTROSAURINE CERATOPSIANS FROM THE CAMPANIAN WAHWEAP FORMATION OF UTAH

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Two centrosaurine ceratopsid dinosaurs extend the range of centrosaurs from bottom to the top of the Campanian Wahweap Formation of southern Utah's Grand Staircase-Escalante National Monument. Previously named centrosaurine ceratopsians from the Wahweap Formation include *Diabloceratops eatoni* from the middle member and *Machairoceratops cronusi* from the upper member. UMNH VP 20600 was recovered from the lower member of the Wahweap Formation below a bentonite horizon dated to 80.6 Ma (although new U/Pb dating suggests that this bentonite may be considerably older) and represents the oldest ceratopsid from Utah. It is represented by vertebrae and portions of a unique parietosquamosal frill characterized by a broad M-shaped parietal with two laterally curved epiparietals (ep1) that lie in the plane of the frill on either side of a medium embayment. The flat, blade-like epiparietals differ from the rounded shape of the ep1 in both *Machairoceratops* and *Diabloceratops*. There is no evidence of any other epiparietals on the parietal, a condition it shares only with *Machairoceratops*. UMNH VP 9549 was recovered from the very top of the upper member on a deflation surface below the capping sandstone of the Wahweap Formation, which is not older than ~77 Ma based on U/Pb dating of detrital zircons in this unit. It consists of some postcranial material and includes the margins of a round parietal with distinct scalloped nodes with attachment scars for epiparietals ep0 through ep6. The scallops are imbricated and all are oriented in the plane of the frill. There is a dorsal groove paralleling the lateral margin of the frill that disappears posteriorly and a corresponding ventral groove on the distmedial portion of the frill that is unique amongst Ceratopsia. These two distinct centrosaurs extend the range of centrosaurines within the Wahweap Formation and combined with *Nasutoceratops* and a second Kaiparowits Formation centrosaur illustrate a unique assemblage of 6 distinct centrosaurs broadly between 82 Ma and 75 Ma in southern Utah.

Technical Session XVII (Saturday, October 12, 2019, 9:15 AM)

SIZE AND MASS DON'T COVARY WITH MATURITY AMONG ADULT SPECIMENS OF *TYRANNOSAURUS REX*

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A recent report of a large and massive adult *Tyrannosaurus rex* (RSM 2523.8) draws attention to the use of size and mass as proxies for maturity of nonavian dinosaurs in growth curves, growth series, and statistical morphometric analyses of growth. However, size is highly variable and does not strictly covary with maturity among extant archosaurs, such as crocodylians. The hypotheses that size and mass are accurate proxies for maturity in *T. rex* was tested through a Spearman rank correlation comparison of size and mass with the ranks of growth stages obtained from a cladistic analysis of 1,602 craniomandibular and postcranial characters and 20 specimens that cover the ontogenetic spectrum from juvenile (e.g., LACM 28471) to adult (e.g., FMNH PR2081).
The analysis was run in PAUP* v. 4.0a and a branch-and-bound analysis recovered a single most parsimonious tree (i.e., an ontogram) of 2,537 steps,

a CI of 0.69, an HI of 0.31, an RI of 0.75, and an RCI of 0.53. The topology is pectinate and linear, with two side branches that include multiple specimens, which represent oversampled growth stages. The ontogram is composed of 16 growth stages, and all but the first are supported by unambiguously optimized synontomorphies. An *a posteriori* analysis that included an artificial adult, which was coded based on the optimizations from the initial analysis, identified FMNH PR2081 as the most mature specimen in the sample. In contrast, the massive RSM 2523.8 was recovered as the least mature adult. The sole unambiguous female specimen (MOR 1125), based on the presence of femoral medullary bone, was recovered as the least mature young adult. Therefore, there is no skeletodental evidence for sexual dimorphism in the data set. Comparison of the ontogram with a previously published growth curve for *T. rex* permits the diagnosis of five discrete higher-level growth categories, namely juvenile, subadult, young adult, adult, and senescent adult.

Scatterplots show that size and mass are congruent with maturity until adulthood, and thereafter no pattern is seen. Statistically significant r_S coefficients were obtained between size and the entire growth series, which ranged from 0.95 to 0.99, and those for mass ranged from 0.762 to 0.833. However, when the tests were done for only the adult segment of the growth series significant r_S coefficients were almost always not seen (e.g., size p = 0.8, mass, p = 0.5), indicating a lack of correlation. Ergo, the evidence shows that size and mass are useful estimates of maturity in the juvenile and subadult growth categories, but not in later growth stages.

Technical Session XVII (Saturday, October 12, 2019, 9:00 AM)

NEW INSIGHTS INTO *ALLOSAURUS FRAGILIS* MARSH, 1877 (DINOSAURIA, THEROPODA) FROM THE TOPOTYPE SPECIMEN, USNM 4734

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USNM 4734 was collected from the Marsh-Felch Quarry in the Morrison Formation near Garden Park, Colorado in 1883–1884 by M. P. Felch, working for Yale University's O. C. Marsh. Eventually transferred to the Smithsonian Institution, the specimen was later described in detail by Charles Gilmore (1920) along with other theropod material from that quarry. As one of a small number of nearly complete individuals of *Allosaurus fragilis*, USNM 4734 has served as a benchmark for this important Late Jurassic theropod taxon for almost a century. But Gilmore's study, while thorough, was made when very few other theropods were available for comparison, and some important anatomical features (such as the furcula) were not described in detail. Furthermore, the skull has been on exhibit since 1916, and the remainder of the specimen since 1981, making further study difficult.

The recent renovation of the Smithsonian's Fossil Halls has allowed us to study USNM 4734 in detail, dismantled and completely free of armature, prior to its reinstallation. Digital mirror-imaging of missing elements was essential in resolving some issues of articulation. A full re-description is underway, but several key aspects are already apparent.

First, we can settle the longstanding debate about the skull of USNM 4734 and the putative existence of a "short-snouted allosaur" in the Morrison. Gilmore had few complete *Allosaurus* skulls for comparison, and the damage and deformation suffered by USNM 4734 resulted in a telescoping of the facial region. This gave the erroneous impression of a blunt rostrum; disassembly of the skull revealed that its proportions conform well to those of other *Allosaurus* individuals. Later workers have suggested that the right premaxilla was too small and belonged to a different individual. However, it articulates properly with the (mirror-imaged) right maxilla and clearly belongs to this specimen.

The rear of the skull agrees well with the morphology exhibited by other specimens assigned to *A. fragilis* (e.g., those from the Cleveland-Lloyd Quarry), rather than those identified as *A. jimmadseni*. The furcula is consistent with those of other *Allosaurus* specimens, with a broad interclavicular angle and a very small ventral tuber. Discrete, circular pneumatic fossae appear to be present along the neural spine bases of the posterior sacrals, as well as within the anterior end of the brevis fossa. These and other newly observed anatomical details will be crucial to deciphering the relationships between the three named species of *Allosaurus*.

Grant Information:
Smithsonian Institution MacMillan Fund

Technical Session XVII (Saturday, October 12, 2019, 11:30 AM)

A COPROLITE-PRESERVED FEATHER ASSEMBLAGE FROM THE UPPER CRETACEOUS HELL CREEK FORMATION

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The rarity of three-dimensional (3D) fossil feather preservation the Mesozoic, particularly in the Late Cretaceous, has historically hindered direct fossil comparison with many aspects of extant bird feathers. We report a feather assemblage displaying the earliest record of modern avian feather structures in a phosphatic coprolite fragment from the Upper Cretaceous Hell Creek Formation, northeastern Montana, U.S.A. Observations of the coprolite surface with optical and scanning electron microscopy (SEM) reveal the preservation of multiple partial avian feathers and bones with likely avian affinity. Despite digestive taphonomic effects including mechanical breakage and selective biodegradation, preservation of 3D macro to nanoscale feather structures can be observed. These features include a central shaft that transitions from a proximally circular and hollow calamus to a square/rectangular pith-filled rachis, barbs with pith-filled rami, and fibers within the barbules, rami, and rachis cortex; features so far only recorded from modern flying birds. SEM analysis revealed elongate, striated fibers (~5–8 microns in diameter) that are aligned in various orientations along the rachis and barb cortices. X-ray fluorescence analysis of coprolite matrix and feather structures suggest a combination of selective biodegradation and multiphase phosphate replacement. This preservation pathway results in clear density contrasts between feather morphologies and surrounding coprolite matrix, allowing for high-fidelity 3D reconstructions of feather inclusions from x-ray computed microtomographic (micro-CT) scans. 3D imaging reveals approximately 20 partial feather rachis inclusions and a relatively complete contour feather with matching morphologies to the surficially exposed feather. The mainly longitudinally aligned feather and bone inclusions, partial digestion of bones, and coprolite diameter (>7 cm) suggests a large carnivore was the producer, likely a large crocodilian or tyrannosaur. The integration of a range of analytical and imaging techniques applied to a traditionally under-sampled fossil resource allowed for an exceptional view into the evolution of the complex, hierarchal, fiber-reinforced composite construction of the modern bird feather.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

AN ASSOCIATED ORNITHOPOD DINOSAUR HIND LIMB FROM THE UPPERMOST CRETACEOUS (MAASTRICHTIAN) LOPEZ DE BERTODANO FORMATION OF THE JAMES ROSS BASIN, WEST ANTARCTICA

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In 2005, one of us (JAC) collected fragmentary but closely associated distal hind limb elements (proximal left fibula and right proximal metatarsals II and IV) of a non-avian dinosaur were collected from the Maastrichtian Sandwich Bluff Mbr of the López de Bertodano Fm on Vega Island, in the James Ross Basin (JRB) of the Antarctic Peninsula. The specimen was collected from the base of the 'Reptile Horizon', which has also yielded other remains (ankylosaur osteoderm, hadrosaurid tooth and avian bones), and is the startigraphically youngest associated dinosaur fossil yet recovered from Antarctica. The new hind limb pertains to a medium-sized, non-hadrosauriform ornithopod that is larger than the two described elasmarian ornithopods from the Snow Hill Island Fm: *Morrosaurus* from the Maastrichtian Cape Lamb Mbr and *Trinisaura* from the Campanian Gamma Mbr.

The new specimen displays a suite of unusual features not seen in other Cretaceous ornithopods from Antarctica or South America: (1) metatarsals II and IV with proximal articular surfaces that are large, comma-shaped, and mirror images of one another; (2) a planar proximal articular surface that extends across metatarsals II–IV; (3) metatarsal IV with significant lateral constriction from the broad proximal end to the diaphysis; and (4) flat proximal articular surfaces between metatarsals II/III and III/IV (in many other ornithopods, a process on metatarsal III articulates with a notch on metatarsal IV).

Morphometric analyses of metatarsal IV dimensions place the new specimen within Dryosauridae, the metatarsal IV proportions are statistically distinct from those of both elasmarians and other iguanodontians. Phylogenetic

analyses based on pedal characters also place the new Antarctic fossil within Dryosauridae (as the sister taxon of *Eousdryosaurus*), but there is virtually no bootstrap support for any of the recovered topologies.
With *Morrosaurus*, *Trinisaura*, and the hadrosaurid, the new hind limb adds a probable fourth ornithopod taxon to the latest Cretaceous non-avian dinosaur fauna of Antarctica. Coupled with the rarity of sauropods—so far known only from a caudal centrum from the Gamma Member—the apparent prevalence of ornithopods in the JRB is consistent with the predominance of these ornithischians that is seen in other high-latitude Gondwanan Cretaceous ecosystems (e.g., those of southern Australia).

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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

10 YEARS OF DISCOVERY: REVISITING THE QUALITY OF THE SAUROPODOMORPH FOSSIL RECORD

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Sauropodomorphs were a successful clade of predominantly quadrupedal herbivorous dinosaurs that dominated many Mesozoic terrestrial ecosystems. Several potential peaks and troughs in their diversity have previously been identified. However, spatiotemporal changes in fossil specimen completeness can bias our understanding of their evolutionary history. The quality of the sauropodomorph fossil record was previously assessed a decade ago, but the number of valid species has since increased by a third, and a third of the species from that study have undergone revision. Here, we assess how 10 years of additional research has changed our outlook on the sauropodomorph fossil record. We quantified the completeness of all 307 sauropodomorph species currently considered valid, using the skeletal completeness metric (SCM), which calculates the proportion of a complete skeleton preserved for each taxon. Mean average SCM scores were calculated for each stage of the Mesozoic to produce a time series. This was statistically compared to species richness and sampling proxies through geological time, with further analyses evaluating variation between different geographical localities, depositional environments, taxonomic and body size subgroups, and against other tetrapod groups. Similarly, to the previous assessment we find non-neosauropods still have significantly more complete record than Neosauropoda, with basal sauropodomorphs having the most complete record and titanosaurs the least. However, we find no significant evidence of a phylogenetic signal for completeness. Completeness also seems to be unrelated to species' body size, even when considering their phylogenetic relationships, and seems relatively uninfluenced by preservation in different depositional environments or continents, plus has a similar spread of latitudinal occurrences in both hemispheres. However, new temporal patterns in mean completeness reveal peaks in the Early and Middle Jurassic, and now a significant drop in the Cretaceous, with lows in the earliest Cretaceous. The record is strongly influenced by taxonomic and stratigraphic age revisions as there is a significant difference with results from the previous assessment, but no statistical difference with the pre-2010 and pre-2000 time series created from our revised data. Completeness still significantly correlates with species richness through time, but also correlates with the theropod dinosaur SCM, possibly indicating that both records are primarily driven by the same sampling biases.

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Technical Session X (Friday, October 11, 2019, 11:00 AM)

INVESTIGATION OF THE EVOLUTIONARY SUCCESS AND EXTINCTION OF PYCNODONT FISHES USING QUANTITATIVE METHODS

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Pycnodont fishes (Pycnodontiformes) were an ecologically successful clade of extinct ray finned fishes with a fossil record spanning 175 million years from the Late Triassic to middle Eocene. These fishes typically lived in shallow marine structured environments such as reefs and had a bodyplan similar to that seen in extant coral reef fishes with a deep laterally compressed body and large median fins for maneuvering around tight spaces. Their paleobiogeography suggests they originated in the Tethys Sea initially and then spread worldwide. Surviving through two mass extinction events at the Late Triassic/Early Jurassic and the K/Pg boundaries indicates that pycnodonts had a range of adaptions that contributed to particularly successful evolutionary strategy. Pycnodonts were predominantly durophages that fed on more or less tough, armoured prey such as molluscs and echinoderms. Throughout their history, pycnodonts shared their environment with fishes that fed on similar prey and/or had similar body morphologies such as Ginglymodi and Dapediiformes during the Mesozoic and acanthomorph teleosts in the Eocene. The role of possible competitive interactions between these clades is currently unknown and could be a strong factor in the evolutionary success of pycnodonts. Using geometric morphometric methods, we assessed shape changes among species in order to investigate the amount of overlap between the morphospaces of the three clades and thus, the potential for competition among them. Additionally, we investigated the changes in body shape through geological time by sorting taxa into five time bins: Late Triassic, Jurassic, Early Cretaceous, Late Cretaceous, and Eocene. Finally, we also analyzed the potential reasons for the extinction of the pycnodonts. This involves assessing the completeness of the fossil record to see how reliable it is in capturing the evolutionary history of the clades studied and whether biotic (competition) or abiotic factors (sea level and rocky outcrop area) are responsible for the decline in diversity and eventual extinction of the pycnodonts. Morphospace results reveal that pycnodonts had high morphological disparity during the Mesozoic.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

ACCOUNTING FOR PHYLOGENETIC AND TEMPORAL CONFLICT AMONG ANATOMICAL PARTITIONS IDENTIFIES AN END-TRIASSIC ORIGIN OF CROWN MAMMALS

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The evolutionary history of Mesozoic mammaliaformes and timing of their radiation is well-studied, yet still poorly resolved. Even though functional and developmental covariation has long been identified as an important source of phylogenetic error, lumping incongruent morphological characters altogether is current practice when reconstructing phylogenetic relationships among extinct taxa. This has strong implications for the placement of taxa, such as australosphenidans, haramiyids and multituberculates, hence for the taxonomic definition and temporal origin of the mammalian crown group. Based on prior hypotheses and homoplasy analysis, we identified and excluded character complexes anticipated to introduce phylogenetic error (correlated homoplastic characters), and improved confidence in tree topology. Integrating morphological and molecular data in a tip- and node-dating analysis improved precision and confirmed an origin of crown mammals close to the Triassic-Jurassic boundary, followed by a rapid diversification of stem lineages of most major Mesozoic mammal clades. In addition, ancestral state reconstructions suggest parallel evolution of key mammalian innovations, often associated with the initial acquisition of endothermy. Therefore, our results strongly emphasize the Triassic-Jurassic boundary as similarly important to the Cretaceous-Paleogene event for the mammalian diversification.

Grant Information:
Australian Research Council Discovery Projects

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW REMINGTONOCETID MATERIAL FROM MIDDLE EOCENE OF KUTCH, INDIA

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The pericratonic Kutch Basin lies in the Western part of India with a continuous succession of Cenozoic marine sediments which have yielded and are still yielding many important vertebrate fossils, among which whales are most common. Recently a nearly complete skull of a whale has been recovered from the Middle Eocene Harudi Formation. The Skull belongs to

the genus *Remingtonocetus* having the length of approximately 80 cm. Like other Remingtonocetids, the skull is long and narrow with the external nares located on the front. It has narrow frontal shields, small orbits, a convex palate and dental formula 3.1.4.3. The nasal bones are elongate with reduced frontals. Position of the external nares, shape of the skull, elongation of the rostrum and dentition indicates its similarity with *R. harudiensis*. However, there are some characters observed to be different from *R. harudiensis* and *R. sloani*. The fossil specimen consists of teeth with well-preserved enamel and serrations on the edges of the teeth. The dental formula follows the pattern I1-2-3, C1, P1-2-3-4, M1-2-3. Diastema between the incisors is 10 cm approximately but the diastema between the last Incisor and Canine is 22.85 mm which is larger than described previously. The diastema between P1 and P2 is 39.02 mm which is again more than *R. harudiensis*. The diastema between P3 and P4 is very low – 2.96 mm and the teeth from P4 to M3 are juxtaposed with each other. The dental plate of the new specimen is 43.5 cm, which is larger than the previously described specimens of *R.harudiensis*. On closer observations the teeth showed sufficient wear and tear, particularly in the canine. The external nares, as stated in previous literatures, are not above the canine. In all the individuals, it is actually positioned between the C 1 and P 4. Hence, this new specimen shows variations within a single species noted from Harudi. Over and above, the rich remingtonocetid fauna of Harudi show high disparity and low diversity. The new skull was collected from brown mudstones that sometimes has a greenish hue due to the presence of glauconite. The horizon, from where the skull is collected occurs just above a coquina bed and consist of foraminifera (*Nummulites)* and echinoids. Glauconitic shale, foraminiferal facies and the whales suggest open marine condition. On the other hand, the coquina beds below, indicates near shore settings. They are restricted in the warmer climate of Middle Eocene time and thrived in near shore to open marine conditions.

Grant Information:
Indian Statistical Institute

Technical Session XII (Friday, October 11, 2019, 10:30 AM)

INTRASKELETAL VARIATION IN *MASSOSPONDYLUS CARINATUS*: IMPLICATIONS FOR ONTOGENY

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Massospondylus carinatus is an iconic basal sauropodomorph dinosaur from southern Africa that lived during the Early Jurassic following the end-Triassic mass extinction (ETE). It has previously been hypothesised that *M. carinatus* underwent a postural shift from quadrupedal to bipedal during ontogeny. Understanding ontogenetic changes in locomotory trajectories is important for comprehending the macroevolutionary patterns of posture in Dinosauria. We compare the forelimb and hindlimb osteohistology of an ontogenetic series comprising 15 *M. carinatus* specimens. We hypothesise that a postural shift would be recorded in the bone tissue, and discernable through inter-elemental differences in tissue organisation or growth rates between the fore- and hind-limb. Our findings confirm the results of previous studies on *M. carinatus* in finding that cyclical fibrolamellar bone is the predominant bone tissue pattern during early and mid-ontogeny. We find a transition to slower-forming parallel-fibered bone during late ontogeny. Using lines of arrested growth (LAGs) circumferences as a proxy of body mass in a complete series of femora, we refute a sigmoidal growth model in *M. carinatus*, instead supporting a constant-rate growth model. The bone tissue is interrupted by irregularly spaced LAGs, indicating temporary cessations in growth. Several elements contain multiple LAGs at various ontogenetic stages, with little consistency between element or stage. These features suggest the presence of developmental plasticity, which may have been a response to the unstable environmental conditions of the Early Jurassic. Although inter-elemental variability is present, with propodial elements growing faster than epipodials, there are no notable differences in growth pattern or rate between the humerus and femur. This suggests that either there was no shift in posture or that osteohistology does not record changes in locomotory trajectories.

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Technical Session XIII (Friday, October 11, 2019, 3:30 PM)

A QUANTITATIVE ANALYSIS OF SKULL GROWTH AND EVOLUTION IN SEA TURTLES (TESTUDINATA: CHELONIOIDEA)

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Ontogeny can have major influences on adult skull shape, and interpreting fossils without ontogenetic data has consistently led to difficulties. Increasing amounts of data show that changes to the ontogenetic trajectory is a significant mechanism for evolutionary change. However there is a lack of studies into these ontogenetic changes for many groups. Sea turtles (Chelonioidea) are one such group. The seven species of living sea turtle belong to two families, the hard shelled Cheloniidae (6 species), and the Dermochelyidae (1 species). Sea turtles undergo significant changes in body size during their lifetime (up to 3 orders of magnitude in mass) that are associated with significant changes in skull proportions (allometry). Differences in ontogenetic trajectory and adult size are evident between different species but these have yet to be examined systematically. Here we address this knowledge gap with a sample of 48 skulls representing all seven living species. We use X-ray micro computed tomography and 3D geometric morphometrics using 46 landmarks. We found that at least three lineages retain juvenile skull proportions as adults (paedomorphy) whereas one expresses hyperadult features (peramorphy). Shifts in ontogenetic trajectory appear to be more heavily influenced by diet rather than common ancestry. These data suggested that heterochrony played a significant role in the evolution of the modern sea turtle skull. The evolutionary changes that resulted appear to be tightly linked to the diversity of feeding specialisations. To explore this possibility further we added 20 skulls of fossil sea turtles to our analysis. These represented: six genera and include members of the extinct family Protostegidae. As it is difficult to determine the biological age of the specimens, size was used as a proxy for age, as there is a very strong relationship between size and skull shape among modern taxa. We found there were significant differences between the ontogenetic trajectories of modern Cheloniids from that of stem cheloniids. Fossil taxa appear to exhibit less allometric change in shape than would be expected given their final adult size. Nevertheless, the smallest specimens appear to be more peramorphic than would be expected whereas the largest specimens appear to be more paedomorphic. No fossil taxa is as paedomorphic as *Dermochelys coriacea.* These results suggest that the ancestral condition may be intermediate between the two modern families and that there was a narrower breadth of dietary specialisation and life history among stem turtles.

Technical Session V (Wednesday, October 9, 2019, 2:00 PM)

TOTAL-EVIDENCE FRAMEWORK REVEALS COMPLEX MORPHOLOGICAL EVOLUTION AND RAPID EVOLUTION IN NIGHTBIRDS (STRISORES)

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Strisores is a clade of often insectivorous neoavian birds that includes specialized fliers such as swifts and hummingbirds, as well as a large diversity of nocturnal species such as nightjars. Despite the use of large-scale molecular datasets, the precise phylogenetic relationships among major strisorean groups remain controversial. Given the lack of consensus among recent phylogenomic datasets, we incorporated anatomical data from living and fossil strisoreans into a Bayesian total-evidence framework. This combined analysis of molecular and morphological data resulted in a phylogenetic topology for Strisores that is congruent with the findings of a recent molecular phylogenomic study of modern birds. However, we found that integration of molecular and morphological data did not yield increased statistical confidence in our topology, highlighting apparent homoplasy in both sequence and anatomical data. We suggest that disparate strisorean lineages have experienced convergent evolution across the skeleton, and that many of the distinctive specializations of strisorean subclades were acquired early in their evolutionary history. Furthermore, the results of applying tip-dating methods to this dataset indicate very rapid diversification of major strisorean lineages shortly following the origin of this clade. These complex patterns have resulted in a challenging phylogenetic problem, which obfuscates the robust inference of ancestral character states.

Grant Information:
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Technical Session IV (Wednesday, October 9, 2019, 1:45 PM)

DEVELOPMENT RELATIONSHIPS BETWEEN TEETH AND JAWBONES IN STEM GNATHOSTOMES AND STEM OSTEICHTHYANS REVEALED BY 3D HISTOLOGY: INSIGHTS INTO THE EVOLUTION OF TOOTH REPLACEMENT AND TOOTH ORGANIZATION

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Osteichthyan dentitions are characterized by cyclic tooth replacement and linear tooth rows. The acquisition of these characters can be explained by an intimate relationship between the growth of jawbone and the initiation of teeth, supported by substantial evidence from synchrotron microtomography that reveals the 3D pattern of successor teeth, vascular canals, growth arrested and resorption surfaces in various Silurian-Devonian gnathostomes. The growing bone provides space for new teeth to attach and the succession of larger teeth maintains the number of teeth as the animal grows. In non-shedding dentitions, whether the spiral addition of acanthodian tooth whorls, the anterior addition of ischnacanthid dentigerous jawbones, or the radial addition of arthrodire gnathal plates, the sequential addition of teeth is synchronized with the appositional growth of bone. The most primitive teeth of the most basal stem gnathostome *Radotina* and *Kosoraspis* already display the lingual addition of tooth rows shared by the gnathostome crown group. When in situ resorption evolved in osteichthyans, the first-generation teeth of the stem osteichthyan *Lophosteus* are shed semi-basally forming deeply overlapping tooth rows. As the bone growth slows down at later developmental stages, the succeeding teeth overlap the preceding ones entirely, causing the preceding teeth to be shed basally and replaced in situ. Therefore, tooth replacement may have emerged via a tooth initiation rate higher than the bone growth rate. When a lingual shelf is formed on the marginal jawbones of crown osteichthyans, the lingual growth of bone is restricted, and new tooth rows cannot be added lingually to the previous rows, only apically. The replacement of the marginal linear tooth row of the basal actinopterygian *Moythomasia* is actually a vertical piling of alternate tooth rows by semi-basal resorption. Thus a single linear tooth row may have transformed from a lingual-labial compressed version of transverse tooth files.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

SHED NEW LIGHT ON THE CONFIGURATION OF THE PTERYGOID AND THE ECTOPTERYGOID IN DERIVED PTEROSAURS THROUGH CT SCANNING

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Recently, all the studies of pterosaur palatal complex pointed out its significance in the pterosaur phylogenetic research. Also, the reconstruction of palatal complex is crucial for a further understanding of pterosaur feeding habits. Because of the rare materials and the highly fusion, some details of pterosaur palatal complex remain poorly known, which leads to different interpretations. Here we shed new light on the palatal complex from two well-preserved specimens of the Early Cretaceous pterosaur *Hamipterus tianshanensis*. In the new material, the pterygoid fused with the opposite one along the midline. The lateral pterygoid process shows a unique shape, and the other two processes form the pterygoid fenestrae ventrally. Besides, the lateral process fused to the medial aspect of the jugal during the ontogeny. Moreover, we have reconstructed partial palatal complex of *Hamipterus* through CT scanning. We discovered that the flat ectopterygoid overlays dorsally the pterygoid, and two sides of the ectopterygoid fused to midline was the same place that pterygoids fused. Hence, the ectopterygoid in *Hamipterus* also forms the anterior margin of the pterygoid fenestrae dorsally. This complicated structure of pterygoid and ectopterygoid can only be observed in the dorsal view of palatal complex, and it consists with the situation in some previous studies. The ectopterygoids in *Hongshanopterus*, *Kunpengopterus*, *Caupedactylus*, *Tupuxuara*, and *Anhanguera* overlay dorsally the pterygoids as well. Our study indicates that this complex structure probably exists in *Gnathosaurus*, *Dsungaripterus*, *Tropeognathus*, and *Coloborhynchus* by comparing with *Hamipterus*, *Caupedactylus*, and *Anhanguera*. Thus, we assume that the ectopterygoid extend across the pterygoid dorsally very early, at least in *Kunpengopterus*, and that this situation probably is a synapomorphy in the Monofenastrata.

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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW INSIGHTS ON THE EVOLUTION OF NEOCERATOPSIAN FRILL: ORNAMENTATIONS ON *PROTOCERATOPS*

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Numerous specimens of the neoceratopsian dinosaur *Protoceratops* have been collected from the Gobi Desert. Based on this plethora of specimens, the biology of the dinosaur, such as ontogenetic changes and individual variation, has been repeatedly investigated. This dinosaur has a developed frill composed of a parietal and squamosal, but it is generally thought that the frill margin is smooth and unornamented, unlike ceratopsid dinosaurs. There is a report of a *Protoceratops andrewsi* specimen with an undulated frill margin, but its importance in reconstructing the evolution of neoceratopsian frill ornamentations has been overlooked.
We re-examined over fifty *Protoceratops* specimens and found at least three additional specimens with undulated frill margins. Among these four specimens from Mongolia (two *P. andrewsi* from Bayn Dzak, one *P. andrewsi* from Tugrikin Shire, and one *Protoceratops* sp. from Udyn Sayr), there are five undulations that are inconsistently spaced along each side of the frill margin. In addition, the location of each undulation is not consistent between specimens. The skull sizes of these specimens range from small (total skull length ca. 250 mm and frill width ca. 135 mm) to large (frill width ca. 600 mm) indicating that the degree of undulation is not correlated to skull size. The undulations of the smallest and the largest specimen are imbricated, which is typical for centrosaurine frill margins, but not for chasmosaurines. Unlike ceratopsid dinosaurs, there is no sign of epimarginal attachment on the undulations, although these undulations are typically equated with the eventual ontogenetic development of epimarginals in ceratopsids.
This study highlights the variable nature of frill margin undulations in *Protoceratops*, which are independent of ontogeny, and a pattern that contrasts with ceratopsids. It is still debated whether or not the evolution of frill ornamentations in ceratopsid dinosaurs were driven by sexual selection, but the pattern seen in *Protoceratops* frill margins suggests that sexual selection was not the primary driver. The current parsimonious interpretation for the presence of frill margin undulations in *Protoceratops* and ceratopsids is individual acquisition of the character in each clade. However, this case study implies that further investigations may reveal the presence of frill margin undulations and imbrications in other non-ceratopsid neoceratopsian dinosaurs and that frill margin undulation may have originated earlier in their evolution than previously thought.

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Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 11:30 AM)

THE COMPLEX TAPHONOMIC HISTORY OF ORGANIC TISSUES WITHIN LITHIFIED COPROLITES

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Most fossilized vertebrate soft tissues are found in association with articulated carcasses or have been extracted from skeletal materials. In contrast, labile tissues preserved within coprolites offer complementary perspectives on vertebrate paleobiology through evidence of interactions with other ancient organisms. However, the taphonomic pathway to fossilization of feces is complex, and quality of preservation varies widely among different coprolite specimens. Much of this variation reflects that fecal contents are determined by food selection and digestive physiology. Physical and chemical digestion function as early taphonomic processes before undigested food residues are packaged in feces with gut bacteria and other materials.
The high percentages of bacteria in fecal matter are relevant to fossilization potential because of the capacity of some bacteria to precipitate minerals. Indeed, analyses of the ground masses of several well-preserved phosphatic coprolites reveal abundant mineralized coccoid shapes which are inferred to be fossilized gram negative bacteria. The appreciable phosphorus content in diets of animal matter appears to provide the source of this element for authigenic phosphatization. Moreover, experimental studies have demonstrated that calcium phosphate precipitation by bacteria can occur within days. Feces from herbivores contain little phosphorus, but lithification can occur through permineralization with allocthonous minerals. Regardless of taphonomic pathway, rapid entombment of fecal matter within a mineralized matrix slows processes of degradation. Yet, this protection may not last in dynamic geological settings, because recrystallization and other forms of late stage diagenesis can eventually destroy even refractory inclusions. Nevertheless, coprolites lithified in relatively stable environments can retain a variety of soft tissues preserved through different modes of fossilization. A growing number of studies have identified organic structures originally composed of chitin, keratin, cutin, collagen, and other materials in lithified coprolites. Organic compounds in the form of lipid biomarkers have also been extracted from mineralized coprolites, including glycerol dialkyl glycerol tetraethers (GDGTs). In other cases, detailed casts reveal the morphology of labile tissues replaced by authigenic minerals. These multimodal forms of soft tissue preservation offer insights on ancient feeding habits, nutrient recycling, trophic interactions, and paleoenvironments.

Technical Session V (Wednesday, October 9, 2019, 1:45 PM)

GROWTH STRATEGIES LINKED TO PREVAILING ENVIRONMENTAL CONDITIONS IN AUSTRALIAN GIANT FLIGHTLESS MIHIRUNG BIRDS (AVES: DROMORNITHIDAE)

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The dromornithids were giant flightless birds endemic to Australia. They are known from the late Paleogene to the late Pleistocene and are represented by eight species in four genera. Here we focus on the largest known dromornithid, and among the heaviest birds (about 610 Kg), the late Miocene aged *Dromornis stirtoni*; and the medium sized *Genyornis newtoni* that probably weighed about 250 Kg. *Genyornis* is the youngest member of the dromornithids and became extinct about 40 000 years ago.
Since little is known about the biology of these birds, we undertook a histological investigation of their bones to deduce various aspects of their life history. This study focuses on four tibiotarsi, two tarsometatarsi and a femur of *Genyornis* that were recovered from the northern desert regions of South Australia. In addition, we expanded our previous osteohistology sample by including additional younger and adult specimens of *Dromornis* from the late Miocene Alcoota Local Fauna in the Northern Territory of Australia.
The bone histology of *Dromornis* and *Genyornis* show that these birds experienced a cyclical pattern of growth with alternating rapid and slower rates of osteogenesis. During faster periods of growth they deposited fibrolamellar bone tissue, whilst during periods of slowed growth they formed lamellar bone tissue, which was sometimes associated with lines of arrested growth indicating pauses in osteogenesis and growth. However, we found that these birds differed in the amount of time taken to grow to maturity: *Dromornis* has over 10 growth cycles while *Genyornis* shows a maximum of 3 growth cycles. Interestingly, in *Genyornis* some of the lamellar deposits are wide, indicating that they grew slowly for longer periods of time.
The main aridification of Australia is considered to have occurred from the Late Miocene through to the Pleistocene. We postulate that the growth dynamics of the dromornithids were adapted to the particular environment in which they lived, i.e., *Dromornis* lived before the main aridification and therefore a k-selected lifestyle strategy would have been advantageous. However, as landscape resources became less predictable, then r-selected strategies were favoured by *Genyornis*. The wide bands of lamellar bone in some of the *Genyornis* samples may be coincident with lengthy stressful periods (drought).

Grant Information:
ARC Discovery Project Grant, DP180101913

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

DETERMINING AUSTRALIAN PLIO-PLEISTOCENE CROCODILIAN DIVERSITY USING THREE DIMENSIONAL MORPHOMETRICS OF DENTAL AND OSTEODERM REMAINS

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Modern crocodilians are a diverse group of mostly amphibious, opportunistic hunters that include twenty-three extant species. A number of extinct species have been described from Australia's Plio-Pleistocene; however, most are based on highly fragmentary cranial remains. The aim of this study was to identify crocodilian species and species diversity using a single well collected Pliocene-aged local fauna, the Chinchilla Local Fauna. Relative to the small number of cranial remains available in these deposits, teeth and osteoderms are far more common, being more numerous and readily fossilised. Thus, they make up the largest dataset available. Our focus began with dentition and will turn to osteoderms in the near future. Differences in tooth size and shape were related to tooth location and dietary preferences, and therefore it is likely that determining the diversity of crocodilian taxa from a single local fauna (Chinchilla Local Fauna) may be possible from teeth alone. At a gross level, crocodilian teeth are similar; therefore, a combination of methods were used to help discriminate tooth shape and differentiate tooth position and species morphotype. Using three-dimensional models for analysis, the teeth were compared to each other to determine a similarity index. This provides an objective comparison that can later be integrated with other morphological traits to enhance inference of morphotypes. Our results show at least two distinct morphotypes within the Chinchilla Local Fauna, most likely those previously allocated to *Pallimnarchus pollens* and *Quinkana* sp. However, jaw specimens from the site show a potential for three different crocodilian taxa occurring in the Chinchilla Local Fauna. This is further supported by detailed analysis of fine features not captured during Computed Tomography (CT) Scanning. These features include differences in denticulated surfaces, serrations and the presence or absence of fluting. All of the available ziphodont teeth have evidence of denticulation. The remainder of the teeth are serrated with different proportions showing evidence of fluting, suggesting at least three taxa within the Chinchilla Local Fauna. Application of these results to other Plio-Pleistocene sites across Queensland indicates a similar level of species diversity where isolated dentition is known. Preliminary assessment of osteoderm morphology supports results from dentition.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

TRABECULAR BONE DENSITY IN ZOO AND WILD FELIDS

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Experimental and observational studies show that bone responds to elevated mechanical loading by increasing in mass and density. Paleontologists and mammalogists who carry out *ex vivo* studies of extant mammals may include samples from zoos as well as those caught in the wild and housed in museum collections. However, the effects of confinement (as is the case in zoos) on bone morphology, especially for mammals with diverse home ranges and/or daily travel distances, have not been fully documented. Bone structural differences may exist between wild and zoo animals that could influence interpretations of morphological data. Therefore, this study examines trabecular bone density between wild and zoo felids with varying daily travel distances with the goal of documenting differences in the two groups potentially associated with the degree of travel. We hypothesize that because zoo felids live in confined spaces, they will exhibit low trabecular bone density due to reduced locomotor loading compared to their wild counterparts. To test this hypothesis, we quantify trabecular bone density using peripheral computed tomography (pQCT) and microCT scanning in the femur and humerus of four species: *P. onca* (jaguar, n=7), *P. pardus* (leopard, n=14), *P. concolor* (cougar, n=14) and *A. jubatus* (cheetah, n=17) from zoos in the U.S.A. and those caught in the wild. Results show that zoo specimens of *P. onca*, *P. pardus* and *A. jubatus* display lower trabecular bone density than wild specimens in both hind and forelimb specimens, supporting our hypothesis. However, *P. concolor* does not follow the predicted pattern, showing no significant difference in the two groups. These preliminary results suggest that *P. onca*, *P. pardus* and *A. jubatus*, with large travel daily distances of 11, 6.8 and 4 km/day, respectively, show a decline in density among zoo specimens compared to *P. concolor*, with a daily travel distance of ~3.5 km/day. This differentiation may be due to the greater reduction in mechanical loading following confinement in the three species with larger daily travel distances in the wild, which may thus have more of an effect on

bone density in these species. Even so, dietary influences and sex differences relating to daily travel distance may also play a role. Understanding the effect of reduced loading on bone among zoo and wild specimens has implications for interpreting morphological data from extant species used as models for interpreting the mammalian fossil record.

Grant Information:
Marshall University and Peter Buck Postdoctoral Fellowship.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

AN EXCEPTIONALLY PRESERVED ANTIARCH AND OTHER DISCOVERIES FROM THE EARLY DEVONIAN GUANSHANPO FORMATION, PINGYIPU GROUP, SICHUAN

CHOO, Brian, Flinders University, Adelaide, Australia; ZHAO, Wen-jin, Chinese Academy of Sciences, Beijing, China; CUI, Xindong, Chinese Academy of Sciences, Beijing, China; JIA, Lian-tao, Chinese Academy of Sciences, Beijing, China

The Longmenshan Mountain Region, Sichuan Extensive contains extensive exposures of Devonian marine and marginal-marine sediments along the Pingtonghe stream, between the villages of Guixi and Shawozi. While fossil invertebrates and microvertebrates have been collected from throughout the section, macrovertebrate remains are restricted to the Guanshanpo Formation of the Pingyipu Group, estimated to be latest-Lochkovian to early-Pragian in age. Previous collections from the 1980s have produced fragmentary yunnanolepiform antiarchs, the petalichthyid *Parapetalichthys* and an indeterminate sarcopterygian.
Researchers from the IVPP, Beijing and Flinders University, Adelaide, revisted the Longmenshan exposures in late 2017 and recovered fresh macrovertebrate remains, primarily from a section of the Guanshanpo Formation, slightly higher in the sequence from previous collections. Several kilometres upstream, ongoing roadworks have made accessible previously unsurveyed sections in the vicinity of the Jile Temple.
Among several well-preserved placoderm specimens collected from this new site is a nearly complete articulated yunnanolepoid antiarch preserved flattened in dorsal view. The specimen notable in displaying a well preserved dermal pelvic girdle, the second example of such a structure preserved in a basal antiarch. While a dermal pelvic girdle has previously been described for *Parayunnanolepis* from the Xitun Formation of Yunnan, the Guanshanpo specimen reveals endoskeletal details not visible on the Xitun fossil. The new fossil also allows the status the antiarch taxa *Chuanbeiolepis* and *Yunlongolepis*, both based on highly fragmentary Guanshanpo material, to be evaluated. Ongoing research indicates a diverse gnathostome fauna in the Pingyipu Group which displays a high degree of genus-level endemism.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

A NEW HYPERSPECIALISED CARNIVOROUS DASYUROMORPHIAN MARSUPIAL FROM EARLY MIOCENE DEPOSITS IN THE RIVERSLEIGH WORLD HERITAGE AREA, NORTH-WESTERN QUEENSLAND

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An extinct Early Miocene marsupial carnivore with highly specialised dentition has been discovered in the Riversleigh World Heritage Area, north-western Queensland. This new dasyuromorphian shares features with a group of hammer-toothed marsupials, the malleodectids, previously described and known only from upper dental material recovered from Riversleigh. However, other Oligo-Miocene dasyuromorphian taxa, many of which are poorly understood, share important dental features with the specimen under focus and help to illuminate crucial evolutionary ties among poorly understood extinct Australian marsupials, including those lacking familial assignment within Dasyuromorphia.
Morphological description, taxonomic differentiation and phylogenetic analyses have been applied to determine the evolutionary relationships and probable ecological role of this specialised marsupial. This research provides significant new insights into the evolutionary history, relationships and paleobiology of this unusual marsupial, including the purpose of its enormous and highly anomalous premolar dentition. This specimen represents an entirely new dasyuromorphian marsupial previously unknown to the Australian paleontological literature; an exciting addition of yet another, different group of hyperspecialised carnivorous marsupials to the extraordinary faunal assemblage of the Riversleigh World Heritage Area, north-western Queensland.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

THE DEEP TIME ORIGIN OF AFRICAN ZEBRAS THROUGH THE EURASIAN "*EQUUS STENONINE*" LINEAGE.

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The extant African zebras include *Equus grevyi* (Ethiopia and Kenya), *Equus quagga* (Ethiopia to southern Africa) and *Equus zebra* (Southern Africa), *E. grevyi* being the largest.
In order to understand the evolution of the zebra clade during the Plio-Pleistocene, we have compared the cranial and postcranial features of *E. grevyi* with the Old World fossil *Equus* from North America Asia, Europe and Africa.
We carried out an analysis of cranial and postcranial elements of the following fossil species *Equus simplicidens* from North America*, Equus sivalensis* from the Indian Sub-Continent, *Equus stenonis* and *Equus stehlini* from Italy, two yet to be named species of *Equus* from the paleoanthropological site of Dmanisi (Georgia), and *Equus koobiforensis* and *Equus oldowayensis* from Kenya.
Herein, we provide new hypotheses for the deep-time origin of African zebras. Remarkable similarities are seen in skulls, mandibles, upper and lower dentitions of the species cited above. Statistical analysis (Log10 ratio diagrams on the third metacarpal and third metatarsal) show similar proportions between *E. simplicidens*, a small species of *Equus* from Dmanisi and *E. grevyi*, suggesting a genuine deep-time origin of *E. grevyi* from a population derived from *E. simplicidens* that dispersed to Eurasia at the base of the Pleistocene, and evolved from a species of Eurasian stenonine horse.
This study shows that *E. simplicidens* is a plausible ancestor for Old World stenonine horses, and that the extant living zebras are descendants of this lineage. These data allow us to conclude that the basic bauplan of *E. grevyi* was present in the Old World stenonine horses, confirming the close correlation between the extant African living zebras and the Plio-Pleistocene horses.

Technical Session X (Friday, October 11, 2019, 10:45 AM)

ABUNDANT LIZARDFISHES (AULOPIFORMES: BATHYSAURIDAE) IN AN EARLIEST PALEOGENE HORIZON IN ANTARCTICA CASTS LIGHT ON THE ORIGIN OF THE ASSEMBLAGE

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The global taxonomic richness of Cretaceous–Paleogene (K–Pg) fishes must have been profound, though only a limited amount of that original biodiversity has been described to date. Further evaluation of K–Pg fish faunas in the context of improved stratigraphic and geochronological data is critical to testing hypotheses regarding the pivotal role that the K–Pg extinction event must have played in shaping extant teleost diversity and niche occupation. During 2016, an Antarctic Peninsula Paleontology Project expedition to K–Pg deposits of the James Ross Basin (JRB) of the Antarctic Peninsula recovered dozens of partial to nearly complete fish skeletons from a stratum immediately overlying the K–Pg boundary on Seymour Island. Assigned to the uppermost López de Bertodano Formation, fishes in this horizon have previously been proposed to comprise a mass death assemblage that was generated as a direct consequence of the K–Pg extinction event. Exceptionally-preserved taphocoenoses such as this 'Seymour Fish Horizon' (SFH) are often generated under unusual environmental or climatic circumstances; moreover, models predict that such perturbations would have been amplified in high-latitude Antarctic K–Pg paleoenvironments. Given the age of the SFH, at least two potentially viable alternatives exist regarding its origin: the assemblage is the result of (1) a catastrophic mass mortality event, possibly related to more global events that occurred at the K–Pg boundary (e.g., the Chicxulub bolide impact); or (2) a more attritional accumulation of fish carcasses amassed through reworking and/or time-averaging of

individuals that died or were killed asynchronously. Fossils in the SFH have historically been described only as "fish debris," without taxonomic specificity. Here we report the first articulated fossils of benthic lizardfishes, similar to the extant *Bathysaurus*, to be recovered from the SFH and the JRB as a whole. Lizardfishes are estimated to have appeared during the Early Cretaceous, and *Bathysaurus* itself is thought to have originated in the Late Cretaceous. Extant lizardfishes are abundant at abyssal depths at temperate and tropical latitudes, mirroring their abundance in the SFH. The Antarctic fossils share with selected extant lizardfishes a medial pelvic girdle process that is joined by cartilage (i.e., unfused) and a brush-like posterodorsal outgrowth of the first neural arch. The recognition of fossils in the SFH as those of deep-sea taxa sheds new light on the genesis of this singular assemblage.

Grant Information:
National Science Foundation, ANT_118473

Technical Session VII (Thursday, October 10, 2019, 9:45 AM)

A NEW BASAL CROCODYLOMORPH FROM THE NUGGET SANDSTONE OF UTAH – THE MOST COMPLETELY KNOWN "SPHENOSUCHIAN"

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"Sphenosuchians" (non-crocodyliform crocodylomorphs) are critical to understanding the origins of many features that are apomorphic for living crocodylians. All currently known specimens are incomplete, several species are known only from the holotype specimen, and ontogenetic changes are not yet documented. We report here a new "sphenosuchian" known from multiple nearly complete skeletons, from the Late Triassic Nugget Sandstone of NE Utah.
The specimens were preserved in interdunal lacustrine sandstones along with remains of theropods, pterosaurs, drepanosaurids, sphenodontians, and procolophonids. A minimum number of 87 individuals are known based on femora, and 35 specimens are articulated to some degree, including 14 articulated, relatively complete skulls. The specimens are relatively small, with skulls ranging from 23 mm to 42 mm and femora from 14 to 59 mm. Despite the range of sizes morphological differences are subtle.

The new taxon is superficially similar to *Terrestrisuchus*, but that is likely due to their small size and possibly to young ontogenetic stages of known specimens. The cranioquadrate passage is open, unlike in *Macelognathus, Almadasuchus,* and crocodyliforms. A heavily fenestrated quadrate is shared with these latter taxa but may reflect an early ontogenetic stage, as in extant crocodylians. Like *Almadasuchus* and crocodyliforms it lacks basipterygoid processes, and instead the basisphenoid has an unusual ventrolateral ridge along its lateral edge. The scapula is relatively narrow anteroposteriorly, unlike the broader element in *Junggarsuchus* and crocodyliforms, and the coracoid has a posteroventral process but lacks the elongate, cylindrical projection of *Dibothrosuchus* and *Junggarsuchus*. The pubis lacks an obturator foramen, unlike *Terrestrisuchus*, and the femoral head is not as distinctly inturned as in *Kayentasuchus, Almadasuchus* and *Hallopus*.
A phylogenetic analysis based on firsthand examination of most sphenosuchians and CT scans of the skull of the Nugget form and several other sphenosuchians places the new taxon with basal "sphenosuchians," indicating that the lack of basipterygoid process and the highly fenestrated quadrate, if present in adults, evolved homoplastically in the new form and in crocodyliforms and some "sphenosuchians". The limited amount of pneumaticity, other than in the quadrate, and more weakly developed femoral head are consistent with other Triassic "sphenosuchians" and unlike most Jurassic taxa.

Grant Information:
NSF EAR 1636753 to JMC

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 9:45 AM)

METABOLIC PHYSIOLOGY EXPLAINS MACROEVOLUTIONARY TRENDS IN THE MELANIC COLOUR SYSTEM ACROSS AMNIOTES

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Metabolism links organisms to their environment through its effects on thermoregulation, ecology and energetics. Genes involved in metabolic processes have described pleiotropic effects on some melanic colour traits. Understanding links between physiology and melanic colour is critical for understanding the role of, and potential constraints on, colour production. Despite considerable variation in metabolic rates and presumed ancestral melanic coloration in vertebrates, few studies have looked at a potential relationship between these two systems in a comparative framework. Here, we test the hypothesis that changes in melanosome shape in integumentary structures track metabolic rate variation across amniotes. Using multivariate comparative analyses and incorporating both extant and fossil taxa, we find significantly faster rates of melanosome shape evolution in taxa with high metabolic rates, aswell as both colour- and clade-specific differences in the relationship between metabolic rate and melanosome shape. Phylogenetic tests recover an expansion in melanosome morphospace in maniraptoran dinosaurs, as well as rate shifts within birds (in songbirds) and mammals. These findings indicate another core phenotype influenced by metabolic changes in vertebrates. They also provide a framework for testing clade-specific gene expression patterns in the melanocortin system and may improve colour reconstructions in extinct taxa.

Grant Information:
NSF EAR 1251922 and NSF EAR 1355292 to J.A.C; Integrative Research Center Postdoctoral Fellowship, FMNH to C.E.

Technical Session XVIII (Saturday, October 12, 2019, 3:00 PM)

EARLIEST PUERCAN 1 (PU1) FAUNAS FROM MONTANA WITH INSIGHTS ON MAMMALIAN TAXONOMIC AND ECOLOGICAL RECOVERY AFTER THE K-PG MASS EXTINCTION EVENT.

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Biotic recovery following ecological disaster is often investigated using taxonomic proxies (e.g., relative abundances and richness). This approach neglects other proxies of ecological recovery (e.g., body size and diet) that can be decoupled from taxonomic proxies. The relative dynamics of these proxies offer insight into models of recovery that are relevant to modern systems. The Cretaceous-Paleogene (K-Pg) mass extinction marked the demise of non-avian dinosaurs and the rise of mammalian-dominated terrestrial ecosystems. The quantity and quality of paleontological data makes this event a superb model to investigate both the taxonomic and ecological aspects of biotic recovery. Here, we build on past work tracking changes in taxonomic composition and diversity by tracking body size and dietary habits within earliest Paleogene mammalian local faunas from Garfield County, Montana, U.S.A. . We recovered mostly isolated mammal teeth via surface collection and screenwashing of the Herpijunk, Morales 1, and Carrie Padgett localities. These localities form a time sequence allowing high-resolution insights into mammalian faunal recovery during the first ~80 Ka after the K-Pg. Body-mass estimates were made using taxon-specific formulae and were averaged for each locality. Average body-mass across sampled localities did not change and remained small (<5kg). Each taxon was assigned to a dietary category (faunivore, animal-dominated omnivore, plant-dominated omnivore and herbivore) according to our observations and the published literature. Animal-dominated omnivores have the highest abundance around 86% on average followed by faunivores. Faunivory, plant-dominated omnivory and herbivory each represent less than 10% of total abundance in each locality. Overall dietary category abundances were stable from the oldest to youngest localities. Previous work investigating these localities support a mammalian recovery model in which older Pu1 localities have high relative abundances of disaster taxa (*Mesodma* spp.) and low richness. Our results indicate stable average body-mass and dietary category abundances in the three localities. There is little evidence demonstrating a decoupling of taxonomic and ecological recovery, which may be a result of the limited temporal range of our study system. Future work will extend the temporal range and resolution of the analysis to continue to investigate the dynamics of biotic recovery.

Technical Session XI (Friday, October 11, 2019, 11:30 AM)

ECOLOGICAL RESPONSE TO LATE MIOCENE COOLING IN SOUTH AMERICA

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Late Miocene cooling (LMC, 7.0-5.4 Ma) marks an interval of significant, rapid temperature decline (up to 6°C) recorded in marine sediments and associated with the establishment of a near-modern climate state. In terrestrial settings, this event correlates with significant global aridification and expansion of C_4-dominated grasslands, with a corresponding increase in the proportion of hypsodont (high crowned) and hypselodont (ever-growing dentition) taxa within mammalian faunas. While contemporaneous terrestrial records from South America suggest a similar pattern, their interpretation is complicated by regional tectonism associated with ongoing uplift of the Andes. Here, we sought to re-evaluate these records by selecting basins from areas where present-day elevations had been established by the Late Miocene, thereby removing tectonic effects, and examining changes in carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopic compositions of pedogenic carbonates and fossil tooth enamel solely within the context of climate change associated with the LMC. These records were then compared with general circulation global climate model simulations to identify the most likely mechanism responsible for changes observed within these terrestrial ecosystems.
Published $\delta^{13}C$ and $\delta^{18}O$ records of pedogenic carbonate and fossil enamel values were compiled from 14 localities in Bolivia and Argentina spanning 15°S to 35°S. Pedogenic carbonate $\delta^{13}C$ and $\delta^{18}O$ values, in general, rose across the LMC, most robustly occurring in the subtropics (25 to 30°S), suggesting aridification and expansion of C_4 grasses. Mammalian faunas from the subtropics showed the strongest response across the LMC with an increase in C_4 grass consumption as evident from elevated enamel $d^{13}C$ values and an increase in abundance of hypsodont and hypseledont taxa. The early acquisition of high-crowned teeth by these taxa would have primed them to take advantage of the expansion of open, arid habitats during the LMC. Climate model simulations, which were run under different magnitudes of LMC steepening of equator-to-pole temperature gradients and CO_2 decline, suggest these environmental changes could be attributed to strengthened Hadley circulation, which would enhance moisture divergence away from the subtropics and towards the Intertropical Convergence Zone.

Grant Information:
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Technical Session III (Wednesday, October 9, 2019, 4:00 PM)

OREODONT ADAPTATION AND EXTINCTION IN THE CENTRAL HIGH PLAINS, MIOCENE NORTH AMERICA

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Oreodonts were not only abundant during the middle Cenozoic, but they were also widespread and diverse. In the Oligocene and Miocene, oreodonts diversified while grasslands expanded and open savannas replaced closed forests, one of the greatest ecological transformations in the Cenozoic. Grassland expansion increased selection pressure for grazing morphologies as grasses became more abundant than leafy browse and the distance between patchy feeding resources increased. The current paradigm attributes oreodont extinction to a lack of adaptive change to grass dominated, open environments. Collections from four museums were used to assess adaptive change in oreodonts between 37 Ma and 9 Ma in the Central High Plains. A series of 73 undeformed skull attributes and 34 postcranial attributes were measured on 237 individuals. To better constrain cranial ecometrics, a new set of cranial measures were adopted to create a three-dimensional mesh of the feeding characters of the skulls. This allowed for comparison of cranial loci orientation and position, increasing the total number of traits, while avoiding the time and costs associated with scanning technologies. Ecometric analysis of the skull attributes resolves four distinct groups through time. The first three groups progress through origination, radiation, and specialization with a directional shift from browsing to grazing. The final survival group shifts back toward a mixed feeding type of medium size. Analysis of limb attributes indicate a more subtle trend through time toward grazing and follows a similar pattern of origination, radiation, specialization, and survival. These results challenge the existing paradigm that oreodonts did not adapt to their changing environment with additional implications for current controversies in oreodont phylogenetics. Grasslands expanded at different rates in the central High Plains and northwestern United States so future research will compare oreodont ecometrics and changing community structures in these areas.

Grant Information:
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Technical Session XIX (Saturday, October 12, 2019, 2:45 PM)

SPECIES-AREA RELATIONSHIPS IN NORTH AMERICAN TERRESTRIAL TETRAPODS ACROSS THE CRETACEOUS/PALEOGENE BOUNDARY

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Species-area relationships are among the most intensely-studied macroecological phenomena in modern-day ecosystems. Diversity scales ubiquitously with sampled area, and the form of this relationship reveals rich information about how diversity at local and regional spatial scales are linked by geographic turnover and nestedness of species assemblages. However, remarkably little is known about the evolution of species-area relationships through deep time. Here, we quantify species-area relationships in non-flying terrestrial tetrapods and key subclades across the Cretaceous/Paleogene (K/Pg) boundary (Campanian–Ypresian) in North America. We use a spatially-explicit framework to estimate coverage-standardized species richness for nested sets of fossil localities spanning small to large spatial scales (~100–2000 km maximum great circle distance). Slopes for species-area relationships in non-avian dinosaurs, mammals, turtles, and terrestrial tetrapods as a whole were significantly gentler in the Maastrichtian than they were in the Campanian. This finding supports previous estimates of low beta diversity in Maastrichtian dinosaurs, which was ascribed to environmental homogeneity caused by the development of epicontinental seaways. Consistent with previous estimates of local and regional diversity patterns, the intercept of the species-area relationship in terrestrial tetrapods increased two- to threefold across the K/Pg boundary, driven by the explosive radiation of mammals. However, the slope of the tetrapod species-area relationship also increased across the boundary. By the Danian, the slope had already returned to a value comparable to that estimated for the Campanian, and similar values were maintained until the Ypresian. Our results show that the form of the species-area relationship can evolve through deep time, perhaps in response to environmental drivers. Nevertheless, there were also intervals of tens of millions of years over which species-area relationships changed relatively little, despite major ecological restructuring in tetrapod communities between the Mesozoic and the Cenozoic.

Grant Information:
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Technical Session X (Friday, October 11, 2019, 8:45 AM)

RETHINKING THE ASSEMBLY OF CHIMAEROID FISHES

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Chimaeroids, now represented by a mere fifty living species, constitute one the four primary divisions of extant gnathostomes. Chimaeroid cranial morphology combines the classic lungfish character-suite of choanae, tooth-plates, fused palate, and reduced hyomandibula, with further specializations including (but not limited to) a deep snout, ethmoid canal, and huge orbits with an elevated skull roof. Although firmly rooted among chondrichthyans, the challenge of relating the earliest chimaeroids to other kinds of fossil shark continues to be problematic because of the paucity of likely transitional forms. However, recently published data on symmoriid crania and new insights into the structure of Carboniferous holocephalans enable re-consideration of the origin of the chimaeroid cranial morphotype, and re-evaluation of long-established transformation scenarios debated by Patterson, De Beer and Moy-Thomas. In summary, our analysis favors the following sequence of character evolution: initially, orbit enlargement, the near-union of left and right otic labyrinth spaces across roof of the hindbrain, and enclosure of the pre-orbital

ophthalmic nerve. These changes preceded the essential structural and functional step of palatal fusion to the braincase. In agreement with De Beer, the ethmoid canal has never been part of the cranial cavity, sensu stricto. Moreover, the precerebral fontanelle persists (in phylogeny) while orbitonasal lamina is expanded and reinforced, and the quadrate-articular jaw joint is moved anteriorly. These changes preceded the origin of tooth-plates. Notably, chimaeroid tooth-plate origin involved spatial changes, the lateral fusion and/or displacement of tooth series, and heterodont and bradyodont trends in tooth generation, implying changes to the distribution and activity of dental laminae through ontogeny and phylogeny. It appears that such changes occurred mostly before the end-Devonian extinction, thereby preconfiguring holocephalan survivors to exploit the exceptional, crinoid-dominated continental shelf environments of the Lower Mississippian, and launching the singular, late Paleozoic evolutionary radiation in the history of this extraordinary vertebrate clade.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

STABILITY OF DENTAL MESOWEAR SCORES THROUGHOUT THE LATE PLEISTOCENE IN LARGE UNGULATES FROM RANCHO LA BREA

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The Rancho La Brea locality (California, U.S.A.) is world famous for its asphalt deposits that trapped late Pleistocene megafauna over the last 50,000 years. This wealth of paleontological data allows for detailed investigation into paleoecological changes through the last glacial maximum into the Holocene. Previous studies have inferred dietary changes in herbivorous taxa at Rancho La Brea using dental mesowear in conjunction with microwear and enamel stable isotopes, focusing on two deposits: Pit 61/67 at ~11.5 Ka and Pit 77 at ~35 Ka. Here, we examined the mesowear of additional specimens of *Bison antiquus*, *Equus occidentalis*, and *Camelops hesternus* from five pits spanning the latest Pleistocene (~12–40 Ka): pits 61/67, 3, 13, 91, and 77. Five observers scored mesowear for each specimen and the mesowear numerical scores (MNS) were compared between pits and taxa, as well as against a modern dataset of grazers and browsers. Mesowear values of each taxon examined did not differ through time (i.e., between pits, all p-values >0.11). Additionally, *E. occidentalis* consistently had higher MNS values (mean of 3.8) than both *B. antiquus* and *C. hesternus* and were indistinguishable from modern grazers (p=0.19). *B. antiquus* and *C. hesternus* MNS values (mean of 1.6 and 1.5, respectively) were consistent with modern browsers (p=0.33 and 0.17, respectively). The values for *B. antiquus* (all pits combined) differ significantly from those for the modern grazer *B. bison* (p<0.001). The stability of mesowear signals between pits is in contrast to previous studies that found changes in diet across the late Pleistocene using microwear and stable enamel isotope dietary proxies. These differences in dietary interpretation may be due to the different signals each proxy represents. Dental mesowear signals reflect abrasives in or on food consumed while dental microwear textures record the textural attributes of food consumed, both representing different amounts of time. Previous studies using age structure and serial enamel isotopes have suggested that *E. occidentalis* and *B. antiquus* migrated into Rancho La Brea yearly, so dental microwear may signal the specific diet consumed at Rancho La Brea while dental mesowear may represent feeding behavior at and beyond Rancho La Brea.

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Technical Session IV (Wednesday, October 9, 2019, 3:15 PM)

SAMPLE SIZE ARTIFACTS IN PALEONTOLOGICAL ANALYSES OF ONTOGENETIC SEQUENCES

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Establishment of ontogenetic sequences for fossil species is generally compromised by small sample sizes. Although this does not diminish the importance of ontogenetic sequence as a tool for estimating the maturity of individuals (often a prerequisite for interpreting whether a specimen represents a different taxon, or simply a different ontogenetic state from a reference specimen), it does mean that certain precautions should be observed when comparing ontogenetic sequences between taxa. Here a hypervolume heuristic is employed to explore the ramifications of sampling bias.

In general, ontogenetic sequence resolution within a taxon or population depends on the number of specimens relative to the number of included events. Complete sequence resolution (i.e., every event's position resolved relative to every other event) minimally requires as many sampled individuals as ontogenetic events. In practical terms, one needs to include many more individuals than events because it is unlikely that all sampled individuals represent a unique ontogenetic condition. Furthermore, ontogenetic event-order can be variable, requiring large samples to establish the frequency of variant sequences. The negative effects of inadequate sampling are predictable, and include poor resolution and underestimation of sequence variation. Unfortunately, many studies assume that lack of resolution indicates event synchroneity, which leads to a false equivalence of sequence position in comparative analyses. Underestimating sequence variation results in a false assertion of fixed sequence order for events, which also affects comparative analysis.

The hypervolume heuristic illustrates the consequences of inadequate sampling, and proffers a framework for sequence comparison. This framework includes a predictable distribution of sequences differing from a reference sequence, and the likelihood for erroneous interpretations when resolution is not adequate. The hypervolume can inform the suitability of sequence comparison between taxa, and presents a rationale for targeted sampling to address sampling biases. In general, while attempts to establish ontogenetic sequences are encouraged, even with limited samples, it is imperative to evaluate sampling effects – particularly with comparative analyses. Analysis of topological differences in ontogenetic hypervolume-space is considered the most promising avenue for interpreting ontogenetic sequence evolution while accounting for sequence sampling artifacts.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

TATE GEOLOGICAL MUSEUM - A VALUABLE RESOURCE FOR VERTEBRATE PALEONTOLOGICAL RESEARCH AS WELL AS ENHANCING LIBERAL ARTS EDUCATION.

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The Tate Geological Museum (TGM) of Casper College, Wyoming will be celebrating its 40th anniversary in the 2019-2020 academic year. The TGM was built as a gift to Casper College by the Tate Family in Casper. Originally a mineralogical museum, the facility has developed into the second most important collection of vertebrate fossils from Wyoming in Wyoming. Like all locally funded museums, it has had its share of growing pains including unstable funding sources and staffing issues. However, in the late 1990's, Casper College recognized the value of having a natural history museum on campus for student access and as a community resource. The addition of full-time staff has allowed the museum to expand into what it is now, with more in the plans. The facility has become a place for internships, training in collections management, and host to an annual conference. For the past dozen years or so, the museum has been recognized by the Bureau of Land Management as a federal fossil repository and houses many important specimens. Along with the generous donations from community members and landowners, the museum is actively collecting from new and older sites and now has an extensive collection of vertebrate taxa from Wyoming, available to researchers and to visitors alike. Recent collections include up to 120 unidentified mammal teeth and jaws from a single ant hill associated with Cretaceous sediments, nearly complete carapace and plastron from the Morrison Formation, a partially articulated *Tyrannosaurus rex*, and access to one of the most numerous pterosaur tracks and trackways in the world. The TGM invites researchers to consider contacting the museum to see what the museum can do to help with their next project.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

CHALICOTHERES OF PAKISTAN: PIECING TOGETHER THE BIOGEOGRAPHIC PUZZLES OF A RARE PERISSODACTYL GROUP IN THE NEOGENE OF SOUTHERN ASIA

COOMBS, Margery C., University of Massachusetts Amherst, Amherst, MA, United States of America; COTE, Susanne, University of Calgary, Calgary, AB, Canada

Chalicotheres (Perissodactyla) have a fragmentary and sporadic Cenozoic fossil record on the Indo-Pakistan subcontinent. Occurrences of these unusual clawed herbivores in Pakistan nonetheless contribute useful windows for viewing regional environments and biogeographic relationships during the Neogene. 1) Chalicotheriids belonging to both the subfamilies Schizotheriinae and Chalicotherinae appear near the Oligocene-Miocene boundary in the Bugti Hills and Zinda Pir in Pakistan. Best known from teeth but otherwise mostly enigmatic, *Phyllotillon naricus* was among the earliest schizotheriines to fuse proximal and middle phalanges of the second digit of the manus. It is thus pivotal for understanding the spread of Miocene Schizotheriinae across Eurasia and into North America. *"Chalicotherium" pilgrimi*, poorly known but recognizable from distinctive postcranial elements, helps elucidate the route via which Chalicotheriinae reached East Africa in the early Miocene. 2) In the mid to late Miocene, *Anisodon salinus* (Chalicotheriinae, Tribe Anisodontini) has an unusually long temporal range (14.1 to 7.4 Ma) in the Middle Siwaliks of the Potwar Plateau. The holotype and most clearly diagnostic specimens of *A. salinus* are relatively early (Chinji Formation); later specimens are less easily confirmable as *A. salinus* but, like earlier representatives, retain characters (such as a relatively short jaw symphysis) found in such basal anisodont chalicotheriines as *Anisodon grande* (Europe). *A. salinus* also resembles *Anisodon yuanmouensis* from Myanmar and southwestern China; the distributions of *A. salinus* and *A. yuanmouensis* suggest a geographic continuum of conservative anisodont chalicotheriines living in subtropical forested environments south and east of the Himalayas into the late Miocene. Schizotheriinae are generally not found in the Middle Siwaliks, though a single tantalizing lower molar from Locality Y596 (~10.1 Ma) is identified as cf. *Ancylotherium* sp., a genus otherwise typical of the Pikermian Biome of northern China, Afghanistan, Iran, and Turkey, extending into southeastern Europe and Africa. 3) *Nestoritherium sivalense* from Upper Siwalik deposits of Plio-Pleistocene age represents the final occurrence of Chalicotheriinae in Pakistan. *Nestoritherium* is a derived anisodont best known from northern China. Its occurrence in Pakistan is more likely the result of immigration than evolution in situ from earlier *Anisodon salinus*.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A MORPHOMETRIC ANALYSIS OF THE CROCODYLIAN SKULL TABLE: TRACKING ALLOMETRY AND PREDICTING ECOLOGY

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The dorsal portion of the crocodylian skull, posterior to the orbits, is referred to as the skull table. To explore shape variability an analysis using geometric morphometric methods is conducted with the inclusion of both extant and fossil taxa. In addition, comparisons of allometric change within taxa are explored - crocodylian body mass greatly increases during development and is associated with significant change in cranial morphology.
This project uses 240 specimens from 58 species. Four separate analyses are performed; two outline analyses, an analysis exploring the allometric trajectories of skull table outlines, and an analysis of the allometric trajectories of skull table outlines with additional landmarks covering the morphology of the supratemporal fenestrae. Each species is assigned categorical variables depending on its phylogenetic relationships and snout length. A permutation procedure is used to test for instances of convergence, parallelism, and divergence among the allometric trajectories.
Results demonstrate overlap in morphospace between Alligatoroidea and Crocodyloidea whereas *Borealosuchus* and Gavialoidea are more restricted. The overlap between Alligatoroidea and Crocodyloidea may be the product of a more recent common ancestor and/or shared snout shape categories. With the inclusion of landmarks representing the supratemporal fenestrae, Gavialoidea is broadly separated from the other groups as a result of having proportionally massive fenestrae.
It has been hypothesized that the size of the supratemporal fenestrae are influenced by snout length, with longer snouts corresponding to larger fenestrae. Although species of the crocodyloids *Tomistoma* and *Euthecodon* approach or exceed the length of the snout in gavialoids their supratemporal fenestrae are proportionally smaller - this suggests a phylogenetic constraint in crocodyloids regardless of snout length.
Among the allometric trajectories adults of the smallest extant taxa plot alongside the juveniles of larger taxa. This may indicate that paedomorphosis is present in the skull table outline of these taxa whose diminutive size may have been achieved via maintenance of juvenile morphologies through ontogeny.
The biological implications of skull table shape, other than raising the eyes and ears above the waterline, are largely unknown. Shape likely plays a role in hydrodynamics, species recognition, and biomechanical adaptations. This study sets the foundation for the quantification of skull table shape in Crocodylia.

Technical Session I (Wednesday, October 9, 2019, 9:30 AM)

DAUNTING DENTITIONS: TUSKS AND TEETH IN THREE OLIGOCENE DOLPHINS FROM NEW ZEALAND

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New Zealand fossil dolphins include 3 named species with elongate procumbent teeth (*Waipatia maerewhenua*, *Otekaikea marplesi* and *Otekaikea huata*; Waipatiidae, Platanistoidea). All the teeth are isolated from their alveoli, with uncertain original positions. Three unnamed new species (based on specimens OU 22397, OU 22126 and OU 22262) now preserve tusks in situ in 22397 and 22126. These longirostral, tusked dolphins are from marine mid-shelf strata, the Kokoamu Greensand and Otekaike Limestone (Chattian, ~26 Ma, to possibly basal Aquitanian, ~23 Ma), of the Waitaki region. Phylogenetic analyses place these in the Platanistoidea, though relationships are unstable.
In all three new species, the maxillary teeth are polydont: markedly heterodont in OU 22262 (which lacks the rostrum); less differentiated in OU 22397; and near-homodont in OU 22126. The latter 2 have well-preserved elongate, attenuate, and dorsoventrally flattened rostra; both rostra are more than twice as wide as deep at the level of the canine. The tusks are embedded in elongate premaxillae which form the anterior 23% of the rostra in both specimens. Only OU 22397 has a relatively complete mandible, which shows alveoli for similarly long procumbent tusks and a long unfused symphysis along 38% of its length.
Where the teeth are in place or alveoli observable, I1 is parasagittal and horizontal, with a symmetrical crown and a straight axis from crown tip to root tip. I2 and I3 are less symmetrical, splayed out laterally. The canine is missing; the cheek teeth pass back to be increasingly re-curved which become more differentiated posteriorly. The posterior cheek teeth in OU 22262 and OU 22397 have reduced accessory denticles which are nearly imperceptible in OU 22126.
The placement of the tusks in the rostra indicates differences in tusk eruption amongst the 3 specimens. None of the teeth show evidence of extensive abrasive wear or attrition, other than right I2 of specimen OU 22397 which appears to have been broken and subsequently worn throughout life at an angle of about 20° to the tooth's long axis.
The generally-pristine condition of the tusks suggests delicate occlusion or contact with exogenous material. How could these unusual tusks have been used? The dorsoventrally compressed rostrum might allow more-rapid lateral movements. Uses could include slashing for feeding (as in Pristidae, sawfish) or hunting infaunal benthic prey, for defence or other agonistic behaviour, or display.

Grant Information:
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Technical Session VI (Thursday, October 10, 2019, 11:30 AM)

AN USUAL FOSSIL HOMINOID ASSEMBLAGE FROM TINDERET, KENYA

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Early Miocene sediments in both Kenya and Uganda sample abundant and diverse remains of early fossil hominoids (apes). One particularly important area is Tinderet in Western Kenya, which includes more than 50 separate fossil localities. Despite their relatively close temporal and geographic proximity, these localities contain different ape species – some taxa are restricted to just a handful of localities (e.g., *Rangwapithecus gordoni*), while others (e.g., *Proconsul major*) appear to be very widespread. Locality "Koru 16" has been known to paleontologists for many decades, and several fossil ape specimens have been described in the literature. Previously, material from Koru 16 has been attributed to *Proconsul major*, *Proconsul africanus*, and *Limnopithecus legetet.*
We recovered additional ape fossils during geological and paleontological fieldwork at Koru 16. These new specimens make it clear that Koru 16 samples a new taxon of large-bodied ape that is similar in size to *P. major*, but morphologically distinct. A single lower molar, likely m2, has well-developed shearing crests, is mesiodistally elongate, and lacks a clear

cingulum. Two large male canines, one collected by us, and one collected in the 1970s and previously referred to *P. major*, are bilaterally compressed, possess bulbous roots, and lack longitudinal fluting and striations on the root and a burrin tip. From these morphological features, the lower molar and upper canines clearly differ from *P. major*. Instead, they are most similar to the Nyanzapithecinae, and may represent the first record of a large-bodied nyanzapithecine.

Our comprehensive review of all hominoid fossils from Koru 16 suggests that *P. major* is not present in this collection. Instead, there is a similarly-sized, but morphologically distinct large nyanzapthecine. *Limnopithecus legetet* is present. The most common taxon is *P. africanus*, and a preliminary review of all material of this species from Tinderet suggests that it is restricted in distribution, and found only at a few localities. This study documents additional previously unrecognized ape diversity at Tinderet, which is a very well-studied and well-sampled fossil site. The new large-bodied nyanzapithecine found at Koru 16 appears to be restricted to this locality, suggesting that it may have been relatively rare or was quite temporally or geographically restricted. This may be a feature of nyanzapithecines, as most species seem to be restricted to one or a few localities rather than being widespread.

Grant Information:
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Technical Session VI (Thursday, October 10, 2019, 9:15 AM)

A TALE OF TWO MICE: *POGONOMYS* AND *LEGGADINA* (RODENTIA: MURINAE) FROM PLEISTOCENE CAVE DEPOSITS AT MT ETNA, EASTERN QUEENSLAND, AUSTRALIA.

CRAMB, Jonathan, Queensland Museum, South Brisbane, Australia; HOCKNULL, Scott, Queensland Museum, Brisbane, Australia; PRICE, Gilbert, The University of Queensland, St Lucia, Australia

Middle Pleistocene cave deposits at Mt Etna (eastern Queensland, Australia (AUS)) record the regional extinction of rainforest and its replacement by xeric habitat. The rainforest assemblage from Mt Etna is similar to older Oligo-Pliocene rainforest faunas by possessing extant lineages that are rainforest obligate. The fauna records the nearest-time fossils of extant rainforest species providing a Quaternary baseline for species diversity within AUS rainforests. An intriguing feature of the Mt Etna rainforest fauna is that it includes taxa with extant members that do not currently inhabit rainforest. This feature has also been observed among marsupials, particularly dasyurids, permelids and pseudocheirids. The origin of these 'atypical' assemblages and the question of how (and when) rainforest faunas became 'modern' are some of the foci of our ongoing research into the Mt Etna Quaternary faunas.

Two recently described murine species give key insights into the unusual nature of the Mt Etna rainforest fauna. One is an extinct species of *Pogonomys*, a genus whose extant members are all associated with rainforests in New Guinea (NG) and north Queensland. The Mt Etna species is the most southerly and oldest record of the genus, making it a potentially important calibration point for murine phylogenetics. The other, *Leggadina webbi*, is a member of a genus whose members (extant and extinct) are presently or prehistorically thought to occupy woodland to arid habitats. The presence of a species of *Leggadina* in a demonstrably rainforest assemblage thus seems anomalous. We may be able to explain this 'atypical' occurrence by considering the evolutionary history of murines in AUS as a whole. *Leggadina webbi* exhibits several plesiomorphic characters, and shows greatest similarity to *L. gregoriensis*, the oldest species of *Leggadina*, from the early Pleistocene. We hypothesise that Pliocene colonisation of the once separated island entities of AUS and NG by murines produced parallel adaptive radiations, with a *Leggadina* lineage occupying rainforest in AUS and *Pogonomys* evolving in NG rainforest. Subsequent uni-directional dispersal from NG to AUS occurred sometime prior to and since 500kya introduced NG lineages into AUS tropical rainforests including species of *Pogonomys*. The resulting hybrid assemblage was then driven locally extinct by a climatic shift after 280 kya, and was replaced by an assemblage of xeric-adapted species.

Technical Session XX (Saturday, October 12, 2019, 2:45 PM)

FUNCTIONAL DISPARITY IN TRIASSIC JURASSIC ARCHOSAUR HINDLIMBS, AND IMPLICATIONS FOR MUSCULOSKELETAL MODELLING

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The late Triassic to early Jurassic was a time of high terrestrial diversity and disparity in archosaurian reptiles, initially with the pseudosuchians and then dinosauromorphs. However, the modern diversity of archosaurs is restricted to crocodilians and birds. Here we investigated the functional disparity of archosaur hindlimbs, widely seen as remarkable, using biomechanics. Skeletal models of fossil and extant species of pseudosuchians (*Batrachotomus*, *Poposaurus* and Nile crocodile) and dinosauromorphs (*Marasuchus*, *Lesothosaurus*, *Coelophysis*, *Mussaurus*, and elegant-crested tinamou) were digitized, and muscles added to these models in musculoskeletal modelling software. We then calculated ranges of motions (ROM) and normalized muscle moment arms of the hip, knee, and ankle. Pseudosuchian taxa generally had the greatest ROM in hip flexion/extension, whilst dinosauromorphs had the greatest ankle extension (due to the absence of the enlarged calcaneal tuber). Across the other joints, ROM was similar between the taxa. Muscle moment arms varied widely depending on the method of size-normalization. When the cube root of body mass was used, smaller taxa had larger moment arms around most joint axes. When scaled against femoral length, *Mussaurus* had the largest hip flexion/extension moment arms for the M. caudofemoralis longus, but the smallest for M. flexor tibialis externus. Extinct pseudosuchians had some of the largest M. gastrocnemius moment arms, as expected from the calcaneal tuber; and comparable to birds. Hence there is a tradeoff in ankle mobility and leverage in archosaurs. The fossil taxa and crocodile retained ancestral hip abduction/adduction moment arms, contrasting to the patterns in birds. By using 3D musculoskeletal models we can explicitly quantify functional disparity in (and evolution of) archosaurian hindlimb function, and we discovered important lessons about tradeoffs between different methods of normalizing muscle moment arms.

Grant Information:
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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

THE UTILITY OF PERIOSTEAL AGING TO ASSESS THE MATURITY OF ISOLATED THEROPOD CRANIAL AND FEMORAL ELEMENTS.

CUNNINGHAM, Patrick, Salt Lake City, UT, United States of America; LOEWEN, Mark A., University of Utah, Salt Lake City, UT, United States of America; SERTICH, Joseph, Denver Museum of Nature & Science, Denver, CO, United States of America

Ontogenetic changes in the periosteal surface textures of appendicular elements have previously been recognized in extinct taxa as well as in extant birds. Typically, a linear, striated surface texture in fast growing juvenile bones progresses to a clotted, interwoven texture in mature adults. Cranial elements and femora of *Allosaurus fragilis* from the Jurassic Cleveland Lloyd Dinosaur Quarry of North America and *Masiakasaurus knopfleri* from the Maastrichtian Maevarano Formation of Madagascar were photographed macroscopically to document bone surface texture. The images were categorized into three groups based on the bone surface texture (striated, intermediate, clotted/interwoven), independent of absolute size. These categories were then compared to linear measurements and to previously reconstructed growth curves based on histologic evidence. Specimens of *Allosaurus* are ideal for analyzing periosteal aging because they provide a vast range of well-preserved elements across multiple sizes. Femoral bone surface textures closely track absolute ages in specimens that have been histologically aged. We examined cranial periosteal surface textures in disarticulated elements of *Allosaurus* and found similar decreases in linear striated surface textures with increases in size in both the maxilla and dentary. We examined femoral and cranial elements of the noasaurid *Masiakasaurus* to determine periosteal surface textures in a more basally-branching, small-bodied theropod. We found woven adult surface textures in most large limb bones, and intermediate texture in smaller individuals. All large cranial materials including the maxilla and dentary show adult texture, while a smaller dentary exhibits intermediate texture. When combined with published reports of bone surface maturity in ceratopsians, tyrannosaurs, and ornithomimids, bone surfaces can give an accurate first approximation of skeletal maturity even in the case of an individual long bone or isolated cranial element. Bone surface texture has a place in assessing maturity and can be used as a reliable proxy for maturity when making taxonomic assessments.

Technical Session X (Friday, October 11, 2019, 10:30 AM)

ASTEROLEPIS SPP. AND OTHER ANTIARCH PLACODERMS FROM THE FRAM FORMATION (UPPER DEVONIAN; FRASNIAN) OF ELLESMERE ISLAND, NUNAVUT TERRITORY, CANADA

DAESCHLER, Ted, The Academy of Natural Sciences of Drexel University, Philadelphia, PA, United States of America; DOWNS, Jason P., Delaware Valley University, Doylestown, PA, United States of America; LO, Nathanael, Swarthmore College, Swarthmore, PA, United States of America; CAREY, Emily N., Drexel University, Philadelphia, PA, United States of America; SHUBIN, Neil H., University of Chicago, Chicago, IL, United States of America

Fieldwork and new species descriptions during the past two decades have revealed many new elements of the vertebrate fauna from the Fram Formation (Upper Devonian; Frasnian) on Ellesmere Island, Nunavut Territory, Canada. Here we report on a large collection of asterolepidid antiarchs collected from a single site, and review other undescribed antiarchs from throughout the Fram Formation. Site NV2K17, a crevasse splay within overbank deposits, is the source of several sarcopterygian taxa including *Laccognathus embryi*, *Holoptychius bergmanni*, *Eusthenopteron jenkinsi* and *Tiktaalik roseae*. Disarticulated antiarch remains are also common at the site and represent at least two species of *Asterolepis*. Distinct, high-crested anterior median dorsal plates diagnose a new species of *Asterolepis*, and *Asterolepis* cf. *radiata* is represented by low-crested AMD plates with radiating ornament. A large number of other antiarch head and trunk plates from the site are referred to the new species, to *Asterolepis* cf. *radiata*, or to varied taxonomic levels within Asterolepidoidei. The NV2K17 site also produced a single AMD plate diagnostic of *Bothriolepis* sp., documenting the co-occurrence of these two antiarch groups in this horizon. An examination of antiarch material from sites throughout the Fram Formation demonstrates the transition from *Asterolepis*-dominated faunas to *Bothriolepis*-dominated faunas during the Frasnian in this region.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A NEW MEGALOSAURID THEROPOD FROM THE MIDDLE JURASSIC XINTIANGOU FORMATION OF CHONGQING, PEOPLE'S REPUBLIC OF CHINA AND ITS IMPLICATION FOR EARLY TETANURAN EVOLUTION

DAI, Hui, Chongqing No. 208 Hydrogeological and Engineering Geological Team, Chongqing, China; XU, Xing, Institute of Vertebrate Paleontology & Paleoanthropology, Beijing, China

Megalosaurids represent one of first radiations of large-bodied theropods, and are mainly known from the Middle–Late Jurassic of Europe and north Africa. Here we report a new theropod, *Yunyangosaurus puanensis* gen. et sp. nov., based on a fragmentary specimen recovered from the Middle Jurassic Xintiangou Formation of Chongqing, southwestern China. It shares several features uniquely with some megalosauroids (the clade of megalosaurids + spinosaurids + piatnitzkysaurids), such as prominent rims around the anterior articular surfaces of cervical centra. Megalosauroid affinities are supported by a numerical cladistic analysis. Nevertheless, it also shows several features that are rare or absent among derived tetanuran theropods, including the presence of a posterior pneumatic foramen (absent in most tetanurans, but variably present in some cervical vertebrae of piatnitzkysaurids), prominent spinoepipophyseal laminae (also present in non-tetanurans and metriacanthosaurid allosauroids), and flat anterior articular surfaces of the cervical centra (also present in piatnitzkysaurids and some early-diverging tetanurans) that are generally absent in most other tetanurans. *Yunyangosaurus* therefore presents a combination of derived and apparently primitive character states with implications for our understanding the character evolution among early tetanuran theropods.

Grant Information:
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Preparators' Session (Thursday, October 10, 2019, 3:00 PM)

MOVING AND UPDATING THE MOUNTED _TYRANNOSAURUS REX_, "SUE"

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FMNH PR2081, or "SUE" is undoubtedly the most well-known *Tyrannosaurus rex* skeleton in the world. After being "temporarily" mounted in Field Museum's large main hall for 18 years, the museum wanted to finally finish the SUE project by moving it into its own exhibit hall as part of the array of halls that make up the Evolving Planet Exhibition on the second floor. As the most complete example of *T. rex,* SUE is both an important scientific specimen, but has also become an icon for both Field Museum and Chicago. The decision to move the specimen presented an opportunity to update the mount and include elements not mounted previously.

Moving any large real fossil skeleton is a challenge but moving one of great intrinsic, academic and monetary value made the project challenging. The job included dismantling the existing mount, executing a condition report on all the bones, and carefully packaging everything for the move upstairs to the new exhibit hall which served as the workshop for the re-assembly. Some changes were made to the mount, and armatures for new elements were added. The museum requested that this whole process be done in public view, further increasing the complexity of the project.

The majority of the mount was reused, but some portions were altered to create a more life-like pose. The cervical ribs were mounted more parallel to the vertebral column, the dorsal ribs were swept back a bit, making the skeleton less barrel-chested, and the right knee was extended giving the animal a less crouched pose. The real, but pathologic, furcula replaced the previous reconstructed element which represented an educated guess at the time the specimen was first mounted. The scapulacoracoids were brought closer to the midline to articulate with the real furcula, which resulted in the pectoral girdle and forelimbs being moved anteriorly and ventrally to fit the ribcage. Finally, a new armature was created for the gastralia adding the largely complete gastral basket to the mount for the first time.

Changing the pose of a skeleton is like pulling a thread. One modification has a ripple effect invariably affecting other areas of the skeleton. The movement of such a large, real skeleton required careful coordination between the mounting crew, exhibit registrar and collections management to preserve this unique specimen. The alterations to the mount of "Sue" were done under the direction of the exhibit curators led by Peter Makovicky, and has resulted one of the most scientifically accurate *Tyrannosaurus rex* skeletons on display today.

ISOTOPIC DIET (&[DELTA] ^{13}C) IN A MATHEMATICAL MIXING MODEL: REFINING THE FOOD RESOURCES THAT EXTINCT LARGE HERBIVORES ATE

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This communication aims at refining paleodietary reconstructions for herbivorous extinct large mammal taxa through a mathematical mixing model using carbon isotopic values, to infer the proportions of three types of food resources, i.e., leaves, fruits and C_4 grass. Different tissues of C_3 plants show different values of enrichment, for example, leaves in C_3 plants are depleted in ^{13}C about -1.0 ‰ compared to other non-photosynthetic tissues like fruits (on average 1.5±0.07 ‰) and roots (on average 1.1±0.09 ‰). In contrast, C_4 plants tend to show no ^{13}C-enrichment in tissues such as fruits and roots compared to leaves. To distinguish different plant food resources, we suggest to applying carbon isotopic differences (using a difference of 5 ‰ between leaves and fruits in C_3 plants) in two equations. The use of carbon in one isotopic mixing model considering three resources allow us to refine the type of C_3 plants (leaves and fruits) consumed by herbivores. The proportions of C_3 (summing proportions of leaves and fruits) and C_4 plants in this model present similar values if we compare the proportions found in one isotopic mixing model suggesting only C_3 and C_4 plants. To test this refinement we used available carbon isotopic data for 11 extant herbivorous mammals from Africa. They belong to three well-defined groups/guilds: browser, mixed-feeders and grazers. Members of the grazer guild were the megaherbivore *Ceratotherium simum*, a specialist grazer (B_A = 0.05±0.02), and the specialists mesoherbivores *Equus quagga* (B_A = 0.09±0.10), *Connochaetes taurinus* (B_A = 0.06±0.10), *Syncerus caffer* (B_A = 0.07±0.09), *Kobus ellipsiprymnus* (B_A = 0.00) and *Oryx beisa* (B_A = 0.07), which have a diet composed mainly of C_4 grass (varying from 92 % to 100 %), consumption of leaves and fruits were low (p_i = 0-3% and 0-8 %, respectively). In the browser guild we have data only for *Giraffa camelopardalis* (B_A = 0.67±0.25) feeding on 52% of leaves and 36 % of fruits, and, in the mixed-feeder guild are *Loxodonta africana* (B_A = 0.83±0.14) and *Diceros bicornis* (B_A = 0.82±0.22), which fed similarly on C_4 grass (p_i = 20-22 %), fruits (p_i = 36 %) and leaves (p_i = 42-44 %). *Hippopotamus amphibius* (B_A = 0.63±0.22) fed more on C_4 grass (p_i = 58 %), and values attributed to fruits and leaves (p_i = 31 and 11 %, respectively) could be C_3 aquatic plants. Our results are in agreement with the feeding habits of the meso- and megaherbivores from Africa, showing that the proposed approach opens new possibilities to refine the isotopic reconstruction of the diet of extinct large herbivore taxa.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

HIGH RESOLUTION REMOTE SENSING APPLIED TO PALEONTOLOGY: CASE STUDIES FROM SATELLITE IMAGERY AND CONVENTIONAL CAMERA PHOTOS

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We present two remote sensing methods used to enhance the probability of fossil discovery in the field.
The two methodologies depend on either the use of high-resolution satellite images or standard camera photos; the former procedure allows researchers to work from the office and is applicable to large tetrapods, while the latter is important during fieldwork to identify middle- and small-size fossils that are exposed at the surface.
Both approaches use intrinsic properties of fossils and their spectral signatures (i.e., the visible and invisible wavelengths in response to solar irradiation) to compare them to the same information from surrounding sedimentary matrices. Where the contrast is detectable, it is possible to infer the position of the fossil in an image of the original depositional scene.
We applied this method to different paleontological contexts in terms of chronology and exposed organisms. The selected localities are the Pisco Basin of Peru (Eocene and Miocene marine mammals), the John Day Fossil Beds of Oregon, U.S.A. (Oligocene medium and small mammals), and Petrified Forest National Forest of Arizona, U.S.A. (Upper Triassic petrified logs).
After spatial computation, we obtained maps of probability predicting where fossils will be detected, and we tested our results through field collection of GPS data as well as visual mapping.
This approach represents a new frontier for fieldwork in terms of discovery of remote, previously unknown fossiliferous localities. It also has important potential for prompt recovery of new specimens with a huge increase of efficiency, allowing scientists to collect specimens before the effects of weathering or illegal collecting remove the specimens from the record. Similarly, it has great potential for land managers monitoring known fossiliferous localities.

Grant Information:
This project is part of a collaboration between the Ca' Foscari University of Venice and the University of Oregon. It has received funding from the EU H2020. Grant No 785821.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

U-PB (CA-TIMS) AGE CONSTRAINTS ON THE MIDDLE PERMIAN LAND VERTEBRATE EVOLUTION FROM THE MAIN KAROO BASIN, SOUTH AFRICA

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The tetrapod fossil record from the Beaufort Group in the Karoo Basin is an invaluable window into tetrapod evolution from the Guadalupian (mid-Permian) to the Middle Triassic. Apart from forming a reference biostratigraphy for correlation with basins elsewhere in Gondwana and the world, the abundance of fossil material and the relative continuity of the succession mean that the Beaufort Group provides a unique natural laboratory for exploring patterns and possible drivers of evolution near the end of Paleozoic. Recently, this line of enquiry has been greatly facilitated by absolute age constraints resulting from a series of high-precision radioisotopic ages for several Permian assemblage zones. As of yet, the established geochronology encompasses the Lopingian (late Permian) and latest Guadalupian part of the sequence, leaving the age and duration of the two oldest and stratigraphically-thickest biozones (i.e., the *Eodicynodon* and *Tapinocephalus* assemblage zones) loosely constrained. Over the past 4 years, we have analyzed zircons from eight tuffaceous horizons from various parts of the Guadalupian Abrahamskraal Formation using the U-Pb CA-TIMS method. These have provided a series of temporally congruent ages that provide robust constraints on the age of the *Tapinocephalus* Assemblage Zone. They also constrain the lowest occurrence of the dicynodont *Diictodon feliceps*, which can be used to differentiate the *Tapinocephalus* Assemblage Zone. Our results clarify the age and duration of the *Tapinocephalus* Assemblage Zone within the Capitanian Stage and further enhance the timeline for the rise of large therapsids in the Permian.

Grant Information:
National Research Foundation (NRF), the DST/NRF Centre of Excellence in Paleosciences, and the Paleontological Scientific Trust (PAST).

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 2:00 PM)

AN EXTINCT SPECIES OF *PROSOBONIA* FROM HENDERSON ISLAND.

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Polynesian sandpipers are small scolopacid waders restricted to remote Pacific islands of eastern Polynesia. Very little is known about their evolutionary history. Only one of the four often recognised species, the Tuamotu Sandpiper *Prosobonia parvirostris*, is still extant. Two of the extinct species are now only represented by paintings: the Christmas Sandpiper *P. cancellata* and the Mo'orea Sandpiper *P. ellisi*. Whether these taxa are conspecific with *P. parvirostris* and the Tahiti Sandpiper *P. leucoptera*, respectively, has often been debated. This taxonomic uncertainty, arising from the lack of (type) specimens, also complicates the identification of skeletal remains from nearby islands. Bones of presumably extinct species of *Prosobonia* have been recovered from the Southern Cook Islands (Mangaia), the Marquesas, and Henderson Island (Pitcairn Group). Multiple skeletal elements belonging to the latter have been recorded. We describe this material in detail and compare it with a comprehensive sample of extant scolopacids and, as far as it is possible, to other Polynesian sandpipers. Despite the close proximity of the Tuamotu Islands to the Pitcairn Group, the species from Henderson clearly differs from *P. parvirostris* in overall leg morphology and other details. Differences with *P. leucoptera*, represented only by one mounted specimen, are more difficult to establish and are therefore restricted to measurements. The phylogenetic relationship between species of *Prosobonia* and other scolopacid waders has so far been somewhat uncertain. Previous analyses of mitochondrial and nuclear gene sequence data recovered a close relationship to other sandpipers and species of *Arenaria* (turnstones), but exactly how they relate to members of this group has remained elusive. To further investigate the phylogenetic relationships of Polynesian sandpipers, we sequenced mitochondrial genomes for *P. parvirostris* and *P. leucoptera*. Based on molecular and morphological data, we provide an evolutionary framework for Polynesian sandpipers.

Grant Information:
VDP and PS were supported by the Marsden Fund (Grant CTM 1601) administered by The Royal Society of New Zealand Te Aparangi.

Technical Session VI (Thursday, October 10, 2019, 8:45 AM)

DENTAL TOPOGRAPHIC EVOLUTION IN RODENTS ACROSS THE EOCENE-OLIGOCENE BOUNDARY IN THE FAYUM DEPRESSION, EGYPT.

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On northern continents, the Eocene-Oligocene boundary (EOB) marked a change from relatively warm and humid environments to relatively cooler and drier habitats, and coincided with well-documented faunal turnover events. This climate shift and its effects on mammalian evolution are less well-understood in Africa. The Fayum Depression of northern Egypt has yielded rodent fossils from several Eocene and Oligocene horizons (ranging in age from ~37 to ~29 Ma) that document the evolution of multiple lineages before and after the EOB. Here we analyze dental topographic variables in these lineages to investigate rodents' evolutionary response to climate change in this part of northern Africa.
Crown morphologies of the second mandibular molar of 21 Fayum rodent species ($\bar{n} = 3$, range = 1-9) were quantified using dental topographic methods. Each tooth was micro-CT scanned and digital models were cropped along the cervical margin, simplified, and smoothed to the same resolution. The variables DNE (curvature), OPCR (complexity), RFI (relief index), and crown area were quantified and analyzed using ANOVAs, PCAs, and ancestral

reconstructions (phytools) in R. The ancestral conditions for DNE and OPCR were close to the average values for the entire sample, and similar to the values observed in one of the oldest Fayum phiomorphs (*Protophiomys*). Multiple phiomorph lineages diverged from this generalized pattern of dental topography to either lower or higher complexity and curvature. The evolution of tooth types with higher complexity and curvature occurred in multiple lineages independently; first in the gaudeamurids, and, post-dating the extinction of that group in the early Oligocene, in *Metaphiomys*. In general, dental complexity is low at L-41 (terminal Eocene, ~34 Ma). Despite this, L-41 rodents display an increased diversity in tooth types following the local extinction of anomaluroid rodents, exceeding the variation observed at the ~37 Ma locality BQ-2 (with or without anomaluroids). This level of dental topographic diversity remains constant across the EOB in Oligocene rodents. Ancestral reconstructions of the lineages that persisted into the Oligocene show a great range in crown area size, but a restricted range of complexity and curvature that cluster around the mean values for the entire sample. These results suggest that rodent lineages with relatively generalized and unspecialized crown morphologies were able to persist through the climatic fluctuations of the early Oligocene, whereas highly specialized lineages were prone to extinction.

Grant Information:
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Technical Session XV (Saturday, October 12, 2019, 9:00 AM)

THE EARLIEST KNOWN OCCURRENCES OF AN EDENTULOUS FROG AND POSSIBLE SIRENID SALAMANDER FROM THE CLOVERLY FORMATION (ALBIAN) OF WYOMING, U.S.A.

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Ongoing study of two taxon- and specimen-rich vertebrate microfossil bonebeds in the Lower Cretaceous (Albian) Cloverly Formation of the Bighorn Basin, Wyoming, U.S.A., has revealed several new lissamphibian occurrences. Here we report on two new taxa that provide important temporal range extensions for their respective groups.
First, a distinctive edentulous anuran maxilla represents the oldest-known toothless frog, predating the next-oldest example from North America, *Tyrrellbatrachus* (middle Campanian, Alberta, Canada), by approximately 30 million years, as well as the oldest edentulous anuran globally, *Saltenia* from the Santonian–Campanian of Argentina. The new maxilla exhibits a unique combination of features that also differ from those of the third edentulous anuran from North America (*Theatonius*: late Campanian, Utah and late Maastrichtian, Montana and Wyoming, U.S.A.), indicating that the Cloverly anuran represents a new genus. Second, several small atlantal centra preserve diagnostic features of the Santonian–Paleocene sirenid salamander *Habrosaurus*, including i) an articular surface for the skull that is continuous across the paired anterior cotyles and anterior and lateral surfaces of the odontoid process, and ii) dorsoventrally depressed, mediolaterally broad, and anteriorly flattened anterior cotyles. However, the odontoid process of the Cloverly taxon differs in being shallower dorsoventrally and in having a midline vertical indentation anteriorly. If confirmed, this would mark the earliest-known occurrence of an unequivocal sirenid, extending the clade's range back more than 25 million years.
The Cloverly Formation also has yielded early representatives of other Late Cretaceous lissamphibian groups in recent years, including a new albanerpetontid species, batrachosauroidid and scapherpetontid salamanders, and multiple toothed frogs (e.g., cf. *Scotiophryne*). Taken together, these occurrences indicate a substantially older emergence of the Late Cretaceous lissamphibian fauna in North America, which retained a relatively stable higher-level composition through the end of the Mesozoic. The co-occurrence of these taxa in two Early Cretaceous-aged fossil sites suggests that Late Cretaceous lissamphibian macroevolution in Western North America largely occurred in place, rather than as a result of sequential invasions over time.

Grant Information:
Small Grant, NMNH, Smithsonian Institution

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

COMPATIBILITY OF THE PATTERNING CASCADE MODEL OF TOOTH DEVELOPMENT WITH PERIPTYCHID "CONDYLARTH" MOLAR DIVERSITY

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Dental morphological characters have long been considered informative in the reconstruction of relationships among extinct taxa. However, the reliability of characters in phylogenetic analysis is reliant on their independence from other characters, and current understanding of the tooth developmental program suggests that many elements of the tooth crown are not independent. The patterning cascade model (PCM), a framework for understanding the origins of cusps and cusp layouts, predicts that cusp occurrence, size, and positioning are developmentally linked as the growth of one cusp inhibits cusp formation in the surrounding region. The PCM has been shown to be consistent with cusp arrangement in individual extant taxa, but data on PCM agreement with changes across an evolutionary radiation are lacking. To this purpose, cusp number, size, and appearance were tracked across the radiation of the Periptychidae, a "condylarth" family found throughout the Paleocene and Eocene. The periptychid radiation included changes in both body size and diet with accompanying variety in tooth morphology, but the basic tooth layout remained similar throughout, making the family ideal for assessing the predictions of the PCM. Three-dimensional measurements were taken of periptychid molars using a digital microscope in order to assess how size and placement of cusps varied across the radiation. Most aspects of periptychid cusp positioning show similar trends to those observed in other taxa, but some morphological features are distinct to the clade. On the upper molars, there is frequently buccal displacement of the protocone relative to the lingual margin. The PCM predicts that such displacement will reduce inhibitory effects on the lingual area of the crown, and here, that is observed in the presence and degree of expression of the protostyle. On the lower molars, cingulid expression and the appearance of a mesiolingual cingular cusp are similarly linked to the buccal displacement of the paraconid. The compatibility of cusp arrangement among the Periptychidae with the predictions of the PCM is useful in evaluating whether the PCM is appropriate to apply to extinct lineages, and raises questions about how to incorporate small, potentially convergent dental characters into phylogenetics.

Technical Session XX (Saturday, October 12, 2019, 2:30 PM)

3D LIMB BIOMECHANICS OF THE STEM-ARCHOSAUR *EUPARKERIA CAPENSIS*

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Archosaurs are a diverse group of reptiles, originating shortly before the Triassic period and radiating rapidly after the Permo-Triassic mass extinction event. In the Triassic they explored disparate morphologies in the pelvis and ankle, which led to different locomotor types and body plans throughout their evolutionary history. The diverse skeletal morphologies in Triassic archosauriforms had an undeniable influence on their locomotion, however the implications for specific functions are still poorly understood. Early archosaurs and sister taxa to Archosauria are essential to understand the evolution of the different locomotor adaptations; however, quantitative locomotor biomechanics studies of extinct archosaurs have so far focused almost exclusively on non-avian dinosaurs. Here, we present the first detailed, quantitative and 3D investigation into the locomotory abilities of the Middle Triassic stem-archosaur *Euparkeria capensis*. Micro-computed tomography scans of multiple specimens from South Africa enabled the reconstruction of the limbs of *Euparkeria* in unprecedented detail and the characterization of previously unknown morphological features. A composite pelvic girdle and hindlimb were created to accommodate for any missing or only partially preserved elements and/or taphonomic distortion. The bones of the individual specimens were scaled isometrically to match those of the holotype. To test previous qualitative hypotheses regarding posture, gait and stance of *Euparkeria*, the mobility of the hindlimb was assessed by quantifying the maximal joint ranges of motion (RoM) in 3D. Two sensitivity analyses were performed to account for the unknown amount of epiphyseal cartilage and the restricting influence of soft-tissue. Due to the medially expanded femoral head and the distinct supra-acetabular rim, *Euparkeria* seems to have been capable of adopting a more crocodile-like "semi-erect" posture, which is further supported by our RoM analysis. The femur could be fully adducted and the feet positioned underneath the body. This is consistent with other evidence

suggesting that the common ancestor of archosaurs had a similar ability to adduct the hindlimbs into less sprawling poses. However, hip (and hence limb) abduction remained feasible, so more sprawling poses were not excluded by our analysis—the hip was quite mobile. Further analyses including moment arms of muscles across the RoM are enabled by this new dataset, and with more taxa we could better reconstruct the evolution of limb function in Archosauria in the future.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

REPLACEMENT OF ARTIODACTYLS FOR PERISSODACTYLS IN THE CENOZOIC MAMMALIAN FAUNAS OF THE TIBETAN PLATEAU

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The Tibetan Plateau has an abundant and distinctive biodiversity, among which mammals hold a very important position. In the modern mammalian fauna of the Tibetan Plateau, artiodactyls are highly diversified with 27 species, but only one perissodactyl species *Equus kiang* lives. In geological records, on the contrary, the earliest mammalian fossil discovered in the Tibetan Plateau is a perissodactyl specimen of Brontotheriidae indet. from the Eocene deposits of the Lunpola Basin in northern Tibet. Since the Miocene, the composition of mammalian faunas has been rich gradually, in which perissodactyls always were important members, such as *Plesiaceratherium* sp. of the Early Miocene Lunbori fauna, *Acerorhinus tsaidamensis* and *Hispanotherium matritense* of the Middle Miocene Olongbuluk fauna, *Hipparion xizangense* and *Chilotherium tanggulaense* of the early Late Miocene Bulong fauna, *Hipparion teilhardi*, *H. weihoense*, *H.* cf. *H. chiai*, *Chalicotherium brevirostris*, *A. tsaidamensis*, and *Dicerorhinus ringstroemi* of the early Late Miocene Toson Nor fauna, *Hipparion forstenae* and *Chilotherium xizangensis* of the late Late Miocene Woma fauna, *Hipparion zandaense* and *Coelodonta thibetana* of the Pliocene Zanda fauna, *Proboscidipparion pater* and Rhinocerotidae indet. of the Pliocene Yuzhu fauna. Compared with the modern fauna, it shows that brontotheres, chalicotheres, and rhinocerotids had lived in the Tibetan Plateau, but all of them were extinct or disappeared, and only equids survived. The success of artiodactyls in competition with perissodactyls is due to the complicated digestive system of the former, i.e., their ruminant four stomach chambers and related intestinal system. The complicated ruminant digestion is exactly the advantage of artiodactyls: they can fast eat plenty of grass and leaves in a hurry before coming of powerful predators, and then rapidly escape from a dangerous area and reach a safe place where they can be ruminant to chew carefully and digest fully. This adaptation and strategy of artiodactyls have a clear superiority in the late Cenozoic when the open grassland expanded constantly. The Tibetan Plateau reached the modern elevation in the Pliocene, so this area became open alpine grassland. As a result, artiodactyls with the ruminant advantage completely won the ecological competition with perissodactyls. It was a representative case that the woolly rhino was replaced by the yak because both of them had a common ecological niche in the Quaternary cryospheric environment of the Tibetan Plateau.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A MIXED ASSEMBLAGE OF PALEOCENE MAMMALS FROM THE SAN JUAN BASIN, NEW MEXICO, U.S.A.

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The Paleocene Nacimiento Formation in the San Juan Basin (New Mexico, U.S.A.) preserves a detailed record of the mammal faunas following the Cretaceous-Paleogene mass extinction and is composed of alternating mudstones, siltstones, and sandstones from alluvial floodplain deposits. New Mexico Museum of Natural History and Science (NMMNH) locality L-1079 is at a shallow pan on the East Flank of Torreon Wash, a few meters below the Ojo Encino Member, near the top of the Torrejonian 6 (Tj6, *Mixodectes pungens* [M] zone, 62.28 Ma) biozone, and is notable for its abundance of fossils.

We studied 166 teeth studied to characterize the mammalian fauna of the site which has a minimum number of individuals (MNI) of 24. The most common taxa are the phenacodontid *Tetraclaenodon puercensis* and the pantodont *Pantolambda bathmodon* with a MNI of 5 and 4 individuals, respectively. The next most abundant taxa are *Mimotricentes subtrigonus* and *Promioclaenus lemuroides* (MNI = 2 individuals). Other taxa present include *Dissacus navajovius, Mioclaenus turgidus, Acmeodon secans, Conoryctes comma,* and *Periptychus carinidens*. Multituberculate teeth, a tooth of *Swaindelphys encinensis* (a metatherian), crocodile vertebrae and osteoderms, squamate vertebrae, and turtle shell fragments are also present. The presence of gar scales indicates that the quarry assemblage has had some freshwater influence. The relative abundances of the taxa at this site (*P. bathmodon* = 17%, *T. puercensis* = 21%, *M. subtrigonus* = 8%) are not congruent with the overall M-zone abundances observed in the basin (*P. bathmodon* = 5%, *T. puercensis* = 30%, *M. subtrigonus* = 15%). Therefore, *Pantolambda bathmodon* is overrepresented in the L-1079 assemblage while taxa like *T. puercensis* and *M. subtrigonus* are underrepresented.

L-1079 can be regarded as mixed assemblage due to time-averaging because the bluff overlying the locality samples across up to 10 meters of stratigraphy. However, the abundant teeth and postcranial bones of *P. bathmodon* at L-1079 originate from a <1 m thick horizon approximately 3-4 m above the pan. Although fragmented by recent erosion, the postcrania from *P. bathmodon* belong to Voorhies Groups I, II, and III. The mixed grouping indicates that the pantodonts in the quarry are not from a lag deposit, nor have the bones been transported a long distance. Minimal transport processes acted on these animals after death. *P. bathmodon* is generally rare within the M zone, but locally abundant at L-1079. This assemblage provides evidence that *P. bathmodon* potentially exhibited gregarious behavior.

Grant Information:
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Symposium: Quarternary Extinctions (Friday, October 11, 2019, 2:15 PM)

DROUGHTS KILL: THE PALEOECOLOGY OF A LATE PLEISTOCENE MASS DEATH ASSEMBLAGE (LANCEFIELD SWAMP) IN AUSTRALIA WITH IMPLICATIONS FOR TODAY

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The Lancefield Swamp site in Victoria, Australia is thought to be a Late Pleistocene mass death assemblage of kangaroos, with ~1000 bones per square meter recovered across a 30m diameter area. The high fatality rate of kangaroos at this site has been thought to have resulted from either drought or predation, although evidence is equivocal. If drought was a primary driver of this mass death assemblage, that knowledge is critical for understanding the consequences of climate change on extinct and extant megafauna. Here, we carried out a multi-proxy approach using dental microwear texture analysis, dental mesowear, and stable carbon isotopes to assess the dietary behavior of the macropodids (kangaroos and relatives) and diprotodontids (giant wombat-like marsupials) found at the site, including the most abundant taxon, *Macropus giganteus titan.* All taxa examined here are dominant C_3 consumers, with *Sthenurus* sp. consuming vegetation from denser cover (significantly lower $\delta^{13}C$ values than all other taxa), and *Diprotodon optatum* consuming vegetation from more open environments than all taxa (including *Macropus giganteus titan*, *Protemnodon* sp., and *Zygomaturus trilobus*, which all have mean $\delta^{13}C$ values that are significantly higher and lower than *Sthenurus* sp. and *Diprotodon optatum*, respectively). Dental mesowear is indistinguishable between all macropodids, which indicates that these taxa processed similar levels of abrasives on or in vegetation consumed. Dental microwear textural attributes (anisotropy and complexity) of *Macropus giganteus titan* were also compared to extant *Macropus giganteus* specimens that died during normal years (i.e., culled specimens) or died during a pronounced drought event (i.e., skulls collected from drought killed individuals). *Macropus giganteus titan* is characterized as having high complexity and low anisotropy, statistically indistinguishable from extant drought killed kangaroos and consistent with the consumption of less preferred woody browse during a massive drought at Lancefield Swamp—consistent with other geological and taphonomic evidence. Understanding the conditions during which these macropodids and diprotodontids died is critical to understanding the vulnerabilities of ancient and modern taxa, of relevance to today. Further, this provides additional evidence that even "arid" adapted

animals remain vulnerable to droughts and that droughts as a major contributor of megafaunal extinctions, cannot be ruled out.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

NEW INFORMATION ON THE HINDLIMB OF *DIMETRODON TEUTONIS*, A PELYCOSAURIAN-GRADE SPENACODONTID SYNPASID FROM THE EARLY PERMIAN BROMACKER LOCALITY OF CENTRAL GERMANY, AND SMALLEST KNOWN SPECIES OF *DIMETRODON*

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The Bromacker locality, in the Tambach Formation (middle Early Permian Artinskian), lowermost formational unit of the Upper Rotliegend Group or Series, in the mid-region of the Thuringian Forest of central Germany preserves a diverse vertebrate assemblage of strictly terrestrial tetrapods including microsaurian, amphibamid, and trematopid amphibians, diadectomorphs, captorhinimorph and bolosaurid reptiles, and three different taxa of pelycosaurian-grade synapsids. The latter include the only known occurrence of the sail-backed *Dimetrodon, D. teutonis,* outside of North America, a new primitive caseid, and the varanopid *Tambacarnifex unguifalcatus.* The distal end of an isolated left femur that was recovered prior to the formal description of any of the synapsids at the Bromacker locality is clearly pelycosaurian in nature. Assuming that it does not represent an entirely newly taxon, it is presumably representative of one of these three taxa. The specimen preserves the anterior and posterior distal condyles and base of a robust femoral shaft. The partial specimen is approximately 3.4 cm in length, suggesting an approximate length of the elements between 7.5 and 8.0 cm. This length is not inconsistent with the femora of the new caseid, but the condylar processes are much better developed than in the caseid. The single specimen of the German varanopid *Tambacarnifex* preserves the partial impression of a femur approximately 9.0 cm in length. Two specimens of *Dimetrodon* are known from the Bromacker. Measurements of the tibia and fibula of the larger of the two *Dimetrodon* specimens suggests a match closer to that of the specimen described here. Thus, despite that no femora were found with either of the definitive *Dimetrodon* specimens, it is likely that the partial femur may be considered a third. If this assignment is correct, the size of the partial femur still supports: (1) earlier analysis of *D. teutonis* as the smallest of known *Dimetrodon* species, estimated at approximately 24 kg; and (2) that the varanopid *Tambacarnifex* is that largest known predator of the strictly terrestrial, upland ecosystem represented at the Bromacker locality.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

THE EARLIEST OCCURENCE OF MULTI-CUSPED DENTITION WITHIN CROCODYLOMORPHA

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Fossil crocodylomorphs express a complex dental morphology that is not present in extant members of their group. To date, complex dentition within fossil crocodylomorphs has mostly been documented within Notosuchia from the Cretaceous Period. Within early branching crocodyliforms it has been only documented in specimens from the Early Jurassic Kayenta Formation of Arizona commonly referred to as the "Kayenta form", in *Edentosuchus tienshanensis* from the Early Cretaceous of China, and in Late Jurassic shartegosuchids of Asia and North America.
Here we report a new crocodylomorph species (UCMP 130082) recovered from higher up in the Kayenta Formation in Arizona. UCMP 130082 is a small-bodied crocodyliform that exhibits heterodonty and significantly more complex multi-cusped post-caniniform teeth than has been documented within basal Crocodyliformes. The posterior mandibular and maxillary teeth are ovate with numerous small cusps, and the teeth are arranged oblique to the axis of the bones. Anterior molariform teeth are dominated by a single central cusp and posterior teeth by three central cusps, and cingular cusps become larger in more posterior teeth. The teeth are similar to the multi-cusped teeth of *Edentosuchus tienshanensis* than to the bicuspid teeth of the Kayenta form.
A phylogenetic analysis of UCMP 97638 finds it as closely related to the Kayenta form within a monophyletic Protosuchidae. The presence of a complex dentition together with derived palatal structures and a unique craniomandibular articulation allows us to speculate that protosuchids inhabited an ecological niche that is not presented within any other crocodylomorph group.

Grant Information:
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Technical Session X (Friday, October 11, 2019, 9:15 AM)

DEVONIAN BIOGEOGRAPHY: EVALUATING DATA AND AREAS

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The work of Arthur J. Boucot (1924-2017) is foundational to Devonian biogeography. Cited over 1000 times and mentioned over 105, 000 times, his classification of the Old World, Eastern Americas, Malvinokaffric realms and constituent units have become the framework for Devonian biogeographic and faunal studies. Established using invertebrate taxa (brachiopoda), the overlap in vertebrate patterns (e.g., Young, 2010) is yet to be considered, or mapped when the vertebrate and invertebrate data are coalesced. This study is the first to test and quantify Boucot's area classification using the distributional data of both invertebrate (trilobita, brachiopoda) and fish (placodermi, acanthodians, actinopterygii, and sarcopterygii) taxa across the Lower, Middle, and Late Devonian.
Biotic similarity analyses are used to assess the relationships of biogeographic areas and rank them within a formal hierarchy. The Temporal Area Approach (TAAp) partitions the areas and permits considerations of changing relationships through time. The biotic similarity analyses were conducted on a database, created by the authors, of 676 genera (ca. 30, 000 occurrences) from the Late Silurian and Devonian. Consequently, this study is the largest test of biogeographical areas undertaken in Devonian biogeography.
Results indicate that key Devonian areas have been misdiagnosed and may not have had the same temporal range has previously believed. Accurate diagnosis of areas is integral to biogeography. This study shows that biotic similarity and metrics of diversity are an informative supplement to area classification and can highlight areas for revision, rather than reinvention. Revision is more informative than reinvention as it allows a shared and transparent foundation upon which to build the biogeography of the future.

Grant Information:
PANGEA research centre, small research grant: $1000
Australian Government RTP: $26 000 p.a.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

COSMOPOLITAN OLIGOCENE ANURAN ASSEMBLAGES: PROXIES FOR THE EFFECTS OF CLIMATE CHANGE?

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Lissamphibian assemblages are poorly represented from the Oligocene, possibly due to increased aridity and cooling across the Eocene-Oligocene transition. It is unclear if the effects of the change in climate were widespread or localized. Anurans are sensitive to climate change, both at present and in the geologic past. Therefore, an inquiry into global Oligocene anuran assemblages was performed using public databases as well as the primary literature to establish if there were trends in the representation of lifestyles between fossil assemblages. More than thirty localities were compared.
Sites cannot be compared taxonomically across continents due to divergence of anuran groups during continental breakup events. However, lifestyle convergence occurs within populations and can be compared. Anurans have three distinct lifestyles: fossorial, arboreal, and semiaquatic. These lifestyles are determined by morphological adaptations to specific habitats and can be used as proxies for paleoenvironment. Using cluster analyses as well as two-way ANOVA, all localities, geographic regions, and latitudinal groups containing anurans were examined for lifestyle similarities and differences. Based on our knowledge of modern anuran habitat preferences, we expected that with an increase in widespread aridity and cooling, fossorial anurans

would dominate, since burrowing fauna may be less affected by surface temperature and humidity changes.
Our analyses revealed that there were more semiaquatic than fossorial and arboreal anurans overall between regions, latitudes, and sites. Geographically distant sites had similar assemblage compositions. Several sites consisted of only fossorial or semiaquatic anurans, but no locality had only arboreal taxa. Sites formed clusters of two to thirteen localities, except the only Australian (Kangaroo Well) and the only Canadian sites (Calf Creek), which did not cluster with any other locality and contained more arboreal taxa. Overall, there were no trends supporting increased representation of fossorial anurans. While anurans can be used as paleoenvironmental proxies, other factors such as preservation or collection biases may affect their utility, particularly for the Oligocene. The effects of climate change may be site-specific, as seen in the Fitterer Ranch anuran assemblage of North Dakota, U.S.A. , which indicates a more mesic environment than other areas of North America during the Oligocene. Comparing anuran assemblages across the Cenozoic is the next step in verifying utility.

Technical Session XX (Saturday, October 12, 2019, 3:15 PM)

LIMB OSTEOLOGY AND PROBABLE DIGGING ADAPTATIONS IN THE AETOSAUR *STAGONOLEPIS OLENKAE* (ARCHOSAURIA: PSEUDOSUCHIA) FROM NORTHERN PANGEA

DRÓŻDŻ, Dawid, Institute of Paleobiology, Warszawa, Poland; SULEJ, Tomasz, Institute of Paleobiology, Warszawa, Poland

Aetosaurs are armoured basal archosaurs that played a significant role in land ecosystems during the Late Triassic (237-201 Ma). The species *Stagonolepis olenkae* Sulej, 2010, found in Krasiejów (southern Poland) is one of the oldest known representatives of the group. Abundant and well-preserved material, including partially articulated specimens, allows for a detailed description of limbs in this species.
The pelvis of *Stagonolepis olenkae* has iliac blades extending laterally allowing for a pillar erect gait, which is unexpected in an early aetosaurs, and similar to derived ones like *Desmatosuchus smalli* and *Typothorax coccinarum.*
Both forelimbs and hind limbs were entirely covered by appendicular osteoderms of round or ellipsoid shape, including the autopodia, which was never observed in any other aetosaur species.
Complete limb material of *Stagonolepis olenkae* allowed for a review of digging ability in this species. We found several adaptations that are usually associated with fossorial animals in reference to limbs.
Stagonolepis olenkae could apply large forces with its limbs which is suggested by the proportions of the limb parts (in both forelimbs and hind limbs the zeugopodia are much shorter than the stylopodia, and the autopodia are shorter than zeugopodia – excluding terminal phalanges); well-developed, enlarged muscle attachments of muscles usually associated with digging:in forelimbs – a prominent deltopectoral crest that extends distally on the humerus (insertion of deltoid) and a wide prominent entepicondyle (flexor of digits), a relatively long olecranon process (triceps), and in hind limbs – a prominent iliofibularis trochanter located in the middle section of fibula and a deep groove at the corresponding level on tibia (probably the attachment for iliotibiales); morphology of autopodium characteristic for diggers – presence of fused radiale and intermedium bone in carpus (stiffening of carpus), short, robust and flattened metacarpals and phalanges, hooked, laterally compressed, claw-like unguals with ornamentation of small pits (indicative of well-developed keratin sheaths).
We suggest that limbs of *Stagonolepis olenkae* were adapted for scratch-digging in a way similar to modern specialized mammals like pangolins, armadillos or aardvarks. *S. olenkae* might have used its robust limbs to break through the compacted soil with its claws and proceed to dig in search of food in softened substrate with the shovel-like expansion at the tip of its snout.

Grant Information:
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Technical Session XVII (Saturday, October 12, 2019, 8:15 AM)

PERINATAL REMAINS SHOW THAT NON-AVIAN AND AVIAN DINOSAURS NESTED IN THE LATE CRETACEOUS PALEO-ARCTIC OF NORTHERN ALASKA

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The Prince Creek Formation of northern Alaska preserves arguably the richest assemblage of terrestrial vertebrates known to have existed at high paleolatitudes (80-85 °N) during the Late Cretaceous. The non-avian and avian dinosaurs inhabiting this forested polar ecosystem would have benefited from seasonally abundant resources provided by several months of continuous summer daylight and warm temperatures (MAT = 6 °C). Correspondingly, winter conditions would have posed challenges to their life history strategies due to four months of complete darkness and occasional snowfall. Given these strongly contrasting seasonal constraints, it has been hypothesized that non-avian dinosaurs either undertook arduous long-distance migrations, perhaps nesting in the Arctic, or alternatively, were year-round residents that overwintered at high paleolatitudes. Direct evidence for either theory in the form of fossils demonstrating reproductive behaviors in the Prince Creek Formation has been lacking. Here, we report on the occurrence of perinatal (late embryonic to immediately post-hatching) non-avian and avian dinosaurs from the PCF, demonstrating polar reproductive behaviors. Perinatal and hatchling-sized teeth and bones were recovered from two recently discovered microvertebrate assemblages exposed along the Colville River. These include diagnostic remains from a diverse array of ornithischian and saurischian clades represented by hadrosaurids, thescelosaurids, ceratopsids, leptoceratopsids, tyrannosaurids, troodontids, dromaeosaurids and avialans. These findings, coupled with prolonged incubation periods for non-avian dinosaurs that limited temporal windows for both migration and reproduction, suggest those dinosaurs were year-round polar denizens. The high degree of dinosaur endemism in the PCF fauna as well as histological differences seen in the PCF dinosaurs compared to those of lower latitude taxa, further support these findings.

Grant Information:
This project was supported by NSF-EAR awards 1226730 to G.M. Erickson and P. Druckenmiller and 1736515 to G.M. Erickson and P. Druckenmiller and J. Eberle.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

TESTING THE EFFECTS OF PROXY SELECTION ON BITE-FORCE ESTIMATES GENERATED USING INDENTATION SIMULATIONS

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Bite-force estimates provide insight into cranial function and associated feeding behaviors. These estimates can be reached in many ways, the most common methods involving direct measurements from modern species or appropriate analogs and anatomical models derived from the mechanical properties of hard and soft tissues. An underused method for estimating vertebrate bite forces is simulation of conditions that formed known feeding traces. In such studies, a model of a tooth is indented normally into a prey proxy at a biologically conservative loading rate, and the associated forces are recorded through use of a mechanical loading frame. This method has been applied to dinosaurian-based studies, but the value of these simulations relies on proper association of trace with trace maker as well as selection of an appropriate prey proxy. Previously, cow (*Bos taurus*) long bones have been used as analogs for dinosaurian prey based on their large size, similar cortical bone thicknesses, and comparable micro-architectures. However, structural

differences between major vertebrate lineages may introduce complications when utilizing established simulation frameworks on non-dinosaurian prey. To test whether proxy clade or proxy bone thickness affects indentation simulation results, we built upon a previous study simulating *Deinonychus antirrhopus* bite marks on *Tenontosaurus tilletti* long bones. The original study used cow femora as a prey proxy; we further sampled *Odocoileus virginianus* (white-tailed deer), *Alligator mississippiensis* (American alligator), and *Dromaius novaehollandiae* (emu) to explore the effects of taxon selection on this type of analysis. We performed ordinary least squares (OLS) regressions on each taxon's dataset and compared them using an analysis of covariance (ANCOVA). This failed to yield statistically significant differences between the proxies, with the caveat that support for the emu and alligator OLS regressions were comparatively low, most likely due to higher rates of breakage during simulations using these physically smaller, more thinly-walled samples. The results of an OLS regression on the pooled dataset yielded broadly comparable results to the initial study based on only cow bones. This suggests that a primary goal of simulation studies is controlling for cortical bone thickness, regardless of phylogeny, gross morphology, or bone micro-structure. This opens up the potential for taxonomically far broader application of tooth indentation simulations than has been considered previously.

Grant Information:
Oklahoma State University Center for Health Sciences Department of Anatomy and Cell Biology

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

THE PRE-SCIENTIFIC USES OF FOSSIL SHARK'S TEETH

DUFFIN, Christopher J., Sutton, Surrey, England

Fossil sharks' teeth were referred to in pre-scientific literature as *Glossopetrae* because their shape resembled that of a tongue. Pliny the Elder was the first to mention them, stating in his *Naturalis Historia* (circa 73 AD) that they were believed to fall from the sky. Medieval lapidaries ascribed various amuletic powers to them, including the ability to confer honest and graceful speech to those that owned them. The double-pronged root morphology of certain lamniform teeth called to mind the forked tongue of a snake. By the doctrine of signatures, this suggested that the teeth might be effective at resisting poisons. From the 13th to the late 17th centuries, specimens had their roots encased in silver mounts suitable for wearing as pendants or, more commonly, suspending from elaborate items of tableware. Royal, noble and papal inventories all record mounted 'serpents' tongues' for use on *natternzungenbaum* or *languiers*, part of the complex system in place to prevent assassination at mealtimes. The teeth were believed to indicate the presence of poison at the table either by sweating when brought close to contaminated food or drink, or changing colour when dipped into poisoned wine. Large teeth of *Otodus megalodon* were particularly popular for this purpose and Malta supplied the apothecaries of Europe with specimens collected mainly from the Phosphorite horizons of the Globigerina Limestones (Miocene). Handbills proclaiming the virtues of the teeth and other Maltese geological medicinal simples were produced in a variety of languages. Petrus Christus' famous painting (1449, Metropolitan Museum of Art) of a goldsmith's shop in Bruges depicts two mounted glossopetrae hanging on the back wall of the artisan's premises. Powdered fossil sharks' teeth were occasionally incorporated into alexipharmic medicines, especially the synthetic *Lapis de Goa*, exported from India to the shops of Europe via Lisbon. 18th and 19th century rosary-like *Fraiskette* or 'convulsion chains', confined to the Austro-Bavarian region, occasionally included shark-tooth amulets. The chains were placed on the bedstead or worn around the necks of young children in order to prevent teething problems, fevers, epilepsy and various evil influences. Fossil sharks' teeth are known from numerous archaeological sites, including gold-mounted specimens from Etruscan graves (4th to 5th century BC), particularly in Italy.

Technical Session XV (Saturday, October 12, 2019, 11:30 AM)

FILLING OLSON'S GAP? A RE-APPRAISAL OF *RARANIMUS DASHANKOUENSIS* (SYNAPSIDA, THERAPSIDA) USING CT SCANNING TECHNOLOGIES AND BAYESIAN ANALYSIS.

DUHAMEL, Aliénor E., University of the Witwatersrand, Johannesburg, South Africa; BENOIT, Julien, University of the Witwatersrand, Johannesburg, South Africa; RUBIDGE, Bruce S., University of the Witwatersrand, Johannesburg, South Africa; LIU, Jun, Chinese Academy of Sciences, Beijing, China

Non-mammalian Therapsida is a paraphyletic group of Permian-Jurassic amniotes closely related to mammals. Understanding the origin of Therapsida is complicated by the existence of a phylogenetic gap in the fossil record termed Olson's gap. Because of its assumed low stratigraphic occurrence and basal phylogenetic position, *Raranimus dashankouensis*, from the Dashankou fauna, Qingtoushan Formation, China, is the best candidate to fill this gap. However, its phylogenetic position as the basal-most therapsid, recovered using traditional cladistic analyses, is contentious.
Our results obtained from Micro-CT scanning shows that *Raranimus* has five therapsid synapomorphies, the most obvious being a shortened contact between the maxilla and the prefrontal. However, the presence of plesiomorphic characters, such as the presence of a precanine caniniform tooth, manifest retention of typical "pelycosaur" grade features. The maxillary canal morphology of *Raranimus* is comparable to that of the "pelycosaur" *Varanosaurus* and the biarmosuchian *Herpetoskylax*. Overall, this confirms a basal position for *Raranimus* in the therapsid phylogenetic tree. New data on the age of the Qingtoushan Formation indicates a Roadian age for *Raranimus*, simultaneously filling 'Olson's gap' and confirming that the genus is critical in understanding the evolutionary radiation at the base of therapsids.
Applying Bayesian analytical techniques for the first time on non-mammalian synapsids, we present a new tree supporting previous conjectures of the basal position of *Raranimus* among therapsids.

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Technical Session II (Wednesday, October 9, 2019, 10:45 AM)

DESCRIPTION OF FIRST NEORNITHISCHIAN DINOSAUR CRANIAL MATERIAL FROM THE ERIC THE RED WEST LOCALITY (EUMERALLA FORMATION: UPPER APTIAN–LOWER ALBIAN), CAPE OTWAY, VICTORIA, AUSTRALIA

DUNCAN, Ruairidh J., Swinburne University of Technology, Melbourne, Australia; POROPAT, Stephen F., Swinburne University of Technology, Hawthorn, Australia; RICH, Thomas H., Museum Victoria, Melbourne, Australia

The diversity of small-bodied basal neornithischians in the Early Cretaceous dinosaur assemblages of Victoria (southeast Australia) is uncommonly high. To date, five genera have been named from two formations that together span approximately 20 million years (upper Barremian–lower Albian): the Eumeralla Formation (upper Aptian–lower Albian) in the Otway Basin has yielded *Leaellynasaura amicagraphica*, *Atlascopcosaurus loadsi* and *Diluvicursor pickeringi*, whereas the upper Strzelecki Group in the Gippsland Basin has produced *Qantassaurus intrepidus* and *Galleonosaurus dorisae*. The holotype specimens of four of these taxa include (or solely comprise) dentulous cranial elements, and only one (*L. amicagraphica*) has been suggested to also include postcranial elements, although this association has been contested. By contrast, the fifth taxon, *Diluvicursor pickeringi*, lacks cranial remains, having been established on the basis of an articulated skeleton comprising a partial right hind limb and tail. This specimen, from the Eric the Red West locality in Cape Otway, is clearly different from the postcranial remains assigned to *Leaellynasaura*.
Neornithischian skull elements are relatively rare in the Victorian Cretaceous, but these are particularly informative from a phylogenetic standpoint. We describe the first neornithischian cranial material from the Eric the Red West locality (Eumeralla Formation), which is stratigraphically younger than Point Lewis (the *A. loadsi* type site) and older than Dinosaur Cove (the *L. amicagraphica* type site). This material comprises a premaxilla, seven maxillae, eight dentaries and numerous isolated teeth. To date, *Diluvicursor pickeringi* is the only neornithischian taxon to have been described from the Eric the Red West locality. Consequently, it is possible that one or more of the dentulous elements in our sample might pertain to this taxon. Although this cannot be established with certainty, what can be determined is whether any of the already named taxa from the Victorian Early Cretaceous are present at Eric the Red West. If so, then the probability that *Diluvicursor* is a junior synonym of an existing taxon will be able to be assessed. Preliminary observations of the specimens in question suggest that at least one of the specimens is somewhat *Galleonosaurus*-like. This is potentially of great significance, since the stratigraphic range of this taxon would then extend from the upper Strzelecki Group to the Eumeralla Formation, as also seems to be the case with *Atlascopcosaurus*.

Technical Session XII (Friday, October 11, 2019, 9:00 AM)

CLIMATE AS A MAJOR CONTROL ON EARLY DINOSAUR GLOBAL DISTRIBUTION

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During their rise to ecological dominance, the spatiotemporal patterns of dinosaur diversity are hypothesized to have been intrinsically linked to environmental conditions. For example, sauropodomorph dinosaurs are proposed to have been absent from low latitude regions in the Late Triassic due to 'unstable' climatic conditions, but in the Early Jurassic they have a more global distribution. However, these hypotheses proposing climate-driven paleolatitudinal structuring of early dinosaur faunas remain largely untested, in part due to the absence of paleoclimate data with sufficient temporal and spatial coverage to examine diversity across large intervals of deep time. To test hypotheses linking dinosaur diversity with climate during the Late Triassic and Early Jurassic, we used, for the first time, the results of a spatially-explicit general circulation climate model combined with a comprehensive dataset of global early dinosaur occurrences from the Paleobiology Database and a supertree of early dinosaur species relationships. We explored the effects of climate on dinosaur global distribution and evolution by mapping climatic variables as continuous characters onto the supertree, testing different potential models of climate niche evolution, and examining climate niche disparity through time. Our results document a general shift in the Early Jurassic towards warmer, drier areas for sauropodomorphs and ornithischians. In the Late Triassic dinosaurs preferentially occupied wetter and cooler environments and sauropodomorphs occupied areas with significantly lower mean annual temperatures and high seasonal temperature ranges. However, in the Early Jurassic, dinosaurs, and sauropodomorphs specifically, occupied environments that are climatically similar to those occupied by other tetrapods. There is considerable variation in environmental conditions in the areas occupied by dinosaurs in the Late Triassic, suggesting that major clades were not restricted by climatic conditions at this time. In contrast, in the Early Jurassic, there is less variation across the major clades. Using phylogenetic generalized least squares models we found statistical support for dinosaur diversity being constrained by climatic conditions. This work provides the first quantitative support for paleoclimate as a major control on the global distribution of early dinosaurs

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

STABLE ISOTOPE ANALYSES (&[DELTA] ^{13}C, &[DELTA] ^{18}O) OF FOSSIL REPTILE REMAINS FROM THE GRAY FOSSIL SITE, SOUTHERN APPALACHIANS, TENNESSEE

DURHAM, Travis L., East Tennessee State University, Johnson City, TN, United States of America

Stable isotopes of reptile bioapatite have the potential to better define the climate and ecology of the early Pliocene Gray Fossil Site (GFS) in northeastern Tennessee. Stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes from fossil *Alligator* tooth enamel and bone from *Hesperotestudo* and *Trachemys haugrudi* were compared to modern *Alligator mississippiensis* taxa from Georgia, *Trachemys scripta scripta* and *Gopherus polyphemus* from Florida. The $\delta^{13}C$ of carbonate from GFS fossil bioapatite is, overall, less negative than the bioapatite of modern samples. GFS $\delta^{13}C$ *Alligator* values are also similar to Miocene *Alligator* from Florida. More negative $\delta^{18}O$ in GFS bioapatite suggests cooler Pliocene temperatures in comparison to the modern dataset and Miocene Florida. Overall, stable isotopes of bone and enamel CO_3 from GFS reptiles, in combination with local mammalian faunal and pollen samples, suggests that the early Pliocene paleoclimate in eastern Tennessee was cooler than other fossil and modern sites, even sites with a similar herpetofauna. This may also explain the reduction in size of *Alligator* specimens from the GFS compared to larger specimens from fossil and modern sites that likely dwelled in habitats with higher median temperatures.

Grant Information:
Funding for analyses was provided by the Don Sundquist Center of Excellence in paleontology at East Tennessee State University.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

DIRECT ESR DATING OF THE LATE MIDDLE PLEISTOCENE VERTEBRATE ASSEMBLAGE FROM KHOK SUNG LOCALITY, THAILAND

DUVAL, Mathieu, Griffith University, Brisbane, Australia

Southeast Asia, and Thailand in particular, is a region of great importance for the study of Pleistocene migration pathways of large mammals between South China and Java. However, the number of paleontological sites identified in this area is very limited, and most of them have not been independently dated by means of numerical methods.
The present study provides a small contribution to the big picture by giving direct ages for the fossil assemblage from Khok Sung locality, Thailand, which was found in a peculiar open-air environment (i.e., within fluvial deposits), while most of the sites in this area are found in caves. In total, five fossil teeth have been selected from the fossiliferous Unit F and dated by means of the combined U-series and Electron Spin Resonance dating approach (US-ESR).
Dating results are overall consistent to provide a late Middle Pleistocene age estimate for the fossil assemblage, suggesting a correlation to the MIS7. These results make Khok Sung locality one of the very few sites numerically dated in Thailand. This is also probably the only Middle Pleistocene fossil assemblage for which a direct and finite numerical age is available.
Full details about the work may be found in the following publication:
Duval M., Fang F., Suraprasit K., Jaeger J.-J., Benammi M., Chaimanee Y., Iglesias Cibanal J., Grün R. (submitted). Direct ESR dating of the late Middle Pleistocene vertebrate assemblage from Khok Sung locality, Nakhon Ratchasima Province, Northeast Thailand. *Submitted to Paleontologia Electronica.*

Technical Session XII (Friday, October 11, 2019, 12:00 PM)

HISTOPATHOLOGY OF A PACHYCEPHALOSAUR FRONTOPARIETAL DOME

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Paleontologists have debated the function of the pachycephalosaur frontoparietal dome, with the most prominent hypothesis being that the dome was used in intraspecific head-butting combat. Combative behaviours are likely to damage bone, making paleopathology a useful tool in assessing the behaviours of fossil vertebrates. Previous studies utilized CT scans to identify pathologic woven bone remodeling and sclerosis (pathologic dense bone) in the lesion floors of numerous frontoparietal domes. These histopathologic features were used to diagnose such pathologies as osteomyelitis (bone infections that can form after trauma), which was used to support the hypothesis that pachycephalosaurs used their domes in intraspecific head-butting combat. However, CT scan resolution is often too coarse to identify tissue-level, pathologic features such as woven and sclerotic bone. Therefore, closer tissue-level examination is required to diagnosis osteomyelitis in pachycephalosaur domes. This study used micro-CT scans and thin-sections to test for histological evidence of bone resorption (a response to bone infection), secondary woven bone, and sclerosis in UALVP 8504 (cf. *Foraminacephale*), a suspected pathologic dome from the Dinosaur Park Formation, which possessed external lesions morphologically consistent with previously diagnosed osteomyelitic specimens.

Micro-CT scans produced insufficient resolution for histological analysis, possibly due to the state of preservation of UALVP 8504. Thin-sections of UALVP 8504 revealed Howship's lacunae (a histologic feature of bone resorption) along the floors of its lesions, confirming a pathologic origin. However, secondary woven bone and sclerosis were not identified in thin-sections, falsifying the diagnosis of osteomyelitis. However, the vascularized region (Zone II) of UALVP 8504 exhibits massive bilateral bone remodeling structures. Normally, this region is devoid of major remodelling. Bone remodeling frequently forms to repair microfractures and/or fatigue fractures. The remodeling structures in UALVP 8504 are oriented in the direction of strain that would form from head-butting, and where traumatic microfractures would form. As the bone remodeling indicates that the dome experienced substantial trauma, it's likely that the external pathologies also have a traumatic origin, potentially ulcerative dermatitis (skin infection). The histopathology of UALVP 8504 thus provides some of the most direct evidence of head-butting combat behaviours in pachycephalosaurs.

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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

AUTOPODIA OF PHYTOSAURIA ARE CONSERVED WITHIN THE CLADE AND MAY REPRESENT THE ANCESTRAL CONDITION IN ARCHOSAURIA

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Manus and pes morphology includes key features for understanding archosaur phylogeny, evolution of anatomical systems, and biomechanical transitions. Whereas the ankle and pes received much attention, the manus has not, largely because it is poorly represented in early-diverging archosaurs and stem archosaurs. Moreover, of the few archosaur species that have a manus preserved, few have both the pes and the manus preserved in the same individual. Within Phytosauria there is a complete absence of diagnostic cranial material associated with nearly any hands and feet, which affects our knowledge of the plesiomorphic condition for Archosauria. Here we describe the right manus and pes of the well-preserved phytosaur *Machaeroprosopus pristinus* (UCMP 27235) in order to aid in resolving details of some of the postcranial anatomy within Phytosauria and across archosaurs. UCMP 27235 is a nearly complete articulated skeleton and material includes all of the metatarsals with many associated phalanges as well as the astragalus. The astralagus has a shallow anterior hollow, and the 5th metatarsal is hooked; these characteristics are shared across *Smilosuchus*, *Parasuchus*, and *Diandongosuchus*, demonstrating conserved morphology of the foot of Phytosauria. Of the five metacarpals present, metacarpal three is longest, then the fourth, second, first, and the fifth is the shortest. The first metacarpal articulates to a dorsoventrally compressed ungual. In *M. pristinus* the length of the longest metacarpal is 0.6 that of the longest metatarsal, whereas in *Diadongosuchus* the ratio is 0.51. *M. pristinus* lacks carpals, and the only other manus of a phytosaur described in detail, that of *Parasuchus hislopi*, also lacks carpals, meaning it is possible that these structures never ossified in phytosaurs. Additionally, the absence of ossified carpals and tarsals in UCMP 27235 appears to be shared by all phytosaurs and may indicate that cartilage was a critical factor in the morphology and functionality of the hand and foot in this clade. Furthermore, it may be a signal of semiaquatic ecology. Phytosaurs appear to modify the carpals through clade evolution, but the overall architecture of the hand appears to reflect the ancestral condition for Archosauria.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

CHONDRICHTHYANS AND OSTEICHTHYANS FROM THE LATE CRETACEOUS (CAMPANIAN) ELLISDALE SITE, MONMOUTH COUNTY, NEW JERSEY

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The Ellisdale site, Monmouth County, New Jersey, represents a rich and diverse late Cretaceous (Campanian) fauna from the Marshalltown Formation. This unique locality preserves marine, freshwater and terrestrial taxa, making it one of the most complete glimpses into the paleoecology and biodiversity of the North American subcontinent of Appalachia. The site represents a mixture of marine, lagoonal, estuarine and terrestrial paleoenvironments which date to the middle Campanian. When the Ellisdale site was discovered in 1980, vertebrate taxa recovered included chondrichthyans, osteichthyans, amphibians (frogs and salamanders), reptiles (lizards, turtles and crocodilians), dinosaurs and mammals. Most collecting at the site was done with traditional bulk sampling and screen-washing of matrix. While some sizeable pieces of bone and teeth are occasionally recovered, a majority of the remains are micros. After a 25 year hiatus, active collecting and research of the Ellisdale Site resumed in 2018 yielding many new specimens in a previously uncollected region.

An update to the known chondrichthyan and osteichthyan fauna at Ellisdale is more diverse than previously reported. Representing both marine and freshwater taxa, cartilaginous fish remains include teeth, vertebrae, denticles, cephalic claspers and prismatic cartilage. The diversity of chondrichthyans includes hybodontiform, squatiniform, and lamniform sharks. Batoid remains are further refined and comprise Rajiformes, Myliobatiformes, and Sclerorhynchiformes. The chimaeriform, *Ischyodus bifurcatus*, has also been recovered. Osteichthyan fossil remains include marine and freshwater teeth, vertebrae, skull and jaw material, otoliths and scales. Bony fishes identified from the Ellisdale fauna now include members of the Salmoniformes, Ichthyodectiformes, Pycnodontiformes, Lepisosteiformes, Amiiformes and Acipenseriformes. A majority of the specimens, teeth in particular, are small in size consistent with a low velocity environment and the jagged fragmentary nature indicates specimens have not undergone substantial transport. Thus, given the high volume of small, complete teeth and vertebrae, it is possible that a paleoenvironmental reconstruction of the Ellisdale site might have acted as a refugium for juvenile cartilaginous and bony fishes.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

OSTEOSARCOMA IN A DINOSAUR: A DIAGNOSIS CONFIRMED THROUGH GROSS, RADIOGRAPHIC, AND HISTOLOGIC EXAMINATION

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Osteosarcoma is a rare tumour that affects a wide variety of animals including humans and avian theropods (birds). Others have reported findings suggestive of cancer in dinosaur bones, however no study has been able to histologically confirm the diagnosis. Here we describe a histologically confirmed case of osteosarcoma in a pathological fibula from the ceratopsian dinosaur *Centrosaurus apertus* (Ornithischia: Ceratopsidae). The specimen consists of the distal half of an adult *Centrosaurus* fibula collected from a monodominant bonebed in the Dinosaur Park Formation (Campanian). The specimen was compared to a human fibula with a confirmed osteosarcoma. Both specimens underwent micro computed tomography (micro-CT) as well as microscopic histological examination.

Gross examination of the dinosaur specimen reveals a tumour that takes up the proximal half of the specimen, located about 150mm from the normal, distal end of the bone. The mass measures 155mmx92mmx61mm. The compact bone covering the tumour is quite thin in some places, suggestive of neocortex formation. The micro-CT scan of the dinosaur specimen reveals a Codman triangle, which is indicative of periosteal invasion of the tumour. The histological examination demonstrated a lack of zonation with bone maturation that would be seen if the lesion were a fracture callus, and evidence that the tumour extends throughout the cortex of the bone (confirmed on histological and radiological examination). In addition, there was evidence of extensive and multifocal penetration and destruction of the cortex by architecturally abnormal neoplastic bone with islands of normal bone visible. These findings were consistent with the human fibula specimen with a confirmed diagnosis of osteosarcoma.

The gross, radiographic, and histologic appearance of the dinosaur fibula were identical to the human osteosarcoma, despite the lack of preserved soft tissue structures in the former. We conclude that, with a similar degree of certitude as would be possible in an extant animal, this dinosaur bone demonstrates an osteosarcoma and thus represents the first histologically confirmed case of cancer in a dinosaur. Our findings confirm that dinosaurs suffered from malignancies, and suggest that the exceptionally fast-growing bones of dinosaurs may be particularly prone to the development of osteosarcoma - in the same manner that this tumour commonly occurs in humans.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

ICTHYOFAUNAL COPROLITES FROM THE LATE EOCENE DEPOSITS OF THE FAYUM DEPRESSION, EGYPT

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Coprolites (fossilized fecal pellets) often contain food residues, parasite remains and other fossils that provide an important window into paleoecology and the diets of ancient organisms. Although considerable research has been devoted to the study of Paleogene vertebrates from the Fayum Depression of Egypt, little attention has been paid to their fossilized excreta. Here we present the first study to investigate and describe coprolites of carnivorous fishes from the late Eocene Fayum site Birket Qarun Locality 2 (BQ-2). In recent years, more than 100 coprolite specimens have been collected from BQ-2. The collected material includes a wide range of sizes, shapes and both complete and fragmentary specimens. Surface-collected coprolites from BQ-2 include

no bone fragments, which might indicate a weathering bias. Many of the BQ-2 coprolites have a variety of bone inclusions and bear outer and inner spiral morphology. The latter were generated by intestinal spiral valves and distinguish the digestive tracts of some fishes. Some BQ-2 coprolite specimens appear as white pellets that include many bone fragments of fishes, suggesting piscivorous producers with low digestive efficiency. Coprolites that preserve fish bones include spine, scale, vertebra and bone fragments. In some specimens, very delicate and well-preserved fish scales were found, which have never been recovered via surface collecting. These scales could prove to be important for documenting seasonal variation in climate at BQ-2, and might also help to classify some of the BQ-2 fish fossils. Continued study of coprolites from BQ-2 and other Fayum localities will help to illuminate the evolution of food webs in this part of Egypt, notably across the Eocene-Oligocene boundary.

Grant Information:
Mansoura University Research Fund; Leakey Foundation

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

NEW PERCOMORPH FISH FROM THE LATE EOCENE QASR EL-SAGHA FORMATION, FAYUM, EGYPT

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Fossil fishes previously reported from Eocene–Oligocene formations of the Fayum Depression, Egypt, include numerous taxa, such as catfishes, lungfishes, and elasmobranchs. In addition, several percomorph fishes have been reported, with cichlids, *Lates* and *Parachanna* represented in the predominantly freshwater Jebel Qatrani Formation, and *Diodon, Egertonia, Sphyraena* and *Xiphiorhynchus* recorded from the underlying marine deposits of the Qasr el-Sagha Formation. *Sphyraena* and *Diodon* have also been recovered from the older deposits of the Birket Qarun Formation, along with two more percomorphs, *Cylindracanthus* and *Weilerichthys*. Most of these percomorph fishes are represented by fragmentary remains such as teeth, vertebrae and isolated skull bones, with crania known only for *Lates, Parachanna, Weilerichthys,* and *Ctenodentex*, none of which have been reported from the Qasr el-Sagha Formation. Another Cenozoic percomorph taxon from Africa represented by crania is *Semlikiichthys*, from Miocene deposits of the Lake Albert–Lake Edward Rift and Chad. We here report a new percomorph fish collected from sediments of the type section of the Qasr el-Sagha Formation. The new specimen can be clearly distinguished from all previously reported percomorph crania from the African Cenozoic. It differs from *Lates, Weilerichthys* and *Semlikiichthys* by having a shorter and deeper ethmoid region, from *Parachanna* by having prominent frontoparietal crests, and from *Ctenodentex* by having a rectangular profile with a downturned ethmoid region and elongate basioccipital region. The rectangular profile with downturned snout is similar to serranids, but the laterally expanded vomer is more similar in morphology to the Sciaenidae, but it lacks the cavernous canals of that group. The new percomorph possesses a prominent intercalar, the parietal bones are present and there are strong fronto-parietal crests extending from the posterior edge of the parietals to the middle of the frontals above the middle of the orbit, and the supraoccipital meets the exoccipital bones ventrally. The combination of these features indicates the new fish is related to members of a restricted Perciformes (which may not be monophyletic). In addition, the specimen has a distinctly shaped vomerine head that is laterally expanded with an anterior concavity and no teeth, and has a strongly slanted occipital region with the exoccipitals extending significantly posterior to the level of the pterotics. We consider this specimen to represent a new taxon, with relationships currently unknown.

Grant Information:
Mansoura University Research Fund; Leakey Foundation

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

BODY SIZE CHANGES ACROSS LIZARDS AND CROCODYLIANS CORRESPOND TO CLIMATIC CHANGES THROUGH THE PALEOGENE IN THE WESTERN INTERIOR OF NORTH AMERICA

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Climate is known to influence body size in living reptiles. However, body size changes in response to climatic transitions have not been investigated in extinct reptiles over deep time intervals, nor compared among higher-order groups of reptiles. Here I test the hypothesis that body size range undergoes holistic, synchronized change in lizards and crocodylians in response to climatic transitions over geologic time scales. I sampled dentary length as a proxy for body size in lizards and crocodylians from intermontane basins in the Western Interior of North America through the Paleogene, spanning several warming and cooling periods. The range of dentary length increases in both lizards and crocodylians in the early Eocene. Maximum dentary length doubles relative to the middle Paleocene (25mm vs. 60 mm in lizards, 260 mm vs. 500 mm in crocodylians) and remains elevated through the Eocene. Meanwhile, minimum dentary length remains consistent through the Paleogene in both groups (approximately 10 mm in lizards, 50 mm in crocodylians). This pattern is observed without a consistent latitudinal gradient across intermontane basin communities through the Paleogene. The observed changes in maximum dentary length correspond to changes in mean annual paleotemperature in the Western Interior through the Paleogene. These results suggest that climatic changes may drive overall body size changes in lizards and crocodylians over deep time scales.

Grant Information:
This work was supported by the UC Museum of Paleontology, SVP, Geological Society of America, Evolving Earth Foundation, Sigma Xi, & Burke Museum of Natural History and Culture.

Romer Prize Session (Thursday, October 10, 2019, 8:00 AM)

HETEROGENEOUS EVOLUTIONARY RATES DURING THE FIRST HALF OF TERRESTRIAL TETRAPOD EVOLUTION

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Body size is a fundamental trait of all animals that is linked to metabolic rate, physiology, life history, and fitness. The body size of terrestrial early tetrapods, the four-limbed vertebrates, spanned several orders of magnitude during the first half of their evolutionary history (~385 Ma to 174 Ma). Previous studies of body size evolution in early tetrapods focused on single clades or did not incorporate phylogenetic information. Other studies have suggested that the long-term success of clades was related to rapid rates of (body size) evolution. Using a phylogenetic comparative approach here I present a comprehensive study of evolutionary rates of body size in early tetrapods including all valid terrestrial tetrapod species from the Middle Devonian to the Early Jurassic.

I find overwhelming support for heterogeneous evolutionary rates of body size in terrestrial early tetrapods and a rate pattern akin to the Simpsonian concept of ‘quantum evolution’. Several clades of terrestrial early tetrapods are characterised by an explosive increase of evolutionary rates on single branches. These quick bursts in evolutionary rates are followed by a nearly instantaneous return to ‘baseline’ rates indicating the transition to a new adaptive zone. I find no evidence for an ‘early burst’ (EB) type of evolution with initially high evolutionary rates followed by exponentially decreasing rates.

Temporal trends of evolutionary rates indicate that rates were the highest for the clade Tetrapoda during the Permo-Triassic mass extinction event (PTME). Additional rate peaks were recovered during the late Carboniferous and the early Jurassic. Archosauromorphs, which replaced temnospondyls, therapsids, and parareptiles as the dominant component of terrestrial ecosystems after the PTME, were significantly more likely to exhibit lower evolutionary rates than the less successful clades. Similarly, the more successful non-avian dinosaurs were more likely to have low evolutionary rates compared to pseudosuchians. Elevated evolutionary rates were therefore not necessary for the rise to dominance of archosauromorphs and dinosaurs. High rates of body size evolution do not seem to have conferred a long-term evolutionary advantage in terrestrial early tetrapods.

These results call into question the general idea of clade success being linked to high evolutionary rates and resulting ‘evolvability’. Rates of body size evolution in terrestrial early tetrapods often seem to be connected to stress rather than to long-term success.

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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

INFERRING DIETARY ADAPTATIONS OF PALEOCENE STEM MACROSCELIDEA BY DENTAL TOPOGRAPHY ANALYSES.

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Modern macroscelideans are fully terrestrial, mainly insectivorous and low in diversity. Macroscelidea is known from the Eocene, but several Paleocene mammalian families are considered as stem Macroscelidea, which show a variety of different tooth morphologies. In order to infer dietary adaptations for these stem Macroscelidea, we conducted dental topography analyses, which provide quantitative data on the occlusal surface shape and are informative for dietary categorization. We used three metrics: ariaDNE (a robustly implemented algorithm for Dirichlet energy of the normal), RI (Relief Index) and 3D OPCR (3D Orientation Patch Count Rotated). Micro-CT scans of second lower molars were used to generate three-dimensional dental surface models for the analyses. For this study species from the following families were studied: Adapisoricidae, Apheliscidae, and Louisinidae from the Paleocene of Alberta and Walbeck. Their dentitions range from conservative to slightly modified tribosphenic morphologies, some have acute-cusped and distinctly crested cheek teeth (e.g., *Litocherus*) whereas others (e.g., *Prolouisina*) have bunodont tooth crowns with reduced crests and bulbous cusps.

The RI values of all taxa are below the threshold of extant insectivorous mammals, but the 3D OPCR values nevertheless indicate an insectivorous diet. The lowest RI values show *Adapisorex* spp. within the range of omnivorous taxa, although the cusps of *Adunator* and *Walbeckodon* are more bulbous than those of *Adapisorex* with conical cusp shape. The RI and ariaDNE mean values of the *Adapisorex* spp. vary significantly and show a strong taxonomic signal. The lowest ariaDNE values show *Prolouisina* spp. with low RI values, which are associated with frugivorous and omnivorous taxa.

Our results indicate that none of the studied taxa have been exclusively insectivorous, although early diverging taxa have a stronger tendency towards insectivory, but at the same time, there are frugivorous and omnivorous species present. The studied taxa are all terrestrial and of similar small body size. The different dietary preferences helped to avoid competition for resources.

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Technical Session II (Wednesday, October 9, 2019, 8:45 AM)

A HIGH-LATITUDE ORNITHOPOD AND THEROPOD ICHNOFAUNA FROM THE LATE CRETACEOUS WAPITI FORMATION OF ALBERTA, CANADA

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Abundant dinosaurian tracks complement the often fragmentary skeletal record and provide the possibility to study dinosaurs from a social and behavioural perspective. In 2018, the Boreal Alberta Dinosaur Project (BADP) investigated a large in-situ dinosaur track site within the Wapiti Formation (Campanian–Maastrichtian), near the Alberta/British Columbia border in western Canada. Nicknamed Tyrant's Aisle, the track site spans more than 110 m along the Red Willow River and contains more than 100 individual tracks, distributed across at least three stratigraphic horizons. An *Edmontosaurus*-dominated locality a few km to the west yielded an Ar/Ar age of 72.58 +/- 0.09 Ma, thus the track site is here considered as late Campanian in age. Examination of the tracks reveals an ichnofauna dominated by hadrosaurids, whose prints are assignable to *Hadrosauropodus* based on their typically greater width than length, broad digit impressions, rounded or bi-lobed heels and inward foot rotation. At least three types of theropod are represented: a tyrannosaurid, an indeterminate small tridactyl theropod, and a didactyl morphotype that probably represents a troodontid due to the presence of a relatively short digit IV. The last morphotype constitutes the first troodontid track record from North America. While the majority of tracks recorded at the site are isolated, the presence of aligned hadrosaurid and small theropod trackways suggests social behaviour in each group. Tyrannosaurid tracks from the site are smaller than previously described examples from the Wapiti Formation, which have been assigned to the ichnospecies *Bellatoripes fredlundi*, yet they were likely produced by earlier ontogenetic stages of the same track maker based on stratigraphic near-equivalence and geographic proximity. These tracks provide insights into the pedal ontogeny of a tyrannosaurid and support hypotheses of ontogenetic gait shifting that postulate greater agility and possible cursoriality for juveniles. Relatively increased digit width and an expanded heel pad at larger track lengths also agree with previous skeletal observations that indicate proportionately greater bulk in tyrannosaurids during adulthood. Overall, the locality is congruent with the body fossil record of the upper Wapiti Formation, which is indicative of a hadrosaurid-dominated assemblage on the high paleolatitude (~63°N) floodplains of central-western Alberta during the late Campanian.

Grant Information:
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Technical Session IV (Wednesday, October 9, 2019, 4:00 PM)

A UNIVERSAL POWER LAW FOR THE GROWTH AND FORM OF TEETH, CLAWS, HORNS, THORNS AND BEAKS

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An immense diversity of pointed structures is found throughout biological systems, including teeth, claws, horns, thorns and beaks. While the shapes of some of these structures have been attributed to a logarithmic (or equiangular) spiral, these structures generally do not fit this pattern very well. Here we show a new model of growth and shape based on a power law that generates accurate representations of teeth from all vertebrate groups (Mammalia [Marsupialia, Artiodactyla, Carnivora, Cetacea, Chiroptera, Primates, Proboscidea], Reptilia [Squamata, Dinosauria, Sauropterygia, Ichthyosauria], Aves [*Ichthyornis*], Osteichthyes and Chondrichthyes). For instance, growth of unicuspid teeth as diverse as those found in *Homo sapiens* (R^2 = 0.998), *Smilodon fatalis* (R^2 = 0.999), *Tyrannosaurus rex* (R^2 = 0.998), and *Carcharocles megalodon* (R^2 = 0.997) are extremely well described by this model. It can even be used to describe the growth of individual cusps on multicuspid teeth (such as human molars or seal postcanines), as well as the variation of tooth shape along the tooth row (such as crocodiles and seals) and within species. Additionally, the model can predict the original shape and length of worn and broken teeth, and represents the shape of cusps more accurately than existing *in silico* models of tooth development. We view this model as the third general model of tooth development, along with the patterning cascade model for cusp number and spacing, and the inhibitory cascade model that predicts relative tooth size. Beyond dentitions, the model also depicts growth of claws (Mammalia and Dinosauria), horns (Artiodactyla, Dinosauria and Testudines), beaks (Aves and Cephalopoda), chelicera fangs (Arachnida), and thorns (Plantae). This model provides a mechanistic basis for the generation of these pointed structures across the tree of life.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 9:15 AM)

NEW INSIGHTS INTO THE EVOLUTION OF SECONDARILY MARINE LIFESTYLES, MARINE ADAPTATION, AND DIVERSIFICATION OF TURTLES

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Evolutionary transitions to marine habitats occurred frequently among Mesozoic reptiles, but chelonioid sea turtles are the only clade that survives to the present. Thus, chelonioids provide the chance to investigate macroevolutionary questions, such as the mode and tempo of morphological evolution during this ecological transition informed by total evidence approaches that integrate fossil and recent data. However, uncertainties about turtle phylogeny, particularly the relationships of several secondarily marine groups from the Mesozoic have prohibited a rigorous assessment of divergence times of marine clades, and of patterns of flipper evolution.

I address these issues by reconciling previously available data with novel observations based of a large database of 3D cranial models derived from

>150 CT scans of living and extinct turtles. This resulted in a dataset of 120 taxa and 355 characters, formulated using a consistent coding strategy that accounts for hierarchical homologies of observed variation. Parsimony and Bayesian phylogenetic analyses, incorporating explicit statistical hypothesis tests demonstrate that two major clades (outside pleurodires) evolved a secondarily marine lifestyle: chelonioids and angolachelonians. Angolachelonians comprise all non-pleurodiran marine Mesozoic–Paleogene turtles. The chelonioid crown-group evolved during the early Late Cretaceous, and their stem group extends into the Early Cretaceous by inclusion of protostegids. The general flipper morphology of chelonioids was established early on their stem-lineage, and further morphological innovations appeared at the origin of extant subclades Cheloniidae and Dermochelyidae. Americhelydians, i.e., chelonioids plus their extant sister clade, the chelydroids, are inferred to have a North American origin, but geographic expansion of protostegids occurred rapidly during the Early Cretaceous. The inference of an earlier diversification of americhelydians implies that crown-clades of turtles in general diversified earlier and faster than previously thought. My findings indicate that a total of three independent origins of marine life in Jurassic–Cretaceous turtles gave rise to speciose, long-lived clades (chelonioids, angolachelonians, bothremydid pleurodires). All three clades survived the K/Pg boundary, indicating high survivorship compared to other marine reptiles. Angolachelonians and bothremydids become extinct by the early Neogene, coincident with global cooling, and only chelonioids survived to the present.

Grant Information:
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Technical Session XII (Friday, October 11, 2019, 8:30 AM)

CRACKING THE EVOLUTIONARY AND DEVELOPMENTAL LINK BETWEEN BRAIN AND SKULL IN ARCHOSAURIA: EVOLUTIONARY AND DEVELOPMENTAL PERSPECTIVES

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The brain has a primacy in early cranial development. Extant birds underwent an enlargement of the brain in comparison to other reptiles. This process caused important changes to the bird skull, in particular the skull roof. However, a link between the brain regions and the skull roof elements has never been formally addressed. CT scanning, immunofluorescence and confocal imaging were combined to track mesenchymal condensation and ossification patterns of the skull roof along the development of the brain in a developmental series of diapsids, including squamates, stem and crown crocodilomorphs, dinosaurs and crown avialans. Correlation tests between the boundary of brain regions and the suture between frontal and parietal were statistically significant, suggesting a deep evolutionary link. Mesenchymal cells condense early in organogenesis between the forebrain and midbrain and midbrain and hindbrain. However, it is only after establishment of the facial region and its chondrogenesis that the mesenchymal condensations of the skull roof start to express Collagen I. We found no support for Sox9 and Collagen II expression in these mesenchymal condensations. Moreover, we found no proliferation center in the skull roof, suggesting that physical variables, such as the pressure in the ventricle of the brain, are driving ossification of the dermatocranium surrounding the brain. Birds show a delayed patterning of the skull in comparison to reptiles. We suggest that this is due to the positive allometry of the bird brain, contrary to the negative trajectory observed in reptiles. We regard the skull roof as an example of non-independence character, because strongly influenced by the evolution and development of the brain. This could explain why several bones composing the braincase and not in direct contact with the brain were lost along the evolution of the main branches of Amniota.

Technical Session XV (Saturday, October 12, 2019, 8:45 AM)

RAPID MORPHOLOGICAL EVOLUTION OF THE SALAMANDER SKULL IS CORRELATED WITH DIVERSIFICATION AND DISPERSION DURING PERIODS OF GLOBAL WARMING

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A positive correlation between diversification and rate of phenotypic evolution is predicted by several evolutionary theories, from the ecological theory of adaptive radiation to the hypothesis of punctuated equilibrium. However, most studies of this effect are limited in sampling or representation of morphology. Here, we investigate the relationship between rate of morphological evolution and diversification in the salamander skull using high-dimensional surface geometric morphometrics. We digitised 88 landmarks and 495 curve semilandmarks in Stratovan Checkpoint and patched 356 surface semilandmarks using the R package “Morpho”, for a total of 939 landmarks and sliding semilandmarks that defined 14 cranial regions. These data were gathered for 148 species belonging to all extant families of salamanders and representing 90 percent of living genera. Using a recently published dated phylogeny for Caudata, we conducted analyses of taxonomic diversification and rate of cranial evolution in this dataset.
Our results demonstrate an increase of the rate of cranial evolution during the Late Cretaceous and the Paleocene-Eocene thermal maxima. These two warming events correspond to diversification and dispersal events in Caudata, as well as in several other clades, such as angiosperms, arthropods, and birds. The high diversification and rate of morphological evolution observed approximately 50 million years ago also correspond to the sole invasion of tropical regions by plethodontids, as well as to their transcontinental dispersion in the northern hemisphere. We also demonstrate that different life history strategies show distinct rates of evolution, with paedomorphic and biphasic species showing higher rates of evolution than direct developers. Interestingly, biphasic species do not appear to have achieved greater disparity than direct developers, despite their higher rate of evolution, suggesting a constraint that limits their exploration of cranial morphospace relative to the highly disparate and fast evolving paedomorphic species.
Our results demonstrate that rate of salamander cranial shape evolution increases during episodes of global warming, alongside increases in taxonomic diversification and geographic dispersal. Further analysis of fine-scale patterns of climate change, niche availability, and their interactions with life history and ecology will provide important new insights into the causes of these increased rates of evolution, diversification, and dispersal in Caudata during periods of global warming.

Grant Information:
ERC grant STG-2014–637171

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

REMOVING ASBESTOS FROM RECONSTRUCTED AREAS OF SPECIMENS AT THE SMITHSONIAN MUSEUM OF NATURAL HISTORY SAFELY AND WITH THE LEAST IMPACT TO THE SPECIMEN.

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During the recent renovation of the fossil halls at the Smithsonian Institution’s National Museum of Natural History, the process of testing for asbestos was done prior to disarticulation of the existing skeletal mounts. Three mounts tested positive for asbestos containing building material (ACBM): two *Eremotherium rusconi* skeletons and a *Mammut americanum* skeleton. These specimens contained a substance with 20 to 25% Chrysotile asbestos fiber. The ACBM was within a sculpting material (“guk”) made of plaster, papier-mâché, and Alvar (polyvinyl acetal), with asbestos fibers added to strengthen it. Guk was used in the NMNH prep lab in the 1960’s and ‘70’s to reconstruct and repair fossils, and in some cases to fill the gap where individual bones

articulated. We quickly made ourselves familiar with OSHA asbestos regulations, followed by multiple certification courses for asbestos removal and supervision. It was determined that the project would involve two separate setups for asbestos removal. A temporary enclosure was built at the museum to disarticulate the skeletons, and a permanent enclosure was built at RCI's facility where the fossils could have the asbestos remediated. The permanent facility included a decontamination shower for staff to clean the tools and themselves.
Throughout this process, several methods and procedures for isolating areas of the individual fossil elements that contained ACBM were developed. All of the procedures were done using the proper personal protective equipment (PPE). Glove bags were used for the majority of the work to further prevent and control the release of asbestos fibers. This involved inserting the fossil into a plastic and rubber bag and working on the area with the ACBM. The other parts of the fossil remained outside of the bag, removing them from the wetting process used to prevent the asbestos fibers from becoming airborne. Larger pieces were remediated in the open in the permanent enclosure. In these cases, the areas of the fossils that did not require ACBM removal were isolated with plastic sheeting. The material was removed using a combination of hand tools, such as knives, and hammers and chisels. These tools were used so no dust was generated during the remediation process. Power tools and air scribes generate airborne particulates, and are not to be used according to the OSHA guidelines. The successful goal of these methods was to reduce the amount of impact the remediation had on the fossils, while still maintaining a safe work environment.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

A NEW SPECIES OF *SAURICHTHYS* (ACTINOPTERYGII: SAURICHTHYIDAE) EXTENDS ITS GROUP'S RANGE TO THE LATE TRIASSIC IN EASTERN TETHYS

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The saurichthyiform fishes are a kind of ray-finned fishes which lived from the Upper Permian to the Middle Jurassic. Featured with a pointed rostrum and a streamlined long and slender body plan, they are considered among the top predators of the Mesozoic oceanic ecosystem. They were greatly diversified during the Middle Triassic, both in eastern and western Tethys, but appeared to vanish thereafter on both sides, with no undoubted record in the eastern Tethys for a long time. Recently, a new material of *Saurichthys* was found from the Carnian (Upper Triassic) of Yunnan province, southwestern China. This Locality yielded abundant fossil, such as marine reptiles, crinoids and countless ammonites. The material includes a nearly complete skull preserved together with some ammonites and bivalves. Based on the fairly long rostrum and some distinguishing features of the opercular bones, it is assigned as a new species of *Saurichthys*. The ammonites suggest a Carnian (Late Triassic) age for the fish.
The saurichthyiform fishes survived the end-Permian mass extinction and evolved rapidly shortly after that crisis to accomplish a world-wide distribution in the Early Triassic. They reached the diversity peak in the Middle Triassic, exemplified by nearly ten distinct taxa from the Anisian and Ladinian of Yunnan and Guizhou provinces, South China. However, they seemly 'disappeared' in this area during the Late Triassic, even in the fauna with diverse marine vertebrates. Given their contemporaneous existence in Europe, they were supposed to display a trend to shrink their marine distribution to the north-western Tethyan realm since the Middle Triassic. Our newly discovered *Saurichthys* material confirms their occurrence in the Late Triassic eastern Tethys and suggests that the saurichthyiform fishes might have a wider distribution than previously thought during that geological stage. This discovery promotes an updated understanding of the paleogeographical distribution and the evolutionary history of the saurichthyiform fishes.

Grant Information:
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The Strategic Priority Research Program of the Chinese Academy of Sciences (XDA20070203, XDB26000000)

Technical Session XII (Friday, October 11, 2019, 8:15 AM)

DINOSAURS DISPARIFY DIFFERENTLY: CONTRASTING PATTERNS OF CRANIAL VARIATION AND MACROEVOLUTION ACROSS DINOSAURS AND CROCODYLOMORPHS

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Archosaurs exhibit tremendous variation in cranial structure and function, generated through distinct developmental programmes. Moreover, archosaur clades exhibit heterogenous patterns of ecological and morphological disparity. What factors have driven these divergences across archosaurs? Using a high-dimensional surface geometric morphometric approach, we quantified 3-D skull shape evolution and integration (trait correlations stemming from genetic, developmental, or functional interactions) in avians (n=353), non-avian dinosaurs (n=37), and extinct and extant crocodylomorphs (n=45) with 757-1291 landmarks and sliding semilandmarks. Maximum likelihood and covariance ratio analysis demonstrates that all archosaurs exhibit high integration in the occipital region, but crocodylomorphs show higher integration among facial elements than dinosaurs, including birds. In contrast to non-avian dinosaurs, birds exhibit high pterygoid-quadrate integration, presumably related to cranial kinesis. Crocodylomorphs and birds similarly exhibit high disparity (quantified as Procrustes variance) in the face and low disparity in the neurocranium. The highest rates of evolution occur in the anterior rostrum of birds, but in the nasals of crocodylomorphs. Disparity and rates are largely correlated in birds and non-avian dinosaurs, but decoupled in crocodylomorphs. In particular, the crocodylomorph pterygoid displays high disparity, but low rates of evolution, suggesting that disparity in the secondary palate in this clade accumulated slowly. Non-avian dinosaurs exhibit different patterns, with elevated disparity and rates in the parietal, quadratojugal, and jaw joint and low disparity in the anterior face. This distribution is driven partially by the prevalence of cranial ornaments (e.g., ceratopsians) and variation in the temporal fenestrae. With cranial variation primarily localized to the posterior skull, non-avian dinosaurs are unique among archosaurs. This pattern likely reflects diverse "chewing" mechanisms and display structures in Ornithischia, compared to birds that are constrained by high encephalization to have limited variation in the adductor chamber. Crocodylomorphs show rapid disparification in the face, similar to birds, and slower disparification in the pterygoid related to jaw articulation and extension of the secondary palate. Combined, these results emphasize the dominance of divergent feeding mechanisms in driving disparate patterns of cranial evolution across archosaurs.

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Preparators' Session (Thursday, October 10, 2019, 4:00 PM)

GEOCHEMICAL TRACE ELEMENT ANALYSES ON FOSSIL BONE: A PROVENANCE TOOL FOR EXISTING FOSSIL COLLECTIONS WITH POORLY DOCUMENTED LOCALITIES.

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Interpreting paleobiology and paleoecology requires knowledge of depositional and fossilization environments. However, specimens from older collections commonly lack detailed provenance documentation. Such is the case with many existing collections worldwide, and is especially true of the Darling Downs region of eastern Australia. This is a major Pliocene-Pleistocene vertebrate-bearing fossil region where numerous specimens have been recovered over the past 150 years, but most lack detailed stratigraphic information. Here we applied a series of geochemical (trace element) analyses on fossil collections from two major Darling Downs locations to test if trace element signatures can provide a useful provenance tool. The first locality is a Pleistocene fluvial deposit in Kings Creek, southern Darling Downs, which

was systematically excavated and yields three stratigraphic horizons. The second location includes three Pliocene fluvial sites at Chinchilla, northern Darling Downs, where the fossils lack detailed stratigraphic context. Kings Creek fossil trace element signatures are mostly consistent, regardless of stratigraphic position or taphonomy, suggesting a similar diagenetic setting during deposition and fossilization. However, despite the consistent signature, variation was observed in some specimens from the uppermost horizon suggesting that some reworking may have occurred. Chinchilla fossil trace element signatures are more variable compared to Kings Creek, suggesting more complex site depositional processes and fossilization settings. The three Chinchilla sites share similar trace element signature variability, however, site-specific signatures also occur. There is a notable difference in geochemical signatures between the Chinchilla and Kings Creek datasets. The variability between the two localities demonstrates that trace element analyses can be effectively used to provenance Darling Downs specimens of varying ages from the existing historic fossil collections. This geochemical approach could also easily be adopted across the planet for other collections where fossils remain poorly provenanced.

Grant Information:
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Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

THE USE OF TRADITIONAL MORTARS AND HIDROFUGANTS IN RESTORATION AND PRESERVATION OF PALEOICHNOLOGIAL SITES

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La Rioja (Spain) is one of the richest areas of the world in terms of paleoichnological record, with almost 10000 dinosaur footprints and around 1000 trackways, in a surface of just around 5000 km2. This work presents the analysis and both corrective and preventive actions carried out in “La Virgen del Campo”, one of the best-known sites of this area, found in the Enciso locality (La Rioja, Spain). Many pathologies were identified in this site, that could be causing its deterioration.
First, superficial pathologies such as cracks and fractures were analyzed. They are especially important in this site conservation because of the high temperature and humidity variation, in addition to rainfall erosion and other factors that could be damaging the rock and the footprints in it. The materials and methods used in paleoichnological sites had varied in space and time due to the lack of a uniform action protocol. Considering the advances in conservation and preservation of stone monument heritage, a new protocol for La Rioja paleoichnological sites is being developed.
With this information, we performed laboratory tests on samples taken from the same geological layers of the site to verify the proper functioning of the material before the restoration work in the site. As we know the pathologies and the harm of the site, we can choose the proper materials doing the appropriated tests. There are many researches about the durability and reversibility of lime mortars. We studied different kind of mortars made of hydraulic lime and different types of aggregates, such us sand, silica and calcium carbonate. Depending on the wanted or needed result, we may choose one kind or another.
In addition, there is a problem of accumulation of water in the footprints and cracks. Moreover, sometimes the water leaks under the geological layer. This leaking is problematic because it could erode or dissolve the layer or even induce mineral precipitation that could result in fractures and cracks to the site. For this reason, we decided to test and use a hydrofugant product.
After all the laboratory tests, we performed the same analysis near the site but in the rock itself, not in samples. We applied the different mortars depending on the needs. For the correct application of the mortars by the work team, we designed a diagram with instructions for every possibility. Nowadays we are monitoring the environmental conditions and results of our work, so we can determine the efficiency and durability of this restoration in the future and add some changes if the site needs it.

Technical Session V (Wednesday, October 9, 2019, 2:15 PM)

CLIMATIC SHIFTS DROVE MAJOR CONTRACTIONS IN AVIAN LATITUDINAL DISTRIBUTIONS THROUGHOUT THE CENOZOIC

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Numerous higher-level avian clades are restricted to Earth’s lower latitudes, leading to historical biogeographic reconstructions favoring a Gondwanan origin of crown birds and many deep subclades. However, such ‘tropical-restricted’ clades are frequently represented by stem-lineage fossils well outside the ranges of their closest living relatives, often on northern continents.
To assess the drivers of these geographic disjunctions, we combined ecological niche modeling, paleoclimate models, and the early Cenozoic fossil record to examine the influence of climatic change on avian geographic distributions over the last ~56 million years. By modeling the distribution of suitable habitable area through time, we illustrate that most high latitude Paleogene fossil-bearing localities would have been suitable for occupancy by present-day 'tropical' clade representatives when the fossils were deposited. Potentially-suitable habitat for numerous higher-level clades is inferred to have become progressively restricted towards the tropics throughout the Cenozoic, culminating in relatively narrow circumtropical distributions in the present day. This pattern manifests in a pronounced sharpening of the avian latitudinal diversity gradient through the Paleogene and Neogene.
Our results support coarse-scale niche conservatism at the clade level, and are consistent with a scenario whereby climate change over geological timescales has largely dictated the geographic distributions of major avian clades. The distinctive modern bias towards high avian diversity at tropical latitudes for most hierarchical taxonomic levels may therefore represent a relatively recent phenomenon, overprinting a complex biogeographic history characterized by dramatic geographic range shifts driven by Earth’s changing climate and intercontinental dispersal. Earth’s current climatic trajectory portends a return to a megathermal state, which may dramatically influence the geographic distributions of many range-restricted extant clades.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

CREATING SCIENCE OUTREACH MATERIALS AS A TOOL FOR SCIENTIFIC LITERACY IN HIGH SCHOOL: EXAMPLES FROM PALEONTOLOGY AND NATURAL HISTORY

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Contemporary society is deeply immersed in scientific and technological cultures and, thus, access to scientific cultural goods and skills is fundamental to ensuring the full citizenship of the population. The school is the main space responsible for literacy in science, where the possibilities of mediation of new and old knowledges by teachers are open. However, it is important to note that there is often an epistemological rupture between common and scientific knowledge, which is reflected in the use of different languages and discourses by its practitioners. The consequence of this strangeness is often manifested as low levels of scientific literacy and little interest in science. The case of natural history is even more serious, as there is a growing disconnection between man and nature. The interface between students' previous conceptions about science, and everyday language is a solution for constructing scientific literacy in natural history. The Universidade Federal do Espirito Santo (UFES) and Irma Maria Horta State School developed in partnership the project "Languages, textual genres and scientific literacy in natural sciences: Paleontology as an integrating discipline". Ten high school students acted as fellows in this Junior Scientific Initiation Program creating science outreach material with an easy daily-life language and focusing on internet and social media. The students gathered in two-hour meetings, twice a week, to read about popular science, to write texts, and scripts for podcasts, to record audio, and to create board games about evolution and paleontology. Each month a new topic was discussed in the meetings, always a suggestion of the students. Among the subjects studied were the diversity of past life, major extinctions, evolution, dynamics of planet Earth, among others. Several outreach materials were created by the students (texts, podcasts, games) and made freely available on the internet (in Brazilian Portuguese) to any interested person.

Grant Information:
FAPES grant 0369/2016

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

COMPARISON OF PALEOENVIRONMENTAL AND PALEOCLIMATOLOGICAL PARAMETERS OF CORRELATIVE DINOSAUR-BEARING LATE CRETACEOUS (CAMPANIAN - MAASTRICHTIAN) ROCK UNITS ACROSS ALASKA, U.S.A. : A REGIONAL PERSPECTIVE

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The Late Cretaceous of Alaska records a remarkably diverse fossil vertebrate fauna across much of the region. Within this fauna, hadrosaurs and ceratopsians, are the most commonly found. As the largest-bodied herbivores, these two dinosaurs are likely the keystone species and their presence played a role in structuring this ancient ecosystem. The richest rock units in terms of dinosaur remains are the Prince Creek Formation (PCF), North Slope, the lower Cantwell Formation (LCF), Denali National Park, and the Chignik Formation (CF), Aniakchak National Monument, and together provide an unparalleled opportunity to examine an ancient high-latitude terrestrial ecosystem from a regional perspective.

The PCF consists primarily of small distributary channels, crevasses splays, small ponds and abundant paleosols. Megafloral remains are uncommon, but paleosols contain an abundant palynoflora. The rich dinosaur record is known largely from skeletal remains. The PCF, located at 75-85 ºN paleolatitude, had a MAT of ~ 5-6 ºC. An average MAP value of 1318 +/- 181 mm/yr was obtained from paleosol geochemical calculations. MAP estimates calculated from $d^{13}C$ data yield a low range of 350-1200 mm/yr and a high range of 1000-3900 mm/yr.

The LCF consists primarily of axial braided rivers, alluvial fans, floodplains, ponds and small lakes. Abundant plant megafossils are present but fossil pollen recovery is poor. A rich invertebrate and dinosaurian ichnofauna is known from the LCF. The LCF, located at a paleolatitude of 65-75 ºN, had a MAT of ~ 7-8 ºC. MAP estimates calculated from $d^{13}C$ data yield a range of 168-470 mm/yr during the MME, 353-1050 mm/yr before the MME, and 475-1451 mm/yr after the MME.

The CF is a cyclic succession of sedimentary rocks representing shallow marine environments in the lower part and predominantly non-marine conglomerate, sandstone, mudstone and coal. The CF, located at a paleolatitude of 56-57 ºN, had a MAT of ~ 15ºC. Woody fragments from the CF were measured for their carbon isotopic composition to relate $d^{13}C$ to mean annual precipitation. The sample analyzed from the Chignik Fm. was -24.0‰ vs. VPDB. The CF sample suggests a MAP value of 822 mm/year.

Relative abundances of hadrosaurs and ceratopsians vary somewhat along this north-south transect and different environment. Both dinosaurs are abundant from the PCF and LCF, but the CF is dominated by hadrosaurs. We suggest that the paleoclimatic and paleoenvironmental variances observed played a role in the large-bodied herbivore ecological structure of the ancient north.

Grant Information:
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Technical Session XIX (Saturday, October 12, 2019, 2:15 PM)

WANING AND WAXING MARINE REPTILE DIVERSITY PRIOR TO THE K-PG BOUNDARY

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Diverse clades of reptiles occupied the upper levels of marine food chains in the Mesozoic, an iconic peculiarity of that Era which abruptly ended at the Cretaceous-Paleogene boundary. Among these, several long-lived groups became extinct long before the end of the Cretaceous, as other groups concomitantly radiated, resulting in substantial turnover events within the Mesozoic itself. However, the biodiversity dynamics of Mesozoic marine reptiles as a whole have never been computed, so the evolution of their global diversity is poorly understood. We assembled comprehensive cladistic datasets for the major groups of Jurassic-Cretaceous marine reptiles: Ichthyosauria, Plesiosauria, Mosasauroidea, Thalattosuchia, Dyrosauridae, Hesperornithiformes, Pleurosauria, and Cryptodira. We analysed each of these datasets under a common methodological framework (implied weighting maximum parsimony) and then created 1000 supertrees randomly sampling the most parsimonious trees from each clade prior to time-calibration, under a Bayesian framework (Hedman's algorithm). We then computed the phylogenetic diversity of Mesozoic marine reptiles through time and used Fritz & Purvis'D to mesure the phylogenetic clustering of extinction at each stage boundary of the earliest Jurassic–earliest Paleogene interval. Finally, we calculated the evolution of per-clade disparity using the cladistic datasets.

Our results highlight important episodes of turnover in Middle Jurassic and earliest Cretaceous. Both are marked by high levels of extinction selectivity and temporarily reduced phylogenetic diversity; the severity of some of these events surpasses that of the K-Pg boundary extinction. The effects of a potential 'Jurassic-Cretaceous' boundary extinction were most prominent in the Valanginian, more than 6 Ma after the boundary itself. Furthermore, with more than 110 inferred lineages in the Albian, marine tetrapods were more speciose during the 'middle' Cretaceous than are today's limbed marine tetrapods. This was followed by a gradual decline, as ichthyosaurs, pliosaurids, and early polycotylids vanished, in a series of non-selective (i.e., statistically unclustered) extinctions. However, the disparity of each individual clade remains roughly constant or increases during the Late Cretaceous. The latest Cretaceous extinctions are among the most phylogenetically clustered in our dataset, consistent with the high ecological impact of the Cretaceous-Paleogene event for marine communities.

Grant Information:
MIS grant (#F.4511.19), F.R.S.–FNRS, Belgium

Technical Session I (Wednesday, October 9, 2019, 10:15 AM)

NEW MIOCENE SHARK-TOOTHED DOLPHINS FROM AUSTRALIA SHED LIGHT ON THE PHYLOGENY AND BIOGEOGRAPHY OF SQUALODONTIDAE (CETACEA, ODONTOCETI)

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The Oligocene–Miocene 'shark-toothed dolphins', including several heterodont taxa referred to the family Squalodontidae, have figured prominently in research on the evolution of Cetacea. Despite a plethora of named species, some based on relatively complete cranial remains, a rigorous diagnosis and definition of the nominal clade Squalodontidae remains elusive. Whether some, or all, nominal squalodontids represent stem or crown odontocetes is debatable. Problematically, the character-rich earbones and basicranium are unknown in most of the named species from the Northern Hemisphere.

New specimens of shark-toothed dolphins from Australia contribute to resolving these problems. One species is represented by NMV P165355 (associated partial cranium, earbones, teeth, mandible, postcrania) and NMV P232560 (associated rostrum, basicranium, earbones, teeth, mandible); collected from the Batesford Limestone (late Burdigalian, 17.5–16.0 Ma) in a quarry near Geelong, Victoria. This species is longirostrine, large (bizygomatic width ~400 mm) and has relatively small cheek teeth with small denticles and subtly ornamented crown enamel. SAM P35307 (associated cranium, earbones, teeth, mandibles, vertebrae, scapula) was collected from the upper Mannum Formation (Burdigalian, 20–16 Ma) near Blanchetown, South Australia. SAM P35307 shares several diagnostic features with *Phoberodon arctirostris* (Gaiman Formation, Burdigalian, Argentina), with which it is probably congeneric. Parsimony analysis of these specimens using a published morphological matrix resulted in: a clade of Australian specimens + *Phoberodon arctirostris*, sister to *Inticetus vertizi* (Chilcatay Formation, Burdigalian, Peru); the latter clade being sister to crown Odontoceti; *Squalodon calvertensis* and *Prosqualodon* within Platanistoidea, thus part of crown Odontoceti. These results corroborate some previous analyses showing that Squalodontidae is paraphyletic and in dire need of systematic revision. The co-occurrence of *Phoberodon* (or *Phoberodon*-like species) and *Prosqualodon* in both Patagonia and southern Australia during the Burdigalian evinces some commonality in the cetacean fauna of austral latitudes during the early Miocene.

Grant Information:
ARC LP150100403

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE ROAR AND HOWL OF RANCHO LA BREA'S TOP PREDATORS

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Although the Rancho La Brea (RLB) tar pits assemblages of *Smilodon fatalis* and *Canis dirus* have been extensively studied for over a century, little is known about the hyoids of these species. Composed of nine small bones (in most carnivorans), these bones function as the skeletal support of the vocal production system. The focus of this study is to examine these bones to determine the types of vocalizations these extinct species were able to produce. We hypothesize that *S. fatalis* and *C. dirus* produced vocalizations similar to their living relatives (lions/tigers and wolves respectively). To test these hypotheses, we measured and photographed of 155 *S. fatalis* hyoids and 239 *C. dirus* hyoids from RLB and a comparative sample of extant carnivoran hyoids as well. As in the roaring pantherines, we observed an absence of *S. fatalis* epihyoids suggesting that sabertooths also may have roared. The hyoids of *C. dirus* were similar in their proportions to those of the modern wolves, although significantly larger in several metrics, which suggests that, like wolves, they likely howled, but perhaps at deeper frequencies. Furthermore, we found greater variability within the size and shape of the hyoids of *S. fatalis* than those of *C. dirus* or other living carnivoran species. Although the significance of this variability is hard to interpret, it could imply that individual sabertooths may have made more individually distinctive vocalizations than is seen in other modern large carnivoran taxa.

Romer Prize Session (Thursday, October 10, 2019, 8:15 AM)

DIETARY AND HABITAT PARTITIONING OF JURASSIC MARINE REPTILE ECOSYSTEMS

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Niche partitioning is a fundamental ecological concept that enables ecosystems to support diversified trophic networks. In modern oceans, diverse predator sympatry is facilitated by cranio-dental morphological differentiation, which is intrinsically linked to diet preferences. This notion offers the framework to investigate assembly rules and ecology across geological time. However, to date paleoecological studies of large marine predators have largely been speculative, primarily based on qualitative evidence, and superficial analogies.
In this study I investigate the ecology of an exceptionally diverse Jurassic marine reptile fossil assemblage (from the Sub-Boreal Seaway of the modern United Kingdom) across a ~18 million-year interval of significant environmental perturbations. I developed a quantitative approach that complements morphological data with direct dietary observations on extinct and extant species. This approach allows assigning extinct species to ecologically meaningful "Feeding guilds" based on shared cranio-dental morphology. Then, using a combination of multivariate analysis and comparative biomechanics, I investigated the taxonomic and ecological evolution of the marine reptile fauna through time, and habitat changes.
The results reveal unprecedently detailed evolutionary patterns, and demonstrates that a conserved set of ecological assembly rules regulates marine tetrapod ecosystems through evolutionary time. The lack of overlap amongst groups in the multivariate ordination spaces suggests multiple instances of convergent evolution, indicating that morpho-functional differentiation may have enabled niche specialization. Successive time-binned disparity analyses show that specific guilds-habitat combinations characterized ancient ecosystems. The decline and success of different clades and guilds strongly correlates with sea-level fluctuations. Specifically, sea level deepening favored the diversification of large-bodied, macrophagous pelagic clades, and decline of small-bodied, piscivorous coastal groups.
These parallels between ancient and modern aquatic tetrapod faunas show how comparative approaches constitute a powerful tool to investigate the long-term evolution of ecosystems, and predict how they can adjust to climatic and habitat perturbations.

Grant Information:
School of Geosciences (University of Edinburgh); Small Grant Scheme '2015 Wood Award' (PASW201402); Systematics Research Fund; Richard Owen Research Fund.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

AMPHIBIANS AND SQUAMATES FROM THE LATE PLEISTOCENE OF CAVERNE MARIE-JEANNE (BELGIUM)

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Archaeological sites usually provide important information about the past distribution of the small vertebrate fauna, and by extension about past terrestrial environments and climate in which human activities took place. In this context, Belgium has an interesting location in North-western Europe between the well-studied zooarchaeological record of Germany and England. The Late Pleistocene (Marine Isotope Stages 3 and 2) locality of Caverne Marie-Jeanne (southeast of Belgium, Ardennes region) yielded a large collection of disarticulated bone fragments and numerous plant, mollusk, and archaeological remains. They have been collected during the first field campaign in 1943 and stored in the Quaternary collections of the Royal Belgian Institute of Natural Sciences. A recent revision of the rich micromammal fauna (31 taxa of insectivores, bats, and rodents among 9897 identified specimens, corresponding to a minimum of 4980 individuals) revealed the presence of the steppe lemming and the European pine vole. We present here the revision of the herpetofauna based on the 1970 Jean-Claude Rage's study and the revision of the "indeterminate" small vertebrate specimens. It is now by far the largest Late Pleistocene collection of the Belgian institute with more than 20,500 recognized bones of amphibians and reptiles and covering the last 60,000 years. The herpetofaunal list now comprises two urodeles (*Lissotriton* gr. *L. vulgaris* and *Salamandra salamandra*), four anurans (*Bufo* gr. *B. bufo-spinosus*, *Epidalea calamita*, *Rana temporaria* and *Rana* cf. *R. arvalis*), three lizards (*Lacerta* cf. *L. agilis*, *Zootoca vivipara* and *Anguis* gr. *A. fragilis*) and three snakes (*Natrix* gr. *N. natrix-astreptophora*, *Coronella austriaca* and *Vipera berus*). This study highlights the first fossil record in Belgium for *L.* gr. *L. vulgaris*, *R. arvalis*, *Z. vivipara*, *N.* gr. *N. natrix-astretophora* and *C. austriaca*. This assemblage suggests a patchy humid landscape under colder and dryer climatic conditions in comparison with present ones. The study also underlines the importance to carefully reexamine old collections.

Grant Information:
Grant 2017-SGR-859 (Gov. of Catalonia, AGAUR), CGL2016-80000-P (Spanish Min. of Econ. & Comp.), RYC-2016-19386 (Ramón y Cajal), Synthesys BE-TAF-4385, -5469, -5468, -5708.

Technical Session I (Wednesday, October 9, 2019, 9:45 AM)

A ZIPHIID-LIKE PLATANISTOID DOLPHIN FROM THE OTEKAIKE LIMESTONE (WAITAKIAN STAGE, LATEST OLIGOCENE), HAKATARAMEA VALLEY, NEW ZEALAND

FORDYCE, Robert E., Universityof Otago, Dunedin, New Zealand

A new dolphin from the Otekaike Limestone, Hakataramea Valley, has specialised jaws and a reduced dentition, consistent with a suction-feeding life mode – the first such odontocete from the New Zealand mid-Cenozoic. The dolphin is convergently similar in skull form to living, suction-feeding, beaked whales (Ziphiidae). Dolphin OU 22540 is from the bioclastic upper Otekaike Limestone, just above a mollusc-rich shellbed (Waitakian, latest Oligocene). Massive bedding, well-preserved para-autochthonous macroinvertebrates, and associated skeletons of vertebrates, suggest a mid-shelf setting with limited traction currents below storm wave base.
OU 22540 has a beak-like rostrum with massive maxillae, but no alveoli. Each mandible is straight-edged with an alveolar groove but lacks teeth in situ. The face around the nares is strongly asymmetrical and elevated, consistent with well-developed nasofacial muscles. Similar features occur in beaked whales (Ziphiidae), albeit constructed differently. Other features differ from those of Ziphiidae: the lacrimojugal is fused; the curved parabullary sulcus on the periotic matches archaic platanistoids; the periotic has a prominent articular process; the bulla lacks an enlarged posterior process; and the pterygoid sinus fossa is not enlarged and has a rod-like hamulus. Phylogenetic analysis with 88 OTUs and 284 characters (parsimony, unordered, equal weights) gave a consensus tree with OU 22540 at the base of the Platanistidae +Squalodontidae + Waipatiidae.
Dolphin OU 22540 is from a broad shelf setting facing the Southern Ocean and surrounding the archipelago of Zealandia. Given this setting, was the dolphin a neritic species? Or might its ziphiid-like skull form imply pelagic foraging beyond the shelf break, and perhaps deep-diving?

Technical Session IX (Thursday, October 10, 2019, 2:30 PM)

REASSESSING THE MOSASAUR PECTORAL GIRDLE AND ITS ROLE IN SWIMMING FUNCTION: NOT ENTIRELY WHALE-LIKE AFTER ALL

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Mosasaurs are charismatic marine squamates that were prominent global predators in the Late Cretaceous. Two clades, Mosasaurinae (*Mosasaurus, Plotosaurus, Clidastes*) and Russellosaurina (*Tylosaurus, Platecarpus, Tethysaurus*) make up a bulk of the known taxa. Mosasaurs, like other derived aquatic tetrapods, exhibit convergent marine morphology including streamlined bodies, enclosed paddles, and caudal flukes. With regards to swimming mechanics, most recent functional analyses have likened mosasaurs to whales based on morphological similarities. However, both Mosasaurinae and Russellosaurina have distinct massive pectoral girdles which whales lack, and forelimbs placed more ventrally than in both odontocetes and mysticetes. We analyzed the morphology of the pectoral girdle across both mosasaur clades and suggest that they were actively utilizing their forelimbs for aquatic locomotion. Past studies did make note of the large mosasaur pectoral girdle, but pectoral limb propulsion models have typically been considered less robustly supported than caudal propulsion models. However, given the morphology of the mosasaur pectoral girdle, a dual-module propulsive system, in which both the caudal and pectoral modules contribute significantly to propulsion, remains plausible. LACM 397, a *Plotosaurus* (Niobrara Formation) has exceptional preservation of the pectoral girdle, including the cartilaginous extensions of the scapulae. Based on the large, nearly equal surface areas of the coracoid and scapula in LACM 397, our results indicate that the adduction power would be at least double that of the abduction power at the shoulder. The craniocaudally elongate sternum of LACM 397 (and other mosasaurs) is indicative of significant retraction capacity at the shoulder, as well. The shape of the glenoid is consistent with this interpretation. The pectoral limbs in mosasaurs could have been used in drag-based propulsion for fast starts. They may also have been used in a coordinated fashion with the caudal module, perhaps using a "feathered" stroke similar to modern sea lions and fur seals. This does not preclude use of the pectoral limbs for control and stabilization during sustained swimming, particularly at high speeds. Given their large pectoral girdles, we suggest that mosasaurs may have utilized a dual caudal and forelimb propulsion system not seen in extant animals. With this interpretation it reveals the importance in acknowledging that when reconstructing the life modes of ancient organisms they may be a chimera of multiple analogs.

Grant Information:
This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A NEW NEORNITHISCHIAN (CERAPODAN?) DINOSAUR FROM THE OXFORDIAN SHISHUGOU FORMATION OF CHINA: WHAT IS AN ORNITHOPOD?

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Numerous partial to complete individuals of a new neornithischian dinosaur have been collected from the early Late Jurassic Shishugou Formation in northwestern China. These specimens are distinct from the scanty remains of "*Gongbusaurus" wucaiwanensis,* a putative neornithischian from the same formation. The new taxon includes an ossified clavicle and, uniquely, a patellar sesamoid and trilobate maxillary and dentary teeth. Coeval taxa from the Lower Shaximiao Formation in Sichuan, China (*Hexinlusaurus, Agilisaurus, Yandusaurus*), regarded in many recent analyses as falling outside of Cerapoda (Marginocephalia + Ornithopoda), lack many characters distributed among ornithopods that are present in our new Shishugou taxon, including a large hooked coracoid process, a small quadratojugal foramen, narrow and elongate frontals, strong epipophyseal ridges on the postzygapophyses of anterior cervical vertebrae, and a well-defined and elongate femoral neck with a deep femoral capital sulcus. However, our new taxon also retains some plesiomorphic character states relative to most ornithopods such as having five sacral vertebrae, and a short, narrow lesser trochanter on the femur.
Recent analyses of neornithischian dinosaurs are not in agreement over the composition of Ornithopoda or Cerapoda, or the distribution of characters along this neornithischian branch. Putative synapomorphies of Ornithopoda vary from study to study, as does the composition of the clade. In some studies, many erstwhile "ornithopods" such as *Thescelosaurus* and *Orodromeus* have been pulled out of Cerapoda as basal neornithischians, while other studies recover a more inclusive monophyletic Ornithopoda. The current consensus of basal neornithischian and cerapodan phylogeny is poorly resolved. New taxa such as this that exhibit some, but not all, characters used in many studies to define Ornithopoda may help unclutter some of the resolution at the base of the cerapodan tree and provide a clearer diagnosis for Ornithopoda.

Grant Information:
This research is supported by grants from the National Geographic Society and the National Science Foundation (NSF EAR 0922187 and 0310217).

Technical Session VII (Thursday, October 10, 2019, 10:30 AM)

PHYTOSAUR TOOTH DENTIN REVEALS NORIAN ARIDIFICATION PROCESSES INFLUENCED THE DIAGENETIC ENVIRONMENT OF THE CHINLE FORMATION

FORTNER, John D., Southern Methodist University, Dallas, TX, United States of America

The Upper Triassic (Norian; 228-208 Ma) Chinle Formation of Petrified Forest (PeFo) National Park was deposited during a time of major tectonic breakup and profound changes in atmospheric circulation and terrestrial compositions. Little has been done however to assess whether these changes related to breakdown of the Late Triassic megamonsoon are recorded in similar trends in the diagenetic environment. Here we use phytosaur tooth dentin as a proxy for diagenetic alteration in the Chinle PEFO, its greater susceptibility to alteration to makes it excellent for studying diagenetic conditions in western equatorial Pangea, and other records of the diagenetic environment consistent with other findings of pedogenic and aridification in PEFO. Cement stratigraphy and up-section increase in diagenetic calcite and endogenous carbonate yields suggest progressive porewater alkalinization and improving drainage in PEFO, consistent with Norian aridification. Dentin $\delta^{13}C$ is comparable in value and trend to contemporaneous pedogenic carbonates, though values are too high for tertiary-level consumers in C3-only ecosystems, suggesting that dentin records the $\delta^{13}C$ signal of early-stage diagenetic fluids. Dentin $\delta^{18}O_{CO3}$ shows a positive trend through the Norian consistent with aridification, the onset of which is also coincident with the Adamanian-Revueltian Faunal Transition in PEFO. Dentin $\delta^{18}O_{PO4}$ shows a positive trend only in the late Norian, well-after aridification began in PEFO. These values are within 3‰ of coexisting $\delta^{18}O_{CO3,}$ higher than expected for vertebrate tooth phosphate crystallizing in equilibrium with carbonate; ambient water $\delta^{18}O$ is similarly high, varying between -6 to -2‰. Mean annual temperature estimates from phosphate and ambient water also recover temperatures between 13 to 17°C, too low for *in-vivo* apatite synthesis. Together, these data suggest that Chinle phytosaur teeth record the signal of progressively evaporatively-enriched burial fluids, and that surficial paleoclimate trends influenced the geochemistry of the diagenetic environment.

Grant Information:
NSF Earth and Atmospheric Research 2NJT
Dallas Paleontological Society Frank Crane Memorial Scholarship

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

GEOGRAPHICAL SEGREGATION DUE TO ECOLOGICAL COMPETITION AMONG LATE JURASSIC DIPLODOCID SAUROPODS FROM THE MORRISON FORMATION (WESTERN U.S.A.)

FOSTER, John, Paleo Solutions, Inc., Vernal, UT, United States of America; TSCHOPP, Emanuel, American Museum of Natural History, New York, NY, United States of America; MAIDMENT, Susannah C., Natural History Museum, London, United Kingdom; HARCOURT-SMITH, William E., American Museum of Natural History, New York City, NY, United States of America; NORELL, Mark, American Museum of Natural History, New York City, NY, United States of America

North American diplodocid sauropods were historically subdivided into the slender Diplodocinae and the robust Apatosaurinae. However, recent systematic reassessments indicate that, within these respective subfamilies, two diplodocid lineages with robustly built limbs existed in the Upper Jurassic Morrison Formation. These are the Apatosaurinae (*Apatosaurus*and possibly *Brontosaurus*) and the diplodocine genus *Galeamopus*. To understand the ecological importance of this finding, we assessed the geographical and temporal ranges of these taxa, and combined these data with lithological information and a geometric morphometric (GM) analysis of sauropod humeri. In the past, many specimens were referred to *Apatosaurus* due to the robusticity of appendicular bones, the strongly ventrolaterally expanded cervical ribs, and weakly pneumatized caudal vertebrae. However, because weakly pneumatized caudal vertebrae and robustly built legs have also been recognized in diplodocines (e.g., *Supersaurus*, *Galeamopus*), only the ventrolateral expansion of the cervical ribs remains as an easy-to-identify, diagnostic feature of Apatosaurinae. Therefore, we re-assessed taxonomic identification of more

than 750 reported apatosaurine occurrences (isolated bones to articulated skeletons), resulting in a reduction of the confirmed geographical distribution of Apatosaurinae to southern Wyoming, Colorado, Utah, and Oklahoma (except for one partial skeleton with cervicals from northern Wyoming), whereas *Galeamopus*is known mostly from northern Wyoming and Montana (with one occurrence in southern Wyoming). GM analysis confirmed that the two distinct lineages occupied largely overlapping morphospaces in the forelimb. The two taxa also overlap in occurrence in the same geological systems tracts, as well as in the same lithofacies. Taking the humeral shape as a proxy for locomotor strategy, and given the apparent temporal overlap of the two taxa, this distinct geographical distribution may be a result of both taxa being ecological competitors for a particular niche.
Our results add to a recently identified trend in geographical segregation among diplodocids, stegosaurs, and some other taxa, and show that we can test for such trends with a combination of phylogenetic and GM analyses, integrated with stratigraphic and lithologic data. Analyses at larger scale will need additional fieldwork and collection-based studies re-assessing the taxonomy of incomplete specimens from the Morrison Formation's spatially and temporally less-explored areas.

Grant Information:
Theodore Roosevelt Memorial Fund and Division of Paleontology Postdoctoral Fellowship, American Museum of Natural History

Technical Session XI (Friday, October 11, 2019, 9:00 AM)

BASELINE SHIFTS IN SMALL MAMMAL COMMUNITIES AT RANCHO LA BREA TRACK LATE QUATERNARY ENVIRONMENTAL CHANGES IN SOUTHERN CALIFORNIA

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The extent of environmental change during the late Quaternary in the region around the Rancho La Brea (RLB) tar pits in Los Angeles, California has long been debated. Some studies suggest that environments have been relatively stable over the past 50,000 years while others suggest that local climates mirror regional patterns of increasing temperature and aridity through time. Here, we examine small mammal fossils from four RLB deposits (Project 23 (P23) Deposits 1, 7B, 13 and 14) spanning >50,000 to ~30,000 calibrated years before present and evaluate changes in their community composition, diet, and size through time. Such responses are good proxies for environmental change since small mammals are sensitive to habitat perturbations due to their small home ranges and limited mobility. We evaluate taxon-specific presence and abundance through time by comparing small mammal community composition between the P23 deposits and overall younger RLB Hancock Collection deposits that frequently yield post-glacial dates. Dietary niches are tracked in a subset of taxa via $\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis of individually radiocarbon-dated fossils. Lastly, size changes are quantified from morphometric and geometric morphometric measurements of some P23 taxa and their extant representatives. If past environments of Los Angeles were similar to present conditions, we hypothesize that 1) no directional change in species presence or abundance occurs through time or 2) that no directional change occurs in the autecologies (e.g., geographic, climatic, or dietary functional group affinity) of species that fluctuate in presence or abundance. Further, we expect no directional change to occur in intraspecific size or diet if local conditions remained stable. Results show similar sets of taxa among P23 deposits, though relative abundances vary: more mesic-adapted species generally become less abundant and more xeric-adapted and generalist species become more abundant through time. Compositional and functional differences also occur between P23 and Hancock deposits. Finally, $\delta^{13}C$, $\delta^{15}N$, and size shift through time in several species. These data indicate that the RLB community has shifted across the last glacial transition and that environmental changes, including aridity, seasonality, and/or vegetation changes, likely occurred.

Grant Information:
This project is supported by the National Science Foundation (EAR-1623852), the American Society of Mammologists, and the Paleontological Society.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

A CALL TO ACTION AFTER THE *PALEO TO POLICY WORKSHOP*: HOW TO BUILD BRIDGES BETWEEN PALEONTOLOGICAL RESEARCH AND DECISION MAKING

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The *Paleo to Policy: Building bridges between paleoclimate research and decision making* workshop (February, 2019) brought together a diverse group of paleoscientists, with the following set of objectives: 1) explore best practices and highlight excellent examples of paleoclimate/paleoecology research relevant to decision making, 2) build communication skills in participants specifically for working with policymakers, managers, and conservation groups, 3) provide the foundation for cogeneration of ideas for research with scientists, conservation experts, managers, and policymakers, and 4) build a network of researchers across career stages that are committed to the societal relevance of their work and continuing to work together on these goals.
The *Paleo to Policy* working group now aims to share the resources and ideas produced by the workshop with a range of paleoscience communities, and is focused on the key challenge of empowering paleontologists to connect and communicate with policy decision makers. In this presentation we will discuss best practices for incorporating paleoclimate/paleoecology work into decision making, including identifying policy claims and understanding the role of values, beliefs and attitudes. We will then highlight broad skills of paleoclimate researchers and successful examples of paleo work being incorporated into the decision-making process. Successful examples provide models for how paleontology research can influence, and potentially shape, policy.
There are clear examples from conservation paleobiology and paleoclimatology to demonstrate how these fields are relevant to policy and decision-making. We suggest that the entire field of paleontology has strong potential for engaging stakeholders, both in terms of communicating the policy relevance of research findings and making intentional connections to policy makers during the design and implementation of projects. While some areas of vertebrate paleontology may have more obvious links to policy (i.e., Quaternary mammalian records used to inform species listing and land management), connecting all areas of vertebrate paleontology (across the spectra of temporal and taxonomic categories) is important work that will require creative development and implementation.

Grant Information:
The *Paleo to Policy* workshop was funded by a NSF CAREER award to T. Hill (OCE 144451).

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

DOCUMENTING AN ECOLOGICAL REPLACEMENT EVENT FROM THE MIOCENE ON AN ECOLOGICAL TIMESCALE

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Invasive species are generally recognized as a threat to global biodiversity, with anthropogenically introduced taxa causing local extinctions of native species in ecosystems around the world. It is important to understand the dynamics of ecological replacement in scenarios without human influence in order to form a baseline against which to compare anthropogenic invasions, but the pervasiveness of human impacts globally and the difficulty of conducting long-term monitoring before an invasion takes place makes this impractical to address with neontological studies. While the fossil record has many examples of community composition changing through time, there are few documented cases where species invasion can be correlated with local extinction. Varved diatomite beds located in a quarry near Fernley, Nevada provide an example of such an ecological replacement event in lacustrine fish during the Late Miocene (Truckee Formation), which is documented at a nearly annual temporal resolution. Fossil sticklebacks (*Gasterosteus doryssus*) are found ubiquitously throughout the majority of the section, but in the uppermost section exposed in the quarry the dominant species abruptly transitions to killifish (*Fundulus nevadensis*). Changing diatom composition through the section suggests that the fossils were deposited in a small, isolated body of water which later became connected to a larger regional system of lakes, implying a potential environmental mechanism for the replacement of

sticklebacks with killifish. Based on initial occurrence data, killifish and sticklebacks overlapped in the lake for a period of around 300 years, above and below which the non-dominant species is virtually absent. This interval of time puts the transition at close to an order of magnitude slower than most reported modern ecological replacement events, although it has a similar outcome. Measurements of fish size and morphology through the transition have implications for competition occurring between the two taxa. These findings suggest that modern species invasions may be accelerated, but fundamentally similar to those in the past, and underscore the utility of paleontological studies with high temporal resolution for contextualizing modern ecological change.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

TAXONOMIC IMPLICATIONS OF MEASUREMENT INDICES OF THE IDENTIFICATION OF ISOLATED SAUROPOD TEETH

FRAUENFELDER, Timothy, University of New England, Armidale, Australia; CAMPIONE, Nicolas E., University of New England, Armidale, Australia; BELL, Phil, University of New England, Armidale, Australia

Slenderness and Compression indices (SI and CI, respectively) are commonly used to categorize sauropod teeth. The SI distinguishes broad-crowned (e.g., *Camarasaurus*, Brachiosauridae; SI<4) from narrow-crowned taxa (e.g., diplodocoids, Titanosauria; SI>4), whereas the CI has been used sparingly to separate isolated titanosaurian teeth based on labiolingual compression. Whilst the indices likely reflect an aspect of tooth function, they are generally used for broad taxonomic purposes. However, the measurements used to generate these ratios (tooth height, length and width) have yet to be explored within an allometric framework. Here we use line-fitting bivariate statistics to test the taxonomic utility of these indices based on an extensive dataset of sauropod tooth measurements (N=705).
Overall differential scaling between tooth height and length (SI measurements) is recovered between sauropod groups ($p_{overall}<<0.001$), including notable separation between the broad- and narrow-crowned sauropods. As expected, both diplodocoids and titanosaurs have the narrowest teeth of all groups. However, whilst these two groups do not differ in SI values, they differ in scaling of both slope and elevation. Differential scaling between taxonomic units is also recovered when comparing tooth width and length (CI measurements; $p_{overall}<<0.001$). Therefore, our results generally support the use of these indices for interpreting broad taxonomic levels.
Some caution, however, is warranted. Indices do not consider body size, ontogeny, or positional variation within the jaw and, in particular, they assume that slope coefficients between groups are consistent. Our results reject this assumption in certain groups. For instance, tooth height is positively allometric relative to its length in diplodocines and camarasauromorphs compared to the more isometric patterns noted in most other groups. This means that, among certain groups, index values will vary with size. Considerations of scaling are especially important for intermediate teeth that fit neither the typical 'broad' vs. 'narrow' categories. From an evolutionary perspective, bivariate plots indicate that early groups of sauropods (e.g., Plateosauridae) were relatively constrained, in terms of their morphospace. In comparison, later forms, such as diplodocoids and titanosaurs, explored more extreme regions of morphospace. Our study reveals the importance of understanding measurement data within an allometric framework, which can be extended to understand evolutionary processes.

Grant Information:
This project was funded by the University of New England.

Technical Session XV (Saturday, October 12, 2019, 11:45 AM)

RATES OF MORPHOLOGICAL EVOLUTION IN ANOMODONTIA (THERAPSIDA) ACROSS THE END-PERMIAN MASS EXTINCTION

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Anomodonts were the most speciose Permian-Triassic therapsid clade and had an impressive morphological and ecological diversity. They obtained a cosmopolitan distribution and became the dominant herbivores of their time. However, they were severely affected by the end-Permian mass extinction, experiencing a massive bottleneck in their taxonomic diversity. In contrast, anomodont disparity reached an early peak in the mid Permian and declined continuously throughout the evolutionary history of the clade, being little effected by the end-Permian event. For the purpose of this study we investigated rates of change of discrete morphological characters throughout the anomodont's evolutionary history and across the end-Permian mass extinction. Based on a recent phylogenetic data set and up-to-date stratigraphic ranges, node and branch rates of morphological evolution were calculated to identify whether a clade, branch or time period had a significantly high, low, or nonsignificant rate variation. To rule out age uncertainties, 100 time-calibrated trees were produced based on 100 randomly-drawn first and last appearance datums from a taxon-specific stratigraphic probability distribution and each tree was subjected to the analysis of rate variation separately. Our results show (i) high evolutionary rates in taxa that show morphological innovations (reflecting a specialized lifestyle) before the end-Permian mass extinction, such as the arboreal basal anomodont *Suminia* and the fossorial cistecephalids; (ii) high evolutionary rates in the early evolutionary history (Wuchiapingian) of the genus *Lystrosaurus*, but low post-extinction evolutionary rates, reflecting the lack of new morphological features; and (iii) in general lower evolutionary rates following the end-Permian mass extinction, reflecting the morphologically conservative evolution of the Kannemeyeriiformes.

Grant Information:
This research was funded by the German Research Foundation (DFG).

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

MORPHOLOGY AND NEUROVASCULAR ANATOMY OF A TITANOSAUR SAUROPOD OSTEODERM FROM THE UPPER CRETACEOUS OF BIG BEND NATIONAL PARK, TEXAS

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Osteoderms are among the most distinctive attributes of the Lithostrotia, a speciose clade of Cretaceous titanosaur sauropods, yet the function of the osteoderms remains uncertain. Hollow spaces inside some osteoderms have been used to suggest a function as mineral storage sites, accessed during times of environmental stress or egg-laying. Subsequently, varying stages in the development of internal hollows have been reported from other osteoderms. A new specimen (TMM 45888) from the Upper Cretaceous Javelina Formation of Big Bend National Park, Texas, provides additional insight into the diversity of internal structure among lithostrotian osteoderms. Found in isolation, TMM 45888 can presently only be referred to Lithostrotia *incertae sedis*. It exhibits an ellipsoid morphology with a low bulb lacking a cingulum. The surface is ornamented with ridges and grooves radiating outwards from its long axis. Although TMM 45888 shares these features with an osteoderm of *Alamosaurus* (USNM 15560) from Utah, it is much thicker, about three-quarters as thick as it is long. In this, it more closely resembles some osteoderms of *Mendozasaurus*.
The interior is composed of trabecular bone, lacking hollow or low-density spaces. Several large, dendritic canals pass from basal neurovascular foramina towards the external face of the osteoderm. Some canals pass through the center of the element, and others curve upwards along the lateral margins. In some titanosaur osteoderms, a central longitudinal canal is associated with the development of an internal hollow, but no such canal occurs in TMM 45888. This does not rule out that this osteoderm could have been hollowed by resorption, and therefore have functioned as a mineral reservoir, but any resorption would have proceeded in a different spatial pattern than has previously been documented. These results add to a growing understanding of neurovascular diversity among titanosaur osteoderms that can inform future analyses of osteoderm function.

Romer Prize Session (Thursday, October 10, 2019, 9:00 AM)

GROWTH AND BEHAVIOUR IN OVIRAPTOROSAURS

FUNSTON, Gregory F., University of Alberta, Edmonton, AB, Canada

Oviraptorosaurs were feathered theropod dinosaurs from the Cretaceous (145–66 Ma) of Asia and North America. They are typically divided into four clades: the basal caudipterygids and avimimids, and the more derived caenagnathids and oviraptorids. Of these, oviraptorids are the best known, represented by dozens of complete skeletons, some associated with clutches of eggs. Although this has allowed oviraptorid reproduction to be relatively well understood, few studies have explored other aspects of their biology—a problem even more true of other oviraptorosaurs. Regardless, their phylogenetic position close to Aves and the abundance of fossil material makes oviraptorosaurs ideal organisms for understanding the ancestral conditions of modern birds.
Here, I capitalize on this opportunity by systematically examining two important, understudied aspects of oviraptorosaur biology: growth and gregarious behaviour. Growth is examined via osteohistology, using ontogenetic series from representatives of avimimids, caenagnathids, and oviraptorids. Gregarious behaviour is revealed through spectacular new fossil discoveries that elucidate the population structure and specific behaviours of flocks of oviraptorosaurs. To understand the evolution of these traits, oviraptorosaur phylogeny is comprehensively revised, using new specimens

to clarify the taxonomy of problematic species and updated character scoring to improve phylogenetic resolution.
The results show disparate patterns in the growth and gregariousness of oviraptorosaurs. Whereas basal oviraptorosaurs had stunted growth limiting body size, caenagnathids and oviraptorids were able to achieve much higher growth rates and therefore larger body sizes. Limitation of body size early in avimimid ontogeny may indicate that skeletal maturity was reached before sexual maturity, whereas remnants of medullary bone in a caenagnathid shows that it was still actively growing while reproductive. Gregarious behaviour has a strong phylogenetic signal, suggesting two independent origins within oviraptorosaurs. Evidence of huddling behaviour in an oviraptorid suggests relatively advanced sociality and provides a thermoregulatory mechanism for the origin of sociality in birds. These findings greatly improve our knowledge of oviraptorosaurs and suggest that they may have converged on birdlike biology more than previously recognized.

Grant Information:
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Technical Session XI (Friday, October 11, 2019, 9:30 AM)

MAMMALIAN RESPONSES TO LATE QUATERNARY ENVIRONMENTAL CHANGE IN EASTERN AUSTRALIA.

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Characterizing the longer-term impacts of climatic shifts and human activities on species is among the most vital insights that paleontology can offer, providing benchmarks for calibrating modern and projected future ecological change. However, its potential in this regard has been markedly underutilized, especially in Australia. To date, only a few studies have sought to track paleoecological change in Australian vertebrates over the relatively recent geological past, with most focused in southern Australia. Here we investigate changes in mammalian species composition and relative abundances through a 5-m-deep sequence of infill sediments in Cathedral Cave, in the Wellington Caves system of central-eastern Australia. The proximity of this locality to the boundaries of four rainfall zones (arid, uniform, summer, winter) means that it is ideally positioned to capture zone shifts associated with glacial–interglacial cycling. We have identified remains of 63 mammal, 11 bird, 24 reptile and 5 frog species within the Cathedral Cave assemblage, which accumulated via pitfall and as regurgitated pellets from roosting owls. Preliminary luminescence and radiocarbon dating indicate deposition from c. 70,000–40,000 years ago, followed by a hiatus, with deposition reinitiated c. 6,000 years ago. The assemblage includes 19 now-extinct 'megafaunal' species, including six species not hitherto recorded from the late Pleistocene in Australia. Variations in assemblage composition and relative-abundance trajectories of small-mammal species align with vegetation shifts inferred from co-interred fossil pollen, and point to a drier climate in early MIS 3. Thus, Cathedral Cave preserves the only diverse vertebrate and pollen assemblages known from Australia that accumulated across the 30,000-year interval leading up to human arrival on the continent and the final phase of megafaunal extinctions.

Grant Information:
Australian Research Council Discovery grant to G J Prideaux (DP150100264)
Maxim Foundation
Royal Society of South Aust
Australian Nuclear Science & Technology Organisation

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

FIRST RECORDS OF THE SAWFISHES *PRISTIS* (LINCK, 1790) AND *ANOXYPRISTIS* (WHITE AND MOY-THOMAS, 1941) FROM THE OLIGOCENE OF NORTH AND SOUTH CAROLINA, U.S.A.

GALE, Ashby W., Charleston Fossil Adventures, LLC, Charleston, SC, United States of America

Sawfishes are reported from Cenozoic marine deposits across the southeast, and are known primarily from their rostral denticles, teeth, rostra, and centra. Denticles and partial rostra are reported from the Eocene of the Gulf and Atlantic Coastal Plain and the Mio-Pliocene of the Atlantic Coastal Plain, leaving a published gap during the Oligocene, unrepresentative of the lineage. Rostral denticles referred to the sawfish *Pristis* sp. are described here from the upper Oligocene (Chattian) Chandler Bridge Formation in Ladson, Berkeley County, South Carolina. A partial rostrum referred to *Anoxypristis* sp. is described from the lower Oligocene (Rupelian) Ashley Formation in Summerville, Dorchester County, South Carolina. Further specimens include *Anoxypristis* centra and rostral denticles from John's Island, Charleston County, South Carolina. Records from North Carolina include 12 isolated *Anoxypristis* rostral denticles surface collected from Oligocene dredge spoils in the Belgrade Quarry, Jones County, North Carolina. These occurrences are the first publicly accessible records of Pristidae from Oligocene deposits of the Atlantic Coastal Plain, indicating the continuous Cenozoic existence of Pristidae from the Eocene.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

EXPLORING THE OLFACTORY CAPABILITIES OF ANT-EATING MAMMALS USING THE CRIBRIFORM PLATE AS AN OSTEOLOGICAL PROXY

GARLAND, Kathleen L., Montpellier University, Montpellier, France; HAUTIER, Lionel, Montpellier University, Montpellier, France; FERREIRA-CARDOSO, Sergio, Montpellier University, Montpellier, France; WRIGHT, Mark, Harvard University, Cambridge, MA, United States of America; MARTINEZ, Quentin, Montpellier University, Montpellier, France; FABRE, Pierre-Henri, Montpellier University, Montpellier, France; LEBRUN, Renaud, Montpellier University, Montpellier, France; DELSUC, Frédéric, Montpellier University, Montpellier, France

All myrmecophagous (ant-and termite-eating) mammals possess convergently evolved feeding morphologies, specialised for their strict diet. It is unknown, however, if these morphological convergences reflect similarities in their ability to detect ants/termites. All myrmecophagous species have been found to share similar sniffing behaviours when foraging, suggesting a specialisation to detect ant/termite chemical odorants. Cribriform plate (CP) morphology metrics (surface area and foramina number) have been previously used to reliably predict the number of functional olfactory receptor genes in mammalian species, which is directly linked to their olfactory capabilities. Consequently, the CP has been suggested to be an osteological proxy for predicting the olfactory capabilities in living and extinct mammals. Likewise, the surface area and complexity of turbinal bones in the snout has been related to olfactory capabilities. Here, we used X-ray micro-computed tomography to compare the CP and turbinal morphologies of nine myrmecophagous species and their sister taxa. The CP and olfactory turbinal morphologies of the giant armadillo (*Priodontes maximus*) and the aardvark (*Orycteropus afer*) were shown to be highly convergent, which might be related to their unique fossorial behaviour. Otherwise, no clear pattern of convergence was detected among myrmecophagous mammals. Using generalized least squares analyses, we found that CP and olfactory turbinal surface area were strongly correlated, suggesting strong developmental, and underlying functional, integration patterns in the rostrum.

Grant Information:
Funded by the European Research Council consolidator grant, the Centre National de la Recherche Scientifique and the Erasmus Mundus Master Programme in Evolutionary Biology.

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 3:45 PM)

PREDATORS AND PREY FROM THE MIDDLE PLEISTOCENE RECORD AT CUDDIE SPRINGS

GARVEY, Jillian, Dr, Melbourne, Australia; FIELD, Judith, UNSW, Sydney, Australia

The Cuddie Springs site in Western New South Wales contains a faunal sequence dates to c.900,000 years. While renowned internationally for its human-megafauna sequence between c 40-30ka, Cuddie Springs also documents the most southern appearance of Quinknana sp., Palimnarchus sp. and Crocodylus sp. The former two species have been identified as the primary agents in the accumulation of a range of megafauna in a discrete horizon dated between 350-600 (mean. 400 ka) by ESR dating. The excellent preservation of the skeletal material and microscopic pollen has allowed a reconstruction of the local environment and associated faunal suite. An ephemeral waterhole, predator crocodiles and a marsupial megafauna occur together in a warmer and wetter environment, providing a unique picture of middle Pleistocene Australia. Cuddie Springs is one of the few sequences in an open setting from semiarid/arid Australia and provides important insights to the rich prehistory of the Australian continent.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

REDIAGNOSIS OF *PARASAUROLOPHUS CYRTOCRISTATUS* BASED ON NEW MATERIAL FROM THE FRUITLAND FORMATION, NORTHWESTERN NEW MEXICO

GATES, Terry A., North Carolina State University, Raleigh, NC, United States of America; SERTICH, Joseph, Denver Museum of Nature & Science, Denver, CO, United States of America

Of all hadrosaurid ornithopod dinosaurs, the genus *Parasaurolophus* maybe the most distinctive, with the three recognized species possessing a hollow, tube-shaped crest extending posterodorsally beyond the skull roof. Unique features of crest shape have provided the bulk of characteristics used in specific diagnoses, largely ignoring other features of the skull. This practice is problematic because the holotype specimen of *P. cyrtocristatus* (FMNH P-27939) includes a cranium with only a partial premaxilla, partial skull roof and braincase, and a complete, uniquely shaped curving crest that forms the basis of its diagnosis. For over 55 years, this specimen had been the only with a hypercurved crest until abundant, new *Parasaurolophus* specimens from Utah revealed that crest curvature is an ontogenetic artifact, bringing into question the validity of *P. cyrtocristatus* on the basis of that feature alone. A new partial subadult skull (DMNH EVP.132300) collected from the Fossil Forest Member of the Fruitland Formation demonstrates that *P. cyrtocristatus* can be diagnosed by at least four cranial, non-crest characteristics in addition to at least two crest-related traits independent of crest curvature. These traits are: straight preorbital premaxillae; dorsally raised squamosals on posterior margin; midline indentation between squamosal and supraoccipital; notch between pre- and post-cotyloid processes; common median chamber elongate and equal to narial tracts in size; and unique shape of the terminal lateral premaxillary process. A phylogenetic tree produced from a recently published matrix with the addition of six new characters produced a strict consensus tree that unites *P. cyrtocristatus* with *P. tubicen*. This hypothesized arrangement makes intuitive sense considering that both species occur in close geographic proximity in successive formations temporally separated by only ~1.5 million years. Yet, this study is the first to produce such an evolutionary hypothesis because crest shape and length have been the major character traits used in phylogenetic studies, consistently placing the two 'long-crested' species, *P. tubicen* and *P. walkeri*, together. Future work will use the diagnostic information each of *Parasaurolophus* species to identify the taxon found in the Kaiparowits Formation of Utah, based a series of skulls and postcranial material.

Technical Session II (Wednesday, October 9, 2019, 9:00 AM)

CT IMAGING OF DINOSAUR FOOTPRINTS: HIDDEN TOPOGRAPHY AND THE ORIGIN OF PENETRATIVE TRACK DIVERSITY

GATESY, Stephen M., Brown University, Providence, RI, United States of America; TURNER, Morgan L., Brown University, Providence, RI, United States of America; FALKINGHAM, Peter L., Liverpool John Moores University, Liverpool, United Kingdom

Dinosaur footprints are trace fossils documenting the interaction of live animals with deformable ground. Although some tracks are relatively accurate molds of the foot, most are not. Factors such as substrate consistency and foot motion are known to give rise to disparate track morphologies that may differ considerably from static pedal anatomy. Although typically viewed as surfaces, any given track is a sample of a broader, typically hidden, volumetric phenomenon. On relatively soft substrates, dinosaurs sank deeply. Such penetrative tracks preserve evidence of entry and withdrawal (as depressed and elevated features) through multiple layers. But how closely do the visible surfaces of exposed slabs reflect the actual, underlying topography?
We used CT imaging to reconstruct internal surfaces of penetrative tracks from the Early Jurassic (~200 MYA) of the Connecticut Valley. Our first glimpse inside these fossil slabs confirms that natural breaks, mechanical splitting, and subsequent preparation have significantly damaged most exposed surfaces. In particular, delicate elevated features documenting foot withdrawal were either too fragile to survive slab separation or were mistakenly removed. Such topographic structures are key to understanding how deep tracks formed and to explaining the origin of Connecticut Valley footprint disparity. CT data enable us to more clearly observe the results of foot-sediment interactions than is possible from exposed surfaces alone, and serve as key constraints on reconstructions of extinct dinosaur limb kinematics.

Grant Information:
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Technical Session II (Wednesday, October 9, 2019, 12:00 PM)

A SUPERFOOD FOR MESOZOIC HERBIVORES? EMERGING DATA ON THE EXTREME DIGESTIBILITY OF *EQUISETUM* AND IMPLICATIONS FOR YOUNG, GROWING HERBIVOROUS SAUROPODS

GEE, Carole T., University of Bonn, Bonn, Germany; HOWELL, Mariah M., University of Bonn, Bonn, Germany; BÖTTGER, Christian, University of Bonn, Bonn, Germany; SÜDEKUM, Karl-Heinz, University of Bonn, Bonn, Germany

Although the notion of a super nutritious "power bar" for the herbivorous dinosaurs has been scoffed at, it has been documented through an extensive series of laboratory experiments that many of the nearest living relatives of the Jurassic flora would have been very good sources of nutrition for Mesozoic herbivores. Based on fermentation experiments using a well-established feed evaluation test for livestock, among the best sources of energy would have been the gymnospermous leaves of *Araucaria*, *Ginkgo*, and the pinaceous conifers. Yet, there is another plant group that surpasses all other plant groups, even forage grass, in regard to nutritional quality—*Equisetum*. Here we present new data on the energy yield of several species of horsetail as evaluated by the Hohenheim Gas Test. Altogether, seven samples of *Equisetum* spp. were tested by *in vitro* experiments in the laboratory and comparative analysis. In all trials on its digestibility for herbivores, *Equisetum* consistently released more energy than all other plant groups, exceeding the average amount of calories released by 16 species of grasses. The energy release of *Equisetum* is rapid from the onset, and its fermentation curve remains high throughout the course of 72 hours. Furthermore, nutritional analysis shows that horsetails also provide high quantities of protein and mineral nutrition, both of which are essential for growth, especially in young animals. Morphologically, the genus *Equisetum* has remained virtually unchanged since the Jurassic. Assuming that living *Equisetum* and its ancient relatives had a similar physiology and thus nutritional qualities, the small-stature, ground-dwelling, colony-forming stands of Mesozoic horsetails along rivers and around lakes and ponds would have offered herbivores, especially hatchlings and young herbivorous dinosaurs, a plentiful, accessible, and extremely nutritious source of food. Comparisons to the dietary preferences of modern wild fowl that depend on *Equisetum* spp. as a "superfood" during brooding and the early stages of life will be discussed, as well as the food ecology and behavior adaptations of living herbivorous reptiles.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

HIGH RESOLUTION REMOTE SENSING APPLIED TO FOSSIL DISCOVERY: OVERVIEW AND PROSPECTS

GHEZZO, Elena, University of Venice/University of Oregon, Eugene, OR, United States of America; MASSIRONI, Matteo, University of Padova, Padova, Italy; DAVIS, Edward B., Universityof California Berkeley, Eugene, OR, United States of America

We have analyzed the physical properties of fossils in museum collections and compared them to the regional-scale information recorded by optical sensors (RGB and multispectral cameras) gathered from satellites, drones, weather balloons, and kites.
Such an approach allows researchers to record visual details of fossils in the original context of deposition in the field and, more importantly, to determine the position of uncollected specimens still exposed at the ground surface in areas that are difficult to access.
When a fossil exposed on the ground is captured by a camera, it records information related to the color and physical properties of the specimen in accordance with the sensitivity of the used sensor. Therefore, the possibility of discerning it from the depositional matrix is related to the other information transmitted by the rest of the image.
Keeping in mind these limitations, we introduce the principal concepts of Remote Sensing applied to paleontology with insights of the methodologies and spatial algorithms we have used. In particular, we discuss the spectral signatures of fossils, their recalibration for multispectral and visible bands, and their application to imagery of specific paleontological collecting areas including the Pisco Basin and the John Day Fossil Beds.
We have statistically evaluated spatial maps of probabilities to assess whether the spectral signature of specific fossils analyzed in the lab match with the information in the pixels of the remote sensing images.
This method is applicable to any kind of fossils, from large tetrapods to vegetation, allows researchers to exactly locate fossils in advance of fieldwork, so we expect it to become a significant step forward in the approach to fieldwork, for monitoring paleontological resources, and to increase the fossil record available for future paleontological studies.

Grant Information:
This project is part of a collaboration between the Ca' Foscari University of Venice and the University of Oregon. It has received funding from the EU, grant agreement No 785821

Technical Session V (Wednesday, October 9, 2019, 3:00 PM)

A NEW SPHENISCIFORM FOSSIL FROM THE NORTH ISLAND OF NEW ZEALAND FURTHER RESOLVES THE BAUPLAN OF EXTINCT GIANT PENGUINS

GIOVANARDI, Simone, Massey University Albany, Auckland, New Zealand; KSEPKA, Daniel T., Bruce Museum, Greenwich, CT, United States of America; THOMAS, Daniel B., Massey University Albany, Auckland, New Zealand

New Zealand is a key area for understanding the ancient history of penguins (Order Sphenisciformes). Fossils from New Zealand range in age from Paleocene up to Pleistocene, constituting a sampling period that spans more than 60 million years. The New Zealand fossil record includes many 'giant' penguin species (i.e., larger than living penguins) which may have represented an extinct foraging guild. *Kairuku*, *Pachydyptes*, *Palaeeudyptes* and *Kumimanu* were all from New Zealand but taxa belonging to this guild were found also in Antarctica, South America and Australia. These taxa are characterized by different forelimb proportions and elongated spear-like beaks in addition to their large body sizes. These traits hint at differences in locomotion and foraging when compared with living species, although most body plans for ancient penguins are inferred from largely incomplete skeletons. Here we describe a mostly-complete giant-sized penguin with many bones articulated in life position. The fossil was found in an Oligocene silty mudstone from the North Island of New Zealand and currently represents the most complete pre-Pleistocene vertebrate reported from this region. The specimen shares several morphological features with the New Zealand-endemic taxon *Kairuku* and in preliminary phylogenetic analyses the new fossil forms a clade with this genus. Furthermore, the forelimb elements of *Kairuku grebneffi*, a similarly-aged giant penguin from the South Island of New Zealand, are almost identical in size when compared with the North Island specimen. The hindlimbs elements of the North Island fossil are significantly longer, exceeding in length all previously described specimens of *Kairuku*. Moreover, the specimen presents a mixture of characters that show a transitional state between the ancestral body plan found in other Eocene-Oligocene giant penguins and the apomorphic body plan found in *Kairuku*, providing insight into the diversification of 'giant' penguins.

Grant Information:
Massey University Doctoral Scholarship

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A DIVERSE MIOCENE TOOTHED WHALE (ODONTOCETI) FAUNA FROM CALVERT CLIFFS, ATLANTIC COASTAL PLAIN, U.S.A.

GODFREY, Stephen, Calvert Marine Museum, Solomons, MD, United States of America; LAMBERT, Olivier, Institut royal des Sciences naturelles de Belgique, Bruxelles, Belgium

A diverse odontocete fauna of 29 extinct species is known from along Calvert Cliffs, Maryland, U.S.A and other Miocene-age outcrops within the Chesapeake Bay region (comprising the Calvert, Choptank, and St. Marys formations). Squalodontidae is represented by three species; *Squalodon calvertensis*, *S. whitmorei*, and a new species intermediate in size between the two aforementioned forms. Physeteroidea includes the physeterids *Aulophyseter mediatlanticus* and *Orycterocetus crocodilinus*, and an unnamed taxon with macroraptorial teeth. Ziphiidae includes two unnamed species: cf. *Messapicetus* sp. and Ziphiidae incertae sedis. Squalodelphinidae is known by two species: *Phocageneus venustus* and *Notocetus* sp., and Platanistidae by four species: *Araeodelphis natator*, *Zarhachis flagellator*, *Pomatodelphis inaequalis*, and a new species. Eurhinodelphinidae features prominently with at least four species; *Xiphiacetus bossi*, *X. cristatus*, *Schizodelphis barnesi,* and *S. morckhoviensis*. Early delphinidans are the most diverse, including *Delphinodon dividum*, *Kentriodon pernix*, *Hadrodelphis calvertense*, *Macrokentriodon morani*, *Liolithax pappus*, *Pithanodelphis cornutus*, *Lophocetus calvertensis*, and at least three new species. Finally, Pontoporiidae is represented by *Stenasodelphis russellae*. Four of these families have living representatives: Physeteridae (sperm whales), Ziphiidae (beaked whales), Platanistidae (Ganges river dolphin), and Pontoporiidae (La Plata dolphin). The long and slender-snouted eurhinodelphinids are the most common odontocetes along Calvert Cliffs, squalodontids the most archaic, and physeteroids the largest. Squalodelphinids, ziphiids, and pontoporiids are known only from a few incomplete skulls, so much remains to be learned from future discoveries and the reassessment of collection specimens.
In terms of its taxonomic diversity and number of specimens, this fauna rivals the Neogene odontocete faunas in Peru, Antwerp basin (Belgium), Belluno (Italy), Mexico, and elsewhere in the United States (Lee Creek Mine in North Carolina, Florida, Shark Tooth Hill in California, and Pollack Farm site in Delaware).
As for their stratigraphic distribution, these odontocetes range in age from the Aquitanian through to the Tortonian, with the large majority occurring within the Burdigalian and Langhian (the latter being the most speciose). These two stages encompass the Mid Miocene Climatic Optimum (MMCO), a time (ca. 16-14 Ma) when average global temperatures may have been ca. 3º C warmer than today.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

THE OLDEST RECORD OF BASILOSAURID WHALES FROM AFRICA AND ITS IMPLICATION ON THE EARLY EVOLUTION OF PELAGICETI (MAMMALIA, CETACEA)

GOHAR, Abdullah S., Mansoura University Vertebrate Paleontology center (MUVP), Mansoura, Egypt; ANTAR, Mohamed S., Egyptian Environmental Affairs Agency, Cairo, Egypt; SABRY, Dalia A., Faculty of Science, Mansoura University, Mansoura, Egypt; EL-SAYED, Sanaa, Mansoura University Vertebrate Paleontology center (MUVP), Mansoura, Egypt; SALLAM, Hesham M., Mansoura University Vertebrate Paleontology center (MUVP), Mansoura, Egypt

Pelagiceti is a clade of the obligatory aquatic cetaceans, comprising basilosauridae and living cetaceans, Neoceti. Broadly speaking, Basilosauridae is the basal fully aquatic cetaceans in whale evolutionary history. Except for specimens reported from the late Early Eocene (Ypresian) of Antarctica, basilosauridae is known from the late middle and late Eocene (Bartonian and Priabonian) worldwide, and it is the key for understanding the evolutionary transition from terrestrial whales' ancestors to completely aquatic living cetaceans. Eocene basilosaurid archaeocete whales of Africa have been reported from Egypt, Libya, Tunisia, Senegal and Western Sahara. The African fossil record of basilosaurid whales is especially limited for the Bartonian and Priabonian of the Eocene.
Here we document a new remains of basilosaurid whale from early middle Eocene (Lutetian) of Wadi El-Rayan Group of the Fayum Depression, Egypt. X-ray computed tomographic (CT) scanning has been highly informative in studying these remains. CT scans of the Wadi El-Rayan marl block have revealed a nearly complete skull, isolated auditory bullae, both left and right sides of the mandible with associated teeth and the first cervical vertebra (the Atlas). The presence of multiple accessory denticles (cusps) on cheek teeth, a flat palate narrowing anteriorly and well-developed pterygoid sinuses around the ear are shared diagnostic features of basilosaurids and the newly unearthed remains.
Given the age of the Wadi El-Rayan Group that has been assessed to the middle Lutetian-early Bartonian (46-40 Ma), this material constitutes the oldest record of basilosaurid whales from Egypt and indeed the oldest from the whole Africa. In addition, this record is among the oldest occurrences of basilosaurids worldwide, indicating a vast radiation and dispersal of the Pelagiceti since at least the early middle Eocene. This discovery confirms the presence of Basilosauridae (and indeed the Pelagiceti) in the early middle Eocene of Africa and extends the basilosaurid whales fossil record of Africa further back into the early middle Eocene, helping to fill in an important biogeographic and evolutionary gap and increasing our knowledge of the paleobiogeographic distribution of basilosaurids and whole Pelagiceti during the middle Eocene. Finally, this discovery underscores the importance of surveying the basilosaurids in early-middle Eocene strata generally and Wadi El-Rayan Group especially.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

A NEW DREPANOSAUROMORPH FROM THE CHINLE FORMATION OF PETRIFIED FOREST NATIONAL PARK, ARIZONA

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Drepanosauromorpha is an extinct group of basal diapsid reptiles known from the Middle to Late Triassic (237–212 MA). The clade currently includes seven genera (*Avicranium, Dolabrosaurus, Drepanosaurus, Hypuronector, Kyrgzsaurus, Megalancosaurus,* and *Vallesaurus*) that are known from fossils collected in Europe (Italy, U.K.), North America (Arizona, New Mexico, New Jersey), and Asia (Kyrgyzstan). The first described drepanosauromorph, *Drepanosaurus unguicaudatus*, was based on a flattened holotype preserving

most of a complete skeleton. Here, we describe a new drepanosauromorph species from the Chinle Formation in Petrified Forest National Park, Arizona based on a three-dimensionally preserved ungual phalanx of the second digit of the hand. One characteristic that distinguishes this claw is its size. The proximodistal length of the manual ungual phalanges of most drepanosauromorphs (except *Drepanosaurus*) fall within a range from about 0.125 cm to 1 cm. Measuring from the dorsal edge of the cotyle to the distal edge of the apex of the phalanx, the specimen is 2.23 cm in length, whereas the corresponding ungual from the holotype of *Drepanosaurus unguicaudautus* is 2.88 cm and the right second manual ungual from the Hayden Quarry *Drepanosaurus* is 2.07 cm in length. In addition, the Petrified Forest specimen differs significantly from all known *Drepanosaurus* specimens because of the shortened dorsoventral height of the claw, a lack of compression along the pre-axial/post-axial plane, and the overall morphology of the specimen. Its ventral margin starts to recurve at around 1 cm from the proximal end of the specimen, near the proximal margin of the lateral tuberosities, and around 1.2 cm on the dorsal margin. This contrasts with the condition in species of *Drepanosaurus*, which either recurve throughout the entire length of the specimen or the ventral margin recurves near the most distal end of the specimen. This new Petrified Forest taxon helps show how much morphological variation there is within Drepanosauromorpha. Future work on finding more material of small-bodied reptiles within the Chinle can help paint a clearer understanding of the hidden diversity that exists for these organisms and flesh out the ghost lineages of certain groups. This work, as well as future work, helps create a clearer understanding of the evolutionary history of small-bodied reptiles within the Chinle Formation.

Technical Session XVIII (Saturday, October 12, 2019, 4:00 PM)

DIET AND ECOLOGY OF TWO LOPHIALETIDS FROM THE EOCENE OF ERLIAN BASIN, CHINA: COMBINED EVIDENCE FROM MESOWEAR AND STABLE ISOTOPE ANALYSES

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Lophialetidae are endemic Asiatic tapiroids that were widely distributed in Asia during the Eocene. The two extinct lophialetids, *Schlosseria magister* and *Lophialetes expeditus* are the most abundant species in this family. However, their dietary and ecological characteristics have been largely unknown to date. In this study, we reconstructed for the first time the paleodiet and habitat of these two lophialetids using mesowear and stable carbon isotope analyses of fossil teeth excavated from the Huheboerhe area of the Erlian Basin, Nei Mongol, China. The mesowear analyses suggest that the diets of *S. magister and L. expeditus* changed from browsers, browse-dominated mixed feeders, mixed feeders, to grazers in the area from ~52 to ~42 Ma. It means that the dietary structure of *S. magister and L. expeditus* varied from less abrasive diets to more abrasive diets through time. The stable carbon isotope analyses suggest that both *S. magister* and *L. expeditus* had pure C_3 diets and inhabited an environment dominated by C_3 vegetation. The habitats of *S. magister* and *L. expeditus*, as a whole, became drier and/or more open in the area from ~52 to ~42 Ma as indicated by the more enriched $\delta^{13}C$ values. We find that the dietary shifts of the two lophialetids inferred from mesowear were consistent with the evident changes in habitat inferred from stable carbon isotope. The changes in diets and habitat of *S. magister* and *L. expeditus* were likely related to global climate change in that time period. The gradual drop of the global temperature as revealed by the marine oxygen isotope records after the Early Eocene Climatic Optimum led to a drier and more open terrestrial ecosystem in the Huheboerhe area in the Erlian Basin, probably resulting in gradual changes in floral composition of the forest environment inhabited by *S. magister* and *L. expeditus* through time. Hence, herbivores highly susceptible to vegetation modification had to develop new resource exploitation strategies to adapt to the change. *S. magister*, ultimately, which are considered as the direct ancestor of *L. expeditus* and having low level of ecological flexibility, were unable to adapt to the dramatic changes in habitat and became extinct at ~45 Ma.

Grant Information:
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Preparators' Session (Thursday, October 10, 2019, 3:45 PM)

DISTINGUISHING REGURGITALITES AND COPROLITES: A CASE STUDY USING A TRIASSIC BROMALITE CONTAINING SOFT TISSUE FROM *REVUELTOSAURUS*

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There is currently no consensus procedure for distinguishing fossilized fecal and gastric pellets. Herein, we devise a method for distinguishing coprolites from regurgitalites, using a large bone mass of postcranial material and soft tissue fibers (YPM VP.061134) from the Owl Rock Member of the Upper Triassic Chinle Formation. Synapomorphies in the teeth and dermal scutes suggest that these remains belong to the pseudosuchian archosaur *Revueltosaurus*.The bones in this specimen were compacted together and aligned in subparallel, semi-articulated clusters, indicating that this specimen represented a digestive residue (or “bromalite”) and not a sedimentary accumulation. However, it remained unclear whether this bromalite preserved ejecta or fecal matter. To determine whether this bone mass constitutes a regurgitalite or a coprolite, we subjected the specimen to chemical and microstructural analysis. A dearth of gastric etching, the absence of a scat-associated phosphate residue, and the presence of proteinaceous soft tissue suggest that this specimen represents a regurgitalite, and not a coprolite. From this approach, we offer a three-pronged method for distinguishing between different types of digestive remains on the basis of (i) phosphate concentration, (ii) degree of bone corrosion, and (iii) soft tissue preservation. We also comment on the nature of our pseudosuchian soft tissue fibers, and argue that they represent phosphatized skeletal myocytes, which retain individual myofibrils and Z lines.

Technical Session II (Wednesday, October 9, 2019, 9:45 AM)

TITANOSAURIAN SAUROPOD DINOSAUR FOSSILS FROM THE UPPER CRETACEOUS LAPUR SANDSTONE (TURKANA GRITS), TURKANA BASIN, NORTHWESTERN KENYA

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Exploratory efforts in sparse Upper Cretaceous African deposits have yielded only a handful of dinosaurian specimens, largely based on solitary occurrences. Although elusive, several diagnostic African dinosaur species have only recently augmented our understanding of the scarce Late Cretaceous African fossil record relative to better-known coeval deposits elsewhere. Thus far, titanosaurian sauropod dinosaurs have been used to establish initial paleobiogeographical perspectives on the Late Cretaceous of Africa as congruent patterns with other vertebrate clades await further description and testing. Presently, *Mansourasaurus shahinae* from the Campanian of Egypt demonstrates affinities with titanosaurians from Eurasia, whereas *Rukwatitan bisepultus* and *Shingopana songwensis* from the Turonian–Campanian of Tanzania share affinities with taxa from Gondwana suggesting a coarse latitudinal division in Late Cretaceous African faunas. However, questions remain regarding the extent of these early, yet encouraging, interpretations for Late Cretaceous African dinosaur faunas.
Exploratory reconnaissance of the lower beds of the Late Cretaceous (?Maastrichtian) Lapur Sandstone (Turkana grits) of northwestern Kenya has recovered fossil remains of a diverse terrestrial fauna, including turtles, crocodyliforms, and abelisaurid theropod and ornithopod dinosaurs. Due to the coarse depositional environment of the sandstones, titanosaurians represent the most abundant fossils encountered, including the associated skeleton of a small individual, KNM-WT 65086, and various isolated postcranial remains that allude to a diverse sauropod fauna. KNM-WT 65086 is represented by fragments of cervical, sacral, and caudal vertebrae; a partial scapulocoracoid; fragments of the forelimb and hindlimb; and an osteoderm. Unique features of KNM-WT 65086 include a midline ridge along the base of the neural canal and a protuberance on the posterior surface of the neural arch pedicle in several caudal vertebrae. Tip-dated phylogenetic analysis tentatively places KNM-WT 65086 outside of Saltasauridae among a paraphyletic stock of other Gondwanan titanosaurians, in contrast to the Eurasian affinities of *Mansourasaurus*. Additionally, other caudal vertebral morphs were recovered and indicate the presence of gigantic titanosaurs during the Late Cretaceous of Africa, further supported by several large appendicular and dermal elements. Overall, the Lapur Sandstone sauropod assemblage suggests a Gondwanan, rather than Eurasian, signal.

Technical Session VIII (Thursday, October 10, 2019, 2:30 PM)

INTEGRATION, EXTINCTION, CLIMATE, AND THE EVOLUTION OF THE PLACENTAL MAMMAL CRANIUM

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Morphological disparity results from numerous intrinsic and extrinsic factors, from the genetic and developmental processes that generate variation to large-scale climate change and extinction. Unifying these aspects in comprehensive analyses of morphological evolution has been hindered by differences in the type and scale of data used in these fields, but quantitative analysis of shape has the potential to bridge this divide. However, comparisons across large clades are made difficult by limited numbers of landmarks of unambiguous homology, resulting in either low representation of morphology or restriction to a narrow range of taxa. Here, we use high-dimensional surface geometric morphometrics to analyze shape, phenotypic integration (trait correlations resulting from genetic, developmental and functional interactions), disparity, and evolutionary rates in the placental cranium. Our dataset samples the full range of extant placental diversity, with 217 extant specimens representing nearly all families, and over 100 extinct species from the Paleocene to Recent. We digitized these skulls with 74 landmarks and 77 curves (1622 curve sliding semilandmarks) in Stratovan Checkpoint and patched each specimen with 522 surface sliding semilandmarks using the R package 'Morpho'. Combined, these data discriminate 17 cranial regions which were then analysed for pattern of phenotypic integration using maximum likelihood and covariance ratio analyses. All analyses were conducted with a phylogenetic framework, using a composite tree dated using the equal branch-sharing method. We identified a highly modular pattern for the placental mammal skull, with most cranial regions exhibiting high independence from other regions, and further analysed macroevolutionary patterns in these skull modules separately. Phylogenetic signal is moderate in most cranial regions (λ = 0.49-0.66) but is highest in the rostral and cranial base bones (λ = 0.78-0.82). Disparity of most cranial modules outpaces the simulated null expectation for most of the Paleocene, and in some cases the early Eocene, but otherwise largely fall within expected bounds. High rates of evolution are observed in most cranial modules through the Paleocene and late Eocene, but the highest rates for several cranial modules are contemporaneous with the Paleocene-Eocene Thermal Maximum. While some modules show most changes in early in clade history, others show sustained changes throughout the Cenozoic, particularly in bats, whales, and afrotherians.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

EXPANDING THE SCOPE OF MESOZOIC AND CENOZOIC CHONDRICHTHYAN AND BONY FISH RECORDS FROM NEW ZEALAND

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The past three decades have seen a considerable increase in our knowledge of fossil marine vertebrates from New Zealand (NZ). We summarize here several of the most notable relatively recent NZ additions to the fossil record of Mesozoic and Cenozoic chondrichthyans and bony fishes. Among these discoveries is the first phylogenetically basal 'paleoniscoid'-grade actinopterygian from New Zealand (Early Triassic), and a Late Triassic chimaeroid egg capsule ichnospecies (*Chimaerotheca reperepe*) that indicates chimaeroids reached southern Gondwana ~100 million years earlier than previously realized and used a reproductive mode strikingly similar to that of their close living relatives. A new tarpon-like teleost (Elopomorpha, Megalopidae) from the Paleogene of the Chatham Islands of NZ preserves fine 3D morphological detail, including unusual cranial and caudal features, and is the most complete fossil elopomorph yet recovered from the Southern Hemisphere. The Late Oligocene of the South Island, well-known for penguin and cetacean fossils, has also yielded a series of shark finds – the most impressive being an associated specimen (165 teeth and 32 vertebral centra) of the large lamnid shark *Carcharodon* (*Carcharocles*) *angustidens*. Late Oligocene teleosts represented include *Megalampris keyesi*, a giant deep-bodied lampridiform ('moonfish') with a total length of ca. 4 m – twice the length of extant *Lampris* – which is the first fossil lampridiform reported from the Southern Hemisphere. Finally, a morphologically distinctive Late Oligocene xiphioid billfish (*Aglyptorhynchus hakataramea*) is clearly placed in an otherwise exclusively Northern Hemisphere fossil billfish genus.
These records span over 200 million years, and encompass systematic diversity ranging from chimaeroids to phylogenetically derived teleosts. The recent decades of field research in NZ have had a significant impact that includes establishing the presence of a number of chondrichthyan and bony fish groups that would otherwise be either very poorly represented, or in some cases completely unknown, in the Southern Hemisphere fossil record.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

LATE MIO-EARLY PLIOCENE MARINE MAMMAL FAUNA FROM SOUTH AFRICA'S WEST COAST

GOVENDER, Romala, Iziko Museums of South Africa, Cape Town, South Africa

During the Miocene South Africa's west coast was embayed and influenced by marine phosphate upwelling, a moist onshore environment and warmer offshore sea surface temperatures while during the early Pliocene the ocean off the west coast became cold and temperate. During the late Miocene–early Pliocene there was a rich marine mammal fauna which included a diverse cetacean fauna and a phocid seal. The southwestern Cape coast environment varied; at Langebaanweg it progressed from riverine to estuarine to lagoonal while at Koeberg the area was open to the ocean with a barrier forming over time. Along the Northern Cape coast at Hondeklip Bay there was a deep lagoon at times with islands off the coast. *Homiphoca capensis* is the only phocid seal currently recognised. It is known from Langebaanweg (West Coast Fossil Park) and Hondeklip Bay which extends its home range 430 km further north during the early Pliocene. There is evidence of breeding colonies at Langebaanweg while at Hondeklip there are probably nonbreeding adults. An analysis of the tooth morphology and cranial anatomy suggests that *Homiphoca* was a pierce feeder that was capable of filter feeding. A morphometric and anatomical analysis of the skulls suggest the presence of at least two seal taxa at Langebaanweg while the anatomical analysis of the postcranial skeleton suggests two morphotypes. During the late Miocene–early Pliocene there were eight balaenopterids, one balaenid and at least five odontocetes living on South Africa's west coast. This is the first balaenid to be described from South Africa. *Diunatans* and *Fragilicetus* were described for the first time outside the North Sea. The cetacean skeletal elements also show evidence of shark tooth bites. The damage was caused by sharks with serrated and unserrated teeth. There are a number of young animals amongst the material preserved at a time when these lagoons and islands existed and the Benguela Upwelling System was well established.

Grant Information:
NRF/AOP grant (UID 98834) supported research, CoE Paleosciences conference travel grant. University of Cape URC travel grant application submitted.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A GEOMETRIC MORPHOMETRIC EVALUATION OF EQUID TOOTH SHAPE AT NATURAL TRAP CAVE, WYOMING

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Natural Trap Cave is a sinkhole cave located in Big Horn County in northern Wyoming. The cave preserves many Quaternary taxa, including pollen and large carnivorous and herbivorous mammals such as various felids and ungulates. Many of these taxa went extinct in North America following the late Pleistocene megafaunal extinction. The cave was first excavated in the 1970s and 80s by teams from the University of Kansas and the University of Missouri, and more recently by teams from Des Moines University, The

University of Adelaide, and The University of Rochester, along with a wide variety of volunteers. Specimens from this cave have been used to elucidate floral change in the area, disentangle ancient food webs, and extend the hypothesized range for Beringian wolves.

Horses are the most common megafaunal group from this site, encompassing two genera: *Equus* and *Haringtonhippus*, the "New World stilt-legged" horse, based on post-cranial elements and mitochondrial DNA. To date, identification of species made from isolated teeth of equids has been unsuccessful. This study aims to test if isolated equid cheek teeth from Natural Trap Cave can be identified to the genus level, between *Equus* and *Haringtonhippus* using geometric morphometrics. 2D landmarks were taken around the periphery of a set of upper cheek teeth, including the areas of greatest curvature at the metastyle, mesostyle, parastyle, and around the protocone and post protoconal valley. A principal component analysis separates the measured specimens into different groups. The first axis primarily shows variation in the size and orientation of the protocone. The angles and sizes range from parallel with the lingual side and short, to raised approximately 45-degrees towards the posterior side and longer. A modern horse specimen included in the data-set falls out near the group with the shorter and more parallel protocones, indicating the possibility that the other group of specimens may be from *Haringtonhippus*. With the abundance of isolated horse teeth (either *Equus* or *Haringtonhippus*) from Natural Trap Cave, having a reliable means to distinguish between genera will allow us to better study the ecological differences between them and better understand the environment and faunal interactions in late Pleistocene Wyoming.

Grant Information:
NSF EAR/SGP 1425059 (Natural Trap Cave Revisited: Ancient DNA, Climate and the Megafaunal Extinction) Julie Meachen, PI

Technical Session XVII (Saturday, October 12, 2019, 11:15 AM)

ESTABLISHING A COMPARATIVE OSTEO-DEVELOPMENTAL FRAMEWORK FOR EVOLUTIONARY AND FUNCTIONAL STUDIES OF DINOSAUR HEADGEAR THROUGH ANALOGY TO SOUTHERN CASSOWARIES AND NEOGNATHOUS BIRDS

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Studies of avian cranial phenotypic complexity often center on bill morphology and its relationship to taxonomy and diet. Relatively little attention has been given to bony cranial ornament variation and functional morphology despite the appearance of such structures in at least 11 orders of extant birds. Perhaps the best-known cranial ornaments among birds belong to cassowaries (*Casuarius*), which have spade-like casques that have been superficially implicated in numerous functional roles (e.g., display, vocalization, thermoregulation). These structures have been compared to cranial ornaments across non-avian dinosaur species (e.g., hadrosaurs, oviraptorosaurs) in order to develop hypotheses about function and evolution in the fossil record. Surprisingly, however, comprehensive documentation (i.e., including ontogeny) of the internal and external anatomy of cassowary casques has never been conducted, which hampers such interpretations and severely limits the utility of cassowaries as "living models". To remedy this issue, we elucidate ornament ontogeny in cassowaries by tracking the 3D development of individual casque elements across an extensive growth series of *C. casuarius*, comparing casque size to skeletal and sexual maturity, and formally describing phenotypic variation of this ornament in adults. Because cassowaries are the only known paleognaths to possess bony cranial ornaments, we also examined ontogenetic sequences of casqued neognaths (e.g., *Macrocephalon*, *Numida*). We find that neognathous species show ornament configurations consisting of paired dermatocranial bones, while those of paleognathous cassowaries also include an expansive, midline chondrocranial element. To determine which extant birds are appropriate osteo-developmental models for fossil lineages, we next surveyed cranial ornament configuration in non-avian dinosaurs. Our results suggest a lineage-specific utility for modern analogs such that crested neognathous birds are more aligned with most non-avian dinosaur cranial ornaments (e.g., expanded dermatocranial features in basal tetanurans, pachycephalosaurs), whereas cassowaries represent more appropriate analogs for many lambeosaurines (e.g., dermatocranial and chondrocranial features that elongate throughout ontogeny). By combining paleontological and neontological data, we propose a systematic framework for subsequent evaluation of ornament growth and function to better facilitate large-scale comparative studies of phenotypic complexity in the dinosaur head.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

SIMULATED RANGE OF MOTION MAPPING OF DIFFERENT HIP POSTURES DURING LAUNCH OF A MEDIUM SIZED ORNITHOCHEIRID PTEROSAUR

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Pterosauria includes the largest animals to achieve powered flight. How medium to large-sized pterosaurs were able to launch into the air is a matter of debate. Birds employ their legs to accelerate their bodies into the air, but the difficulties large birds face in becoming airborne suggests take-off may limit the maximum size of birds. It has been suggested that pterosaurs employed their fore and hindlimbs in take-off, the so-called quadrupedal launch mechanism, overcoming the size constraint. Range of motion (ROM) studies are a common way of determining the viability of hypothetical poses in extinct animals. Here we use ROM mapping of the hip joint of a mid-sized pterosaur, *Coloborhynchus* (SMNK PAL 1133) to test whether the joint surfaces of the acetabulum and femur were capable of achieving a bipedal and/or a quadrupedal stance during the range of motion required for take-off. Using the software programs Maya and MATLAB, possible intersections and orientations between different bones of the hip joint were identified and coded as viable or unviable. Osteological ROM mapping reveals a quadrupedal stance is more likely in launch, with maximum crouch during quadrupedal launch and flight positions being possible. However, it is important to consider not just osteological ROM but also the effects of soft tissues. ROM simulations can approximate the effect of different soft tissue such as ligamentous constraints and joint cartilage. We find that the required orientation for bipedal launch was not possible without the presence of cartilage. In order to achieve a bipedal stance in this specimen, a minimum of 3 mm of cartilage is required to sufficiently increase the ROM. A ROM study that included ligaments in addition to cartilage reduced the available viable orientations. This ROM generated in this study does not rule out the possibility of a quadrupedal launch in pterosaurs, and provide greater support for the quadrupedal rather than the bipedal launch hypothesis.

Technical Session XIV (Friday, October 11, 2019, 1:45 PM)

THE AVIAN PELVIS POSSESSES ANCESTRAL DINOSAURIAN AND ARCHOSAURIAN CHARACTER STATES EARLY IN ONTOGENY

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Untangling the relative timing of ancestral and apomorphic character appearance during vertebrate ontogeny is a central goal of evolutionary biology, but historically incorporation of data from developmental biology with extinct taxa has been challenging. The origin of the avian *Bauplan* provides an excellent system to tackle this knowledge gap because birds possess a highly apomorphic body plan with the anatomical changes that occurred during this transition constrained by an excellent fossil record of stem-avians. The avian pelvis is particularly distinct: unlike ancestral archosaurian pelves, with a 'closed' acetabulum, an anteroposteriorly short ilium, and a forward-facing pubis, the avian pelvis has an anteroposteriorly expanded ilium and sacrum (≥12 vertebrae), an 'open' acetabulum, and a retroverted pubis. To examine morphogenesis of avian pelvic tissues in a deep-time context, we integrated data from *Alligator* and non-avian theropod (i.e., *Coelophysis*, *Tyrannosaurus*, *Deinonychus*, *Archaeopteryx*) pelves that track the transition from ancestral character states to those of crown birds with embryological data. Specifically, we used a novel embryological technique (CLARITY plus immunofluorescence combined with 3D confocal imaging) conducted on *Alligator* and quail embryos to show embryonic pelvic ontogeny more clearly and at earlier developmental stages than was previously possible. We found many ancestral features are present in early avian morphogenesis, which only transition to typically avian forms later in ontogeny: the early embryonic avian ilium is anteroposteriorly short, the acetabulum is 'closed', and the pubis is anteriorly directed, possessing a pubic 'boot' similar to early theropods. Geometric morphometrics support the qualitative observation that the ontogenetic order of these transitions mirrors character state changes during the transition from early theropods to crown birds recorded in the fossil

record. Unlike the avian cranium, which possesses apomorphic states throughout ontogeny, the pelvis evolved via modifications to relatively late developmental patterns, with early-stage embryos retaining a morphology similar to that of early theropod dinosaurs. Different regions of the avian *Bauplan* evolved via radically disparate developmental modifications. Extinct taxa are critical to correctly identifying the identity of ancestral and apomorphic features appearing during ontogeny.

Grant Information:
National Science Foundation Graduate Research Fellowship Program, Yale University Department of Geosciences, Human Frontier Science Program

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

THE EVOLUTION AND EXTINCTION OF *OTODUS MEGALODON*: NEW INSIGHTS FROM NITROGEN, CALCIUM, AND 'CLUMPED' ISOTOPE RATIOS

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The largest and most iconic shark to have ever lived is the extinct megatoothed shark, *Otodus megalodon*. Fossil teeth and vertebrae indicate this highly successful apex predator achieved lengths up to 15 m, and had a global distribution throughout the Miocene and Pliocene (23-2.5 Ma). A general consensus indicates that the ability of *O.megalodon* to thermoregulate acted as a key driver for the evolution of gigantism that impacted its ecological role and success in surviving environmental changes. Yet, whereas models suggest predator-prey dynamics and/or environmental change influenced its extinction, the ultimate cause for the disappearance of *O. megalodon* is still highly uncertain. To help address these uncertainties, we constrain the body-temperature of some mid-latitude extant and fossil sharks during the Cenozoic using 'clumped' isotopes (^{13}C-^{18}O) based on tooth samples collected from the Pacific, Indian, and Atlantic Oceans. In order to establish trophic-level changes between the different species over time, we additionally measure $^{44}Ca/^{40}Ca$ ($\delta^{44}Ca$) ratios of the enameloid and $^{15}N/^{14}N$ ($\delta^{15}N$) ratios of organic matter bound within the enameloid of these same teeth. Clumped isotope results on aquarium-reared and wild-caught shark teeth do not deviate from previously published calibrations of bioapatite. Applying these same temperature calibration equations to teeth from the Pliocene of North Carolina (U.S.A.) and Japan suggests that *O. megalodon* maintained a high body temperature that was slightly warmer than its modern lamniform equivalent, the white shark (*Carcharodon carcharias*) from the same geologic units. Comparison of $\delta^{15}N$ and $\delta^{44}Ca$ in a suite of shark teeth reveal elevated nitrogen isotope ratios and depleted calcium isotope ratios in *O. megalodon* with respect to other contemporaneous species indicating a very high trophic-level feeding strategy that was likely facilitated by its large body size with high body temperature. These results may provide clues as to what led to the ultimate demise of *O. megalodon* during the Pliocene. For example, a recent hypothesis states that *O. megalodon* went extinct due to sea-level oscillations in the Pliocene, which caused global habitat loss and/or a drop in the diversity of potential prey or appearance of new competitors. If *O. megalodon* primarily fed on higher level prey (e.g., cetaceans), as our isotope results indicate, then large climatic shifts combined with evolutionary limitations could provide the "smoking gun" for the extinction of the largest shark species to ever roam this planet.

Grant Information:
National Science Foundation, Sedimentary Geology and Paleobiology (SGP) EAR-7858820.

Technical Session XV (Saturday, October 12, 2019, 10:45 AM)

BIOSTRATIGRAPHY OF THE LOWERMOST BEAUFORT GROUP IN THE MAIN KAROO BASIN, SOUTH AFRICA: IMPLICATIONS FOR MID- TO LATE-PERMIAN FAUNAL PROVINCIALISM AND KAROO BASIN DEVELOPMENT.

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The Beaufort Group of the Main Karoo Basin (MKB) of South Africa, with its wealth of tetrapod fossils, has been the focus of paleontological investigations for over 170 years and is considered to be the global standard for mid-Permian to Mid-Triassic continental biozonation. Currently eight vertebrate assemblage zones (AZ) are recognized. While fossil tetrapods have been reported from across the basin, the lowermost strata of the Beaufort Group have yielded relatively few fossils, particularly the area north of S31°10′. Reasons for this relative paucity of tetrapod fossils include a more attenuated stratigraphic succession in the distal (northern) sector compared to the proximal (southern) sector, coupled with the shortage of extensive exposures resulting from flatter topography and increased vegetation cover. Intensive fossil collecting in the lowermost Beaufort Group in the northern sector of the basin resulted in new distribution records for several genera. Our sample was augmented using fossil data from the Beaufort Fossil Vertebrate Database maintained by the Evolutionary Studies Institute (ESI), Johannesburg. Our study shows that the mid-Permian *Tapinocephalus* AZ extends further north in the MKB than previously recognized, and is directly overlain by the upper *Cistecephalus* or lower *Daptocephalus* AZ in the southern Free State Province. In the central and northeastern Free State, the *Daptocephalus* AZ is the oldest Beaufort Group vertebrate biozone present. Interestingly, the faunal composition of the *Tapinocephalus* AZ at its northernmost reaches differs from that of the south. This suggests that contemporaneous faunas in the MKB were not uniform across the basin and displayed more variation than currently appreciated. Furthermore, the juxtaposition of the lower *Tapinocephalus* AZ and upper *Cistecephalus*\lower *Daptocephalus* AZ in the southern Free State implies a stratigraphic gap from the middle to late Permian of up to 6 million years. These results have interesting implications for understanding faunal provincialism within Southern Africa during the mid- to late Permian as well as refining basin development models for the MKB.

Grant Information:
The NRF and its African Origins Platform, the Paleontological Scientific Trust (PAST) and the DST-NRF Centre of Excellence in Paleosciences (CoE-Pal) are acklowledged.

Preparators' Session (Thursday, October 10, 2019, 2:15 PM)

DIGITAL AND MECHANICAL PREPARATION OF DELICATE SKELETAL REMAINS FROM AN UPPER CRETACEOUS BONEBED IN MADAGASCAR

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We demonstrate an integrated methodology for using CT in both mechanical and digital preparation of field jackets collected from locality MAD 05-42 in Upper Cretaceous deposits of the Maevarano Formation, Mahajanga Basin, Madagascar. Following in-quarry surface mapping, field jackets were documented in a medical CT scanner before mechanical preparation to provide preliminary identifications and spatial relationships of encased fossils. The initial scanning assisted in both prioritizing and in performing mechanical preparation. Specimens were prepared exclusively under magnification, using insect pins and carbide needles held in pin vices. Paraloid B-72 was used for consolidation of specimens and adhesion of fragments. Cyclododecane served to stabilize elements during disassociation. Specimens too fragile to prepare entirely, or presumed to have delicate materials preserved below exposed and prepared materials, were micro-CT scanned. These data were then digitally prepared (segmented), providing high-resolution information on the spatial arrangements and anatomical details of materials too delicate to be exposed or removed from matrix. The workflow for this effort was coordinated between Ohio University and the Denver Museum of Nature and Science using two software platforms (Avizo and Dragonfly); it involved substantial processing by students and volunteers for

initial segmentation, followed by quality control and data organization prior to study. As a result of preparation, associations of elements from individuals were demonstrable taphonomically (e.g., by connecting fragments of sternum prepared digitally and prototyped for confirmation of fits along pre-depositional breaks) and anatomically (by close physical association of non-overlapping elements, many of which were not visible on the mechanically prepared surface). We created high-resolution taphonomic digital reconstructions of materials across largely unprepared blocks of matrix. The two preparation approaches resulted in the defensible organization of discrete, dispersed anatomical elements into the context of individuals whose anatomy, functional morphology, and phylogenetic relationships can be studied. We also produced prototype outputs of morphology that could not be replicated through molding and casting, resulting in 3D models for primary research and comparative work, as well as for dissemination and exhibition activities.

Grant Information:
National Science Foundation (EAR_1525915)

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

NEW LISSAMPHIBIAN MATERIAL FROM THE LOURINHÃ FORMATION (LATE JURASSIC, PORTUGAL)

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The Upper Jurassic of Portugal has been known for its vertebrate microfossil fauna thanks to the Konzentrat-Lagerstätte of the Guimarota mine, which provided thousands of bone fragments from various vertebrate clades. Hereby are reported three new vertebrate microfossil assemblages from the Lourinhã Formation: Porto das Barcas and Zimbral, from the Praia Azul Member, and Valmitão, from the Porto Novo / Praia da Amoreira Members. All the localities are late Kimmeridgian in age. The assemblages have provided over one thousand vertebrate microfossils, including chondrichthyans, actinopterygians, lissamphibians, squamates, dinosaurs, pterosaurs and crocodylomorphs. All materials are housed at the Museu da Lourinhã collection. Paleoenvironmental reconstructions suggest Porto das Barcas and Zimbral were floodplain mud deposits, and Valmitão was an oxbow lake mud deposit. Nevertheless, the presence of marine bivalve shells suggests at least some brackish influence.

The Lissamphibia remains are one the three most abundant microfossils in the assemblages, after crocodylomorphs and fishes, for which teeth and scales overestimate their real presence. The new material here reported includes over 50 cranial and post-cranial remains belonging to Albanerpetontidae and Anura. Albanerpetontid material comprises fragmented cranial material, including a dozen of dentaries with tricuspid teeth and one fused frontal, thirty hour-glass shaped vertebra centra, and fragmented limb bones, including two pentagonal-shaped proximal humeri and six femora (three proximal parts and three distal parts). Anuran material is scarcer, including a distal part of a humerus with a complex ulnar condyle and an extended olecranon scar, and a tibiofibular They represent the first report of anurans in the Late Jurassic of Portugal outside the Guimarota Mine. Other remains have been attributed to undetermined lissamphibians, including an atlas and a scapula.

The faunal association suggests that all three localities were continental ecosystems with lacustrine influence, dominated by terrestrial and amphibious taxa. Amphibians are indubitable indicators for freshwater environments and their occurrence in the three assemblages strongly support their interpretations as terrestrial ecosystems. It is congruent with previous stratigraphic and sedimentological interpretations on these units.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

PHYLOGENY OF SOUTH AMERICAN MARSUPIAL *DROMICIOPS* THROUGH BRAIN TRAITS

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Dromiciops gliroides "monito del monte" is an extant small and mostly arboreal, nocturnal South American marsupial, and is the only living species belonging to the Order Microbiotheria. The oldest known microbiotherian is from the Early Paleocene of Bolivia, other fossil genera have been discovered in the Paleogene and Neogene of South America and the Middle Eocene of Antarctica.

Dromiciops lives in the temperate Valdivian *Nothofagus*-*Chusquea* forests of southern Chile and adjacent areas in western Argentina. Phylogenetically this south American marsupial is more closely related to Australasian rather than American marsupials.

Here we have analyzed the internal brain anatomy of *Dromiciops gliroides* and compared it with the brains of extant American and Australian marsupials. We examined phylogenetic relationships of *Dromiciops* with extant marsupials based on maximum parsimony analysis using a soft body brain morphology-only matrix, using 21 soft anatomy brain characters and 96 mammalian taxa (93 marsupials, 2 monotremes, and one placental). Six extra soft anatomy brain characters were added to those used by Johnson and co-workers.

Dromiciops does not have a fasciculus aberrans, but does exhibit other features of brain structure that are similar to diprotodontid metatherians (e.g., lamination of the lateral geniculate nucleus of the dorsal thalamus). Cortical organization in *Dromiciops* shows some similarities with that in Australian marsupial carnivores in that the proportional areas of isocortex devoted to somatosensory and visual function are similar in size to each other, and greater in area than that devoted to olfactory or auditory function. This points to similar sensory requirements for the foraging lifestyle of *Dromiciops* and small Australian marsupial carnivores, with isocortical specialization for somatosensation and vision. The results using brain anatomy characters place *Dromiciops* nested within the Australasian marsupial radiation (i.e., within Australidelphia) and recovered *Dromiciops* as a sister group to the Australasian marsupial clade Diprotodontia.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

PALEOPATHOLOGY IN NEW MATERIALS OF *MAJUNGASAURUS CRENATISSIMUS* FROM THE MAEVARANO FORMATION, NORTHWESTERN MADAGASCAR

GUTHERZ, Samuel B., Ohio University, Athens, OH, United States of America; GROENKE, Joseph R., Ohio University, Athens, OH, United States of America; O'CONNOR, Patrick M., Ohio Univ, Athens, OH, United States of America; SERTICH, Joseph, Denver Museum of Nature & Science, Denver, CO, United States of America

Due to the nature of the vertebrate fossil record, it is rare that an extinct species is represented by more than a few elements, let alone multiple relatively complete individuals. Field research conducted in the Upper Cretaceous (Maastrichtian) Maevarano Formation in northwestern Madagascar over the past 14 years has yielded several new partial individual skeletons of the abelisaurid theropod *Majungasaurus crenatissimus*. The number of individuals and quality of preservation, although variable, allows for assessment of pathology in this species. Previous pathologies documented in *Majungasaurus* indicate select infectious (i.e., microbial) and possible traumatic etiologies. Continuing fieldwork and ongoing preparation of materials recovered since 2005 provide many additional opportunities to better characterize the anatomy and paleopathology in *Majungasaurus*. In particular, an almost complete articulated skeleton (FMNH PR 2836) is the focal point of the current study, with selected observations from other new specimens. FMNH PR 2836 preserves multiple osteopathologies, including representative lateral facial and lower jaw elements, vertebrae, ribs and gastralia. A diagnosis with hypothesis of pathological origin is provided for each skeletal entity. The preserved pathologies include necrotic bone infection of the jugal and quadratojugal, healed fractures of several left and right dorsal ribs and gastralia, and a cervical vertebra (C5) with evidence of a healed tooth drag injury on the lateral surface of the neural arch. Putative infections present in the jugal and quadratojugal appear relatively minor, with only small areas affected and the erosions penetrating only the medial surface of each element with some evidence of healing. Given the proximity of the two elements, it is likely that a localized infection affected both bones. The dorsal rib fractures are present bilaterally, occurring sporadically throughout the series, with varying degrees of healing and at different dorsoventral positions. Given both spatial and remodeling variability of the injuries, it is likely that they are the result of multiple interactions with other organisms or the environment. Lastly, a putative drag mark on the fifth cervical vertebra does not show any sign of healing and is likely the result of a post-mortem scavenging. Since osteological pathologies record aspects of life history, observations from this study can provide insight into the physiology, behavior and, potentially, the nature of the environment experienced by *Majungasaurus*.

Grant Information:
National Science Foundation EAR_1525915

Technical Session XI (Friday, October 11, 2019, 10:15 AM)

GEOGRAPHIC PATCHINESS AND ITS EFFECT ON MACROEVOLUTIONARY INFERENCE

HALLIDAY, Thomas J., University of Birmingham, Birmingham, United Kingdom; GARWOOD, Russell J., University of Manchester, Manchester, United Kingdom

The fossil record is biased in space and time. Time intervals are unevenly sampled, and for any given interval, only a small portion of the Earth's surface is preserved, biased towards depositional and taphonomically advantageous environments. Compounding this, taxon distributions are independently structured, functions of environmental tolerance and ancestral range. Evolutionary inferences must be made in the context of this incomplete and structurally biased fossil record, and while such effects are often considered in the context of richness, other aspects of paleobiology might be influenced by geographic biases.

Diversification in an unsampled region cannot be observed directly and may present problems for inference of phylogeny, divergence dates, and rates of evolution. A slowly evolving clade that appears simultaneously in the fossil record as a result of changing geographic distribution has the same pattern of first appearance dates as one adaptively radiating faster than the frame rate of the fossil record. Here, we investigate the effect that these geographic biases have on reconstructions of evolutionary history.

Using a recently-developed agent-based evolutionary model, TREvoSim, we simultaneously simulated the evolution of two communities of constant and equal size. Each community comprised individuals represented by binary character genomes. In each iteration, mutations were introduced during reproduction, and individual fitness was assessed against changing environmental masks, determining the likelihood of reproducing. Dispersal between communities was permitted at a symmetric low-level probability. We tested the impact of several scenarios, including extreme environmental perturbations and increases in dispersal probability.

The resultant matrices were degraded to reflect character and taxon incompleteness and spatial biases in preservation. Topology and divergence dates were inferred from each degraded matrix with MrBayes, and compared with the true tree.

Character and taxon completeness had little effect on tree accuracy or precision except where character completeness was very low. Increased dispersal probability had little effect on tree accuracy, but resulted in lower precision, and more extinction following perturbations. Notably, for taxa that dispersed en masse, inferred divergence dates were consistently too young. These results have important implications for understanding the interactions between the geological and biological processes that underlie paleobiological data.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

MUSCULAR RECONSTRUCTION AND COMPUTATIONAL MODELLING OF THE PECTORAL GIRDLE IN LAMBEOSAURUS (DINOSAURIA, HADROSAURIDAE).

HAMILTON, Samantha M., University of Alberta, Edmonton, AB, Canada; CROSS, Margaret, University of Alberta, Edmonton, AB, Canada; WANG, Yan-Yin, University of Alberta, Edmonton, AB, Canada; RYAN, Michael J., Carleton University, Ottawa, ON, Canada; SULLIVAN, Corwin, University of Alberta, Edmonton, AB, Canada

An animal's posture and gait are fundamental to its ecology and behaviour. Ancestral dinosaurs were likely bipedal, but a number of groups secondarily reverted to quadrupedality. Hadrosaurid ornithischians are often regarded as an example of a secondarily quadrupedal lineage, but their posture has proved contentious, as some researchers have interpreted them as habitual or at least facultative bipeds. Continuing uncertainty on this point complicates attempts to reconstruct the evolution of posture in dinosaurs overall, and hinders investigations of hadrosaurid behavior and ecology.

The functional morphology of the forelimb may hold the key to determining whether hadrosaurs were predominantly bidepal or quadrupedal. The remarkably preserved pectoral girdle and forelimbs of a partial lambeosaurine (crested) hadrosaur skeleton that was recently recovered from the Upper Cretaceous Oldman Formation of southern Alberta, Canada provide suitable material for a thorough description of the pectoral appendicular skeleton, and an analysis of its musculature and osteological range of motion. Manipulation of a digital model of the shoulder joint in Autodesk Maya indicates a maximum of 75º of protraction of the humerus, from an initial vertical orientation, and a maximum retraction of 113º. Abduction and adduction were limited to 40º and 76º respectively. Muscular reconstructions show correspondingly large muscle attachment sites associated with support of the shoulder as well as extension and retraction of the upper arm. For example, most of the blade of scapula is occupied by a very large area of origin for the deltoideus scapularis, which is thought to be involved specifically with retraction of the humerus. In contrast, areas of scarring for muscles associated with abduction and retraction are comparatively small, suggesting that these muscles were less powerful movements and possibly had smaller joint moment arms.

These findings lend support to the hypothesis that hadrosaurs were predominantly quadrupedal animals, as powerful retraction movements of the forelimb would be particularly advantageous in quadrupedal walking. Hadrosaurs likely represent a transitionary stage between bipedalism and quadrupedalism, making these animals a model organism for studying the mechanical evolution of bipedality. Creating thorough biomechanical models of the movements of these animals is therefore a crucial step to understanding how and why this major adaptive event occurred so often in the dinosaur lineage.

Grant Information:
This research was funded by an NSERC Discovery Grant (RGPIN-2017-06246).

Technical Session VIII (Thursday, October 10, 2019, 3:30 PM)

THE EVOLUTION OF PECULIAR CRANIAL MORPHOLOGY IN NASAL-EMITTING TRIDENT BATS (CHIROPTERA: RHINONYCTERIDAE) FROM THE AUSTRALIAN MIOCENE

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In the fossil deposits of the Riversleigh World Heritage Area of northern Australia, trident bats (Rhinonycteridae) and Old World leaf-nosed bats (Hipposideridae) are among the most speciose and abundant mammal taxa. Some 20 species of these bats have been identified in Riversleigh's late Oligocene to middle Miocene karst deposits, and many are represented by hundreds of well-preserved skulls each. These kinds of bats emit pure-tone echolocation calls through the nostrils that allow detection of fluttering prey around vegetation, and have expanded nasal chambers and cochleae which are associated with energy transmission and reception. We used 3D geometric morphometrics to examine cranial traits in one of the most distinctive of these lineages, the *Xenorhinos* group. These extinct bats are characterised by a broad, deep rostrum, voluminous nasal cavities, incomplete nasal septum, broad interorbital region, extremely short palate, splint-like sphenoidal bridge, and conspicuous rostral rotation. A 3D GMM approach enabled recognition of two new species referrable to this group, reappraisal of the lineage's probable phylogenetic relationships, assessment of their likely echolocation call attributes and ecology, and a possible developmental pathway for their unique skull form. Members of the *Xenorhinos* group represent ecomorphs that have been completely lost since the middle Miocene, probably as a result of changing paleoenvironments in northern Australia, but at least some of their striking cranial features persist in the extant trident bats of Africa and Madagascar.

Grant Information:
Australian Research Council Discovery Program DP170101420

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A REVIEW OF THE MIOCENE RHINOCEROSES FROM JAPAN, AND PALEOBIOGEOGRAPHIC IMPLICATIONS

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In Japan, the Miocene rhinocerotid remains have been well reported. Recently, the taxonomy of rhinocerotids from Eurasia has been revised. In contrast, taxonomic revisions of Japanese remains have not been undertaken since their initial descriptions except for a few teeth and mandibular remains. Numerous rhinocerotid footprints have also been reported from the Miocene strata. The Japanese rhinocerotid fossil records give new information on the paleobiogeography of rhinocerotid in far East Asia during the Miocene. However, a comprehensive discussion of Japanese Miocene rhinocerotids has not yet been carried out. Here I review the fossil records of the Japanese rhinocerotids from the Miocene and discuss their taxonomic status and distribution with the paleogeographic change of Japan island through the Miocene Period.

Brachypotherium? *pugnator*, *Plesiaceratherium* sp. and possibly a member of the Teleoceratini have been found from the Early Miocene localities (20-16 Ma). Several fragmentary remains of the Early Miocene which were identified as *Chilotherium* are re-identified as an indeterminate taxon. All rhinocerotid footprints have been found from the early Miocene strata. A lower incisor which is of a member within the Aceratheriinae is only the Middle Miocene record (around 14 Ma). I recognize two Late Miocene (9-6 Ma) remains as members within the Aceratheriini. An isolated lower molar from the early Late Miocene locality is identified as an indeterminate taxon.
In the Early Miocene, proto-Japan was a part of the eastern margin of the Asian Continent. Various species of *Plesiaceratherium* and *Brachypotherium* have been found from the Early Miocene localities in Eurasia. Therefore, Japanese ones imply that these two taxa distributed into the eastern margin of Eurasia in that time. The humid forest dominated environment in Eurasia during the Early Miocene would have affected the wide distribution of these taxa. Proto-Japan was separated from the continent with the opening of the Japan Sea and had become archipelago by the earliest Middle Miocene (around 16 Ma). The latest Early to Middle Miocene rhinocerotid records in Japan suggest that rhinocerotids presented in small islands of proto-Japan. Proto-Japan re-connected Asian continent in the early Late Miocene. Rhinocerotids presented in Japan islands during the Late Miocene. However, it is unclear that whether Japanese Late Miocene taxa are descendants of the Early to Middle Miocene taxa or new immigrants from the continent in the early Late Miocene due to incompleteness fossil records.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A NEW BASAL EUSUCHIAN FROM THE GRIMAN CREEK FORMATION AT LIGHTNING RIDGE, NEW SOUTH WALES, AUSTRALIA.

HART, Lachlan J., University of New England, Armidale, Australia; BELL, Phil, University of New England, Armidale, Australia; SMITH, Elizabeth T., Australian Opal Centre, Lightning Ridge, Australia; SALISBURY, Steven W., Universityof Queensland, Brisbane, Australia

The Australian Mesozoic crocodyliform record is sparse in comparison to other Gondwanan land masses. A single formally-named taxon is known from this interval: *Isisfordia duncani* (upper Albian of the Winton Formation, Queensland). A second taxon, *'Crocodylus (Bottosaurus) selaslophensis'* (Griman Creek Formation, Cenomanian, New South Wales), described in 1917 based on a jaw fragment, is enigmatic, and its taxonomic affinities have never been fully resolved.
We present evidence of a new species of *Isisfordia* from the same location and stratigraphic interval as *'Crocodylus (Bottosaurus) selaslophensis'*. This new species, based on a partial braincase, presents at least one unambiguous autapomorphy of *Isisfordia* and several unique characteristics that differentiate it from *I. duncani*.
The former holotype of '*Crocodylus (Bottosaurus) selaslophensis'* is also referred to this new species. Central to this argument is the re-identification of the jaw fragment as part of the maxilla—rather than the dentary as was previously supposed—combined with the presence of an alveolar groove. Despite the shared presence of an alveolar groove with *I. duncani*, the two differ in the shape of the alveoli and tooth crown bases, suggesting differentiation at the species level. Furthermore, additional cranial and postcranial remains from the Griman Creek Formation, including a series of associated vertebrae, also show features consistent with *Isisfordia* and are potentially assignable to the new taxon.
The identification of a second, roughly contemporaneous species of *Isisfordia* demonstrates that the genus was well-established in eastern Australia during the mid-Cretaceous. *Isisfordia* is the first Australian Mesozoic archosaur with multiple distinct species, further underscoring the paucity of Australia's Mesozoic terrestrial vertebrate fossil record. These discoveries are also significant as they extend the geographical and temporal range of *Isisfordia*, which has traditionally been considered the most basal taxon within Eusuchia.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

USING COMPARATIVE ANATOMY, TAPHONOMY, AND PHYLOGENETIC BRACKETING TO ASSESS RIB ORIENTATION IN NON-AVIAN DINOSAURS

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Estimates of extinct animal volume, center of gravity, and extrapolations from that data (e.g., physiological modeling, reconstructing stance and gait) depend on accurately constraining volumes of individual body segments. This is particularly true of the torso, which is the largest body segment in nearly all tetrapods. Limb girdles and bony ribs provide the potential for accurate torso shape and volume estimates, but competing estimates of rib orientation relative to the axial column significantly alter results. This is true whether estimates are made from multi-view anatomical diagrams or from three-dimensional LIDAR scans.
Inspection of articulated non-avian dinosaur rib cages and undistorted isolated elements confirms previous reports that for anterior thoracic ribs, full seating of tuberculi and capituli against against respective diapophyses and parapophyses results in rib shafts oriented posteroventrally in non-avian dinosaur taxa sampled. This result is consistent with X-ray data and dissections of extant crocodilians and avian-dinosaurs. As these taxa form an extant phylogenetic bracket, posteroventrally oriented anterior thoracic ribs in non-avian dinosaurs are a Level I inference.
Diapophyses and parapophyses on the anterior vertebrae of dinosaurs are frequently offset from one another vertically and horizontally. As a result more posteriorly swept ribs also produce a narrower torso. The location of the pectoral girdle of non-avian dinosaurs is dependent on the shape and anterior extent of the rib cage. Anterior thoracic ribs mounted or reconstructed in a vertical orientation requires the pectoral girdle to be moved anteriorly, functionally elongating the torso and shortening the neck. Calculating mass from competing inferences of rib orientation via double graphic integration shows a variance in whole-animal volumetric estimates of 8-10%. I suggest either adopting the well-supported Level I inference for non-avian dinosaur rib orientation, or for future authors to include these larger error bars into calculations that build upon shape or volume estimates.

Technical Session III (Wednesday, October 9, 2019, 3:00 PM)

THE SOUND OF RANCHO LA BREA

HARTSTONE-ROSE, Adam, North Carolina State University, Raleigh, NC, United States of America; ELMINOWSKI, Erin, North Carolina State University, Raleigh, NC, United States of America; FLORES, Deanna, North Carolina State University, Raleigh, NC, United States of America; ELDRIDGE, Emma, North Carolina State University, Raleigh, NC, United States of America

Withdrawn

Fossils of *Smilodon fatalis* and *Canis dirus* [illegible] Rancho La Brea (RLB) tar pits in [illegible] that [illegible] middle ear bones (the [illegible]) [illegible] have [illegible] of sound from the [illegible] to the [illegible] comparing the ossicles of *S. fatalis* [illegible] to [illegible] living relatives, we aimed to determine the range of [illegible] heard by these prehistoric predators. Due to the phylogenetic relationship, we hypothesize that the extinct species will have frequency ranges similar to their living relatives. To test this, we photographed 56 *S. fatalis* and 51 *C. dirus* auditory ossicles from RLB and digitally measured them and the ossicles of their living relatives (and some other RLB species) and found that the auditory ossicles of *S. fatalis* and *C. dirus* have similar shape and size characteristics of their modern relatives. While *S. fatalis* and *C. dirus* might have had similar hearing to their living relatives, we were also able to examine the auditory ossicles of the large extinct American lion (*Panthera atrox*) and found that its ear bones were substantially larger than those of any living cat species suggesting that it might have had very different – perhaps lower frequency – hearing. Other RLB taxa had ossicles that were so morphologically distinctive to be difficult to acoustically analyze. For instance, the giant ground sloths (*Paramylodon*, *Megalonyx* and *Nothrotheriops*) have no modern analogue remotely similar in shape and scale, and their well-preserved ossicles will require different technical approaches to assess their sound transmission properties.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 10:45 AM)

CALCIUM ISOTOPES AND DINOSAUR RESOURCE PARTITIONING

HASSLER, Auguste, Laboratory of geology of Lyon: Earth, Planets and Environments, Lyon, France; MARTIN, Jeremy E., Laboratory of geology of Lyon: Earth, Planets and Environments, Lyon, France; AMIOT, Romain, Laboratory of geology of Lyon: Earth, Planets and Environments, Lyon, France; TACAIL, Théo, Bristol Isotope Group, School of Earth Sciences, University of Bristol, Clifton, United Kingdom; ARNAUD-GODET, Florent, Laboratory of geology of Lyon: Earth, Planets and Environments, Lyon, France; ALLAIN, Ronan, Sorbonne Universités—CR2P—MNHN, Paris, France; BALTER, Vincent, Laboratory of geology of Lyon: Earth, Planets and Environments, Lyon, France

Decades of field investigations in mid-Cretaceous continental assemblages of North Africa have provided extensive amounts of dinosaur fossils, among which theropods are the most numerous. The large representation of theropods in these environments led paleontologists to identify an “overabundance” of these dinosaurs compared to herbivorous ones. The co-occurrence of taxa such as abelisaurids, carcharodontosaurids and spinosaurids, in environments where herbivorous dinosaurs seem rare but where large crocodylomorphs are also present, raise numerous questions about the ecology of these faunas. How so many large predators could coexist with such few preys available? To address this question we investigated resource partitioning among such faunal assemblages using calcium (Ca) isotopes preserved in tooth enamel. Mainly originating from food items and mineralized tooth enamel, Ca isotopes have proved to be a promising tool to infer trophic structures in recent and long extinct ecosystems. A focus on the mid-Cretaceous deposits of Gadoufaoua (Niger) and Kem Kem Beds (Morocco) has shown the distinct isotopic signature of spinosaurids, the most negative in our dataset. This observation and the distinct taxonomic clustering in Ca isotope values highlight the peculiar diet of spinosaurids and provide unambiguous evidence for niche partitioning between co-existing large predators. These, and other recently published results, should encourage further investigations of calcium isotopes in reconstructing ancient food chains.

Grant Information:
Funding for this work was provided by the LABEX LIO (ANR-10-LABX-0066, ANR-11-IDEX-0007), J.E.M. DIUNIS project from CNRS-INSU, and the Jurassic Foundation Grant Program.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW FOSSILS OF *ANTHRACOSUCHUS* (CROCODYLOMORPHA) FROM THE PALEOCENE OF SOUTH AMERICA AND THE GEOGRAPHIC ORIGIN OF DYROSAURIDAE

HASTINGS, Alexander K., Science Museum of Minnesota, Saint Paul, MN, United States of America; MORENO-BERNAL, Jorge W., Universidad del Norte, Barranquilla, Colombia; WHITING, Evan T., University of Minnesota, Minneapolis, MN, United States of America; RINCÓN, Aldo F., Universidad del Norte, Barranquilla, Colombia; JARAMILLO, Carlos, Smithsonian Tropical Research Institute, Balboa Ancon, Panama; BLOCH, Jonathan I., Florida Museum of Natural History, University of Florida, Gainesville, FL, United States of America

Previously described vertebrate fossils from the middle Paleocene (58–60 million years ago) Cerrejón Formation, northeastern Colombia, include a diversity of side-necked turtles, a giant boid snake (*Titanoboa*), and three distinct genera of the extinct crocodyliform family Dyrosauridae, all previously unknown in the fossil record. Partial mandibles and skulls were recovered for the dyrosaurids *Acherontisuchus* and *Cerrejonisuchus*, but the mandible of *Anthracosuchus* has until now been unknown. Recent preparation of previously collected plaster jackets has resulted in the recovery of a large right mandible that exhibits a very large external mandibular fenestra (EMF), which in other dyrosaurids is either highly reduced or entirely absent. Teeth and alveoli of the mandible are very poorly preserved, leaving open questions about tooth count and relative spacing that could otherwise be used for diagnosis. Otherwise, the proportions of the jaw are fairly similar to what would be expected based on the skull of *Anthracosuchus*, as are two associated teeth. Associated osteoderms exhibit the same great thickness and rectangular shape as those referred to *Anthracosuchus* (completely unique among crocodyliforms). Also recovered in association with the jaw was a well-preserved squamosal, which is entirely consistent with *Anthracosuchus* and indicates a broad, flat skull table with an enlarged supratemporal fenestra (STF). In different crocodyliform lineages, taxa often have either an expanded STF or EMF to house musculature to close the lower jaw. A taxon with both fenestrae enlarged would likely indicate a much more powerful bite than previously recognized for any other crocodyliform.
The new morphology was scored and added to *Anthracosuchus* using a combined data matrix, which included 151 taxa scored for 476 characters. The addition of the new scorings shifted the relationships at the base of Dyrosauridae from the African *Chenanisuchus* as the most basal member to a sister relationship of *Anthracosuchus* + *Cerrejonisuchus* at the base of the clade. This would suggest that the family originated in South America, rather than Africa, which has been supported in all previous cladistic studies. Given that Late Cretaceous dyrosaurid remains have been recovered in Africa, this would further suggest an unknown lineage extending before the mass extinction event in South America.

Grant Information:

Financial support from NSF EAR 1839102 and DEB 0733725, Smithsonian Tropical Research Institute Paleobiology Fund, Florida Museum of Natural History and Cerrejón Mine.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

3D PRINTING OF THE GIANT SNAKE *TITANOBOA* AS A MEANS OF STEM ENGAGEMENT IN HIGH SCHOOL PROGRAMMING

HASTINGS, Alexander K., Science Museum of Minnesota, Saint Paul, MN, United States of America; VARGAS-GRANT, Claudia, Florida Museum of Natural History, Gainesville, FL, United States of America; SAHLSTROM, Sabrina, Delta Charter High School, Aptos, CA, United States of America; REUSS, Cameron, Delta Charter High School, Aptos, CA, United States of America; HART, Camille, Delta Charter High School, Aptos, CA, United States of America

Under-served schools often suffer from lack of opportunities for STEM integrated activities and therefore lack of student engagement in sciences and math. Projects that get students actively involved in STEM-based principles can have a dramatic impact on students' STEM identities, career goals and a general increase of science literacy. The University of Florida and the Science Museum of Minnesota recently partnered with Delta Charter High School in Aptos, California to implement a STEM program centered on the giant boid snake *Titanoboa*. This extinct relative of the anaconda was recovered from Paleocene sediments (about 60 million years old) from Colombia, in northern South America. Length estimates for the snake are roughly 13 meters, far exceeding the length of any other known snake.
Because hands-on lessons are more engaging and provide opportunities for STEM integration, hundreds of snake vertebrae were 3D printed in order to have students actively involved in the reconstruction of *Titanoboa*. Due to the incomplete nature of the fossil record, 3D scans of original *Titanoboa* vertebrae were resized to fill in the vertebral column. The skull and select vertebral sections had to be further supplemented with 3D scans of modern anaconda (*Eunectes murinus*). This allowed for the team to create 250 3D-printed vertebrae, in addition to a skull, in order to 'recreate' for the first time the skeleton of *Titanoboa*. Students arranged each of these bones in class, and used them as part of a further lesson that teaches the students how to calculate body size based on snake vertebrae. An additional component incorporates the known relationships between body size and temperature in snakes, delving into the connection between climate change and the evolution of large body size in reptiles. Following simple regressions generated from the study's original data, students are able to estimate the size of the snake that belonged to 3D printed vertebrae and from that determine approximately how warm it must have been in order for that snake to have been alive.
Students greatly enjoyed the lessons, reflected on engagement and interest, especially those students who normally do not engage in science. Furthermore, the students are currently planning their own traveling exhibit to visit a nearby elementary school and share what they have learned about climate change using the fossil record. The 'reconstruction' is then planned to travel to other institutions to be used in STEM-based programs throughout the country.

Grant Information:
Funding was provided by 'iDigFossils', National Science Foundation Grant 1510410.

Romer Prize Session (Thursday, October 10, 2019, 11:00 AM)

MAKING SPACE FOR GROUND SLOTHS: TESTING THE POTENTIAL FOR MODERN SLOTH STABLE ISOTOPE OFFSETS TO REINTERPRET GROUND SLOTH DIETARY ECOLOGY

HAUPT, Ryan J., University of Wyoming, WY, United States of America

With only two extant genera, the current diversity of sloths belies that of their past, which includes species spanning several orders of magnitude in size, from a few kgs to multi-ton giants. However, a need remains for reliable determinations of their diet have implications for niche partitioning of sympatric megaherbivores as well as their role as ecosystem engineers with no modern analogues. As with other xenarthrans, sloths have evolved life history traits on the extremes of mammalian norms (e.g., slow metabolism, long digesta retention time, and enamel-less teeth) that have complicated interpretation of stable isotope data for ecological insight. Prior analyses have used offset values from distantly-related ungulates due to a lack of data from modern xenarthrans. Here, I examined the stable isotopic composition of various tissues from both genera of tree sloths (n = 16), which phylogenetically encompass most of sloth diversity. The benefit of this approach is that I can sample diet directly via stomach contents and feces, as well as tissues relevant to their fossil record like bone, hair, etc. While I calculated $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ values from a range of tissues, I found $\delta^{13}C$ values of soft and mineralized tissues were the most useful for comparison to fossils because of better preservation potential and the utility of identifying

plant type, feeding height, and trophic level. I found that the diet-tissue offset values in modern sloths are consistent between genera but generally larger than those from comparable mammals. I also find that small amounts of protein in modern sloth diets yield significant shifts in carbonate-collagen spacing of bone $\delta^{13}C$ values, as seen in low-meat omnivory in mammals of similar size. To test these values against the fossil record, I compiled a dataset of new and published dentin, bone, and coprolite isotopic data from a variety of ground sloth taxa. Using sloth-specific offsets, I found higher dietary $\delta^{13}C$ values indicating significantly more CAM and C_4 input in open or arid environments (e.g., Nothrotheriops coprolites, $p = 0.02$), and higher feeding height in C_3-dominated closed environments (e.g., Eremotherium dentin carbonate, which supports the canopy browser hypothesis). Carbonate-collagen spacing continues to show no evidence of animal protein consumption. Overall, recalculated dietary values for $\delta^{13}C$ (carbonate, collagen) are significantly different from previous estimates using ungulate offsets, and can offer a non-contradictory but distinct view of these animals' impactful dietary ecology.

Grant Information:
Funding was provided by an Experiment.com crowd-funding campaign and Paleontology Challenge Grant. A complete list of backers can be found at http://experiment.com/sloths

Technical Session I (Wednesday, October 9, 2019, 8:15 AM)

MICROANATOMICAL SHIFT IN PLESIOSAUR VERTEBRA: EVOLUTIONARY AND ECOLOGICAL SIGNIFICANCE

HAYASHI, Shoji, Okayama University of Science, Okayama, Japan; NAKAJIMA, Yasuhisa, Tokyo City University, Tokyo, Japan; SATO, Tamaki, Tokyo Gakugei University, Koganei City, Tokyo, Japan; HOUSSAYE, Alexandra, CNRS/Muséum National d'Histoire Naturelle, Paris, France; WINTRICH, Tanja, University of Bonn, Bonn, Germany; HIKIDA, Yoshinori, Nakagawa Museum of Natural History, Hokkaido, Japan; SANDER, P. M., University of Bonn, Bonn, Germany

Elasmosaurs are a well-known clade of Late Cretaceous plesiosaurs. Generally, they were highly adapted to the marine environment, but elasmosaurids from the Dinosaur Park Formation (DPF) of western Canada were found in fluvial sediments. Therefore, their paleoecology has been questioned, notably to decipher if they were animals adapted mainly to freshwater/coastal habitats or to the marine environment. Bone inner organization, including compactness and density distribution, can be useful to infer habitat preference of extinct animals, but bone microanatomical studies of these DPF elasmosaurids have never been conducted. We analyzed the histology and microanatomy of adult and juvenile DPF elasmosaurid specimens using thin-sections and CT scans of vertebrae. Comparisons with other plesiosaurs from marine sediments allowed us to better understand the mode of life and evolutionary history of the DPF elasmosaurids within Plesiosauria. Whereas derived plesiosaurs (i.e., elasmosaurids from marine sediments, a polycotylid and *Cryptoclidus*) show a spongious inner organization, all DPF elasmosaurids and juvenile plesiosaurs, e.g., the basal taxa *Plesiosaurus* and *Microcleidus*, differ in displaying osteosclerosis. The DPF elasmosaurid, being a derived plesiosaur, must have secondarily acquired such osteosclerotic vertebrae. Histological observation indicates that thickened trabeculae and lack of bone resorption make these vertebrae dense. In living taxa, bone mass increase provides hydrostatic buoyancy and body trim control suitable for fast-flowing water typical of fluvial and coastal habitats, while spongy bones are associated with the hydrodynamic buoyancy control of active swimmers in the pelagic environment. Our study thus suggests that DPF plesiosaurs had evolved osteosclerosis as an adaptation to estuarine and river habitats. The evolutionary process of bone mass increase might be interpreted as a paedomorphosis, because juveniles of other plesiosaurs tend to have relatively dense bones and because the DPF elasmosaurs are much smaller than other adult elasmosaurs.

Grant Information:
JSPS KAKENHI grant 19K04060

Technical Session XX (Saturday, October 12, 2019, 4:00 PM)

AN ARM AND A LEG: TESTING ONTOGENETIC POSTURE CHANGE IN *MAIASAURA PEEBLESORUM* THROUGH LIMB SCALING AND OSTEOHISTOLOGY.

HECK, Christian, Oklahoma State University - CHS, Tulsa, OK, United States of America; WOODWARD BALLARD, Holly, Tulsa, OK, United States of America

Ontogenetic postural shifts have been proposed for several non-avian dinosaurs, typically characterized as a shift from quadrupedal juveniles to bipedal adults. However, the hadrosaurid dinosaur *Maiasaura peeblesorum* has been proposed to undergo a shift in primary locomotion from bipedal juveniles to quadrupedal adults. This ontogenetic posture change was once suggested to have potentially been a characteristic of hadrosaurs, but a recent study examining limb scaling in the hadrosaurid dinosaur Edmontosaurus found little evidence for postural shifts due to isometric scaling of the appendicular skeletal elements. An ontogenetic postural shift from bipedality to quadrupedality results in a functional change of the forelimb from free floating to weight-bearing. Under the assumption that a postural shift occurs, forelimb element growth should respond to the increased stress of quadrupedality. Recently, we performed a preliminary analysis of osteohistological characters of the humeri and constructed preliminary growth curves based on annual growth marks in the humeri. Here, we examined limb scaling through ontogeny in a large sample of *Maiasaura* humeri and tibiae to assess appendicular growth trends and to further test the ontogenetic postural shift hypothesis. Sampled *Maiasaura* tibiae and humeri were collected from a $2km^2$ laterally expansive monodominant bonebed of disarticulated individuals within the Two Medicine Formation. Humeri were thin-sectioned at the region of least circumference, distal to the delto-pectoral crest, and aged by counting lines of arrested growth (LAGs). Age, body mass, and linear measurements from tibiae were derived from a previous study. Humeri were paired with tibiae based on similar numbers of LAGs. Ordinary least squares regressions were performed using body mass and linear measurements of appendicular skeletal elements as variables. Resulting inferences were based on the assumption that the paired humeri and tibiae reflected true growth trends without sexual size dimorphism or extreme individual variation. The resulting regression analyses revealed isometric growth patterns (regression line slopes of, or around, 1.0) of humeri and tibiae. Our results of isometric limb scaling patterns do not support the ontogenetic postural change hypothesis under the assumption that posture change requires non-isometric growth in regards to forelimb-hindlimb scaling. Examination of extant models is required to confirm these limb scaling requirements.

Grant Information:
Funding for this project was provided by the Jurassic Foundation.

Technical Session XIV (Friday, October 11, 2019, 3:15 PM)

EVOLUTIONARY CONSTRAINT OF THE DIVERSIFICATION OF AVIAN LIMBS

HELLERT, Spencer, Field Museum of Natural History, Chicago, IL, United States of America; POLLY, P. David, Indiana Univ, Bloomington, IN, United States of America; RHODA, Daniel P., Indiana University, Bloomington, IN, United States of America

Genetic and developmental factors (e.g., traits influenced by the same gene), and functional factors (e.g., traits of the same bio-mechanical apparatus) may integrate an organism's traits so that selection cannot optimize its form for a given environment, creating tension between processes that promote anatomical diversification and those that promote integration. In this study, we used geometric morphometric methods to assess the extent to which integration has constrained the diversification of limb elements during the evolution of birds.

Flightless birds have evolved many times, producing unrelated species that share similar limb morphologies, especially in the forelimb. In this study, we compared patterns of covariances in limb bones of flying and flightless birds as a measure of integration using geometric morphometrics, Mantel tests, Principal Components Analyses, Common Principal Components Analyses, Two Block-Partial Least Squares, and cluster analyses to determine whether patterns of integration are different in flying and flightless birds because of reduced functional demand or whether the two groups have a shared pattern of integration that is consistent with shared genetic and developmental constraints across all birds.

A majority of analyses showed that flying and flightless birds have similar integration patterns within elements of both the fore- and hind limb. However, a number of the analyses, especially when phylogenetically independent contrasts were used, showed that patterns of integration between elements are different for flying and flightless birds.

The results support the hypothesis that integration patterns within the elements of avian limbs is constrained by developmental and genetic factors, regardless of flight ability. However, integration between bones may be influenced by functional factors. Therefore, the disparity of functional selection acting of the limbs of flying and flightless birds may promote diverse integration patterns within the limbs of the two groups, while shared genetic and developmental factors constrain the evolution of individual limb elements across all birds.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

AUSTRALIAN ORNITHOPOD DINOSAURS: RECENT DISCOVERIES AND IMPLICATIONS FOR ORNITHOPOD DIVERSITY AND RELATIONSHIPS

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Ornithopods were small- (turkey-sized) to large-bodied (up to 16 tonnes) neornithischian dinosaurs with a fossil record extending for at least 100 Ma up to the K–Pg boundary and a global distribution. The East Gondwanan ornithopod record is limited to Early–middle Cretaceous Australia and to a lesser extent, Late Cretaceous New Zealand. Until recently only five taxa had been recognised from this region: the large-bodied *Muttaburrasaurus* (Albian) from Queensland; three small-bodied ornithopods, *Atlascopcosaurus, Leaellynasaura* and *Qantassaurus* (Barremian–Albian) from Victoria; and *Fulgurotherium* (Cenomanian) from New South Wales, although regarded as a nomen dubium. The past few years have seen an explosion of new information on Australian ornithopods—an enigmatic group that has historically been poorly understood. Here we update new discoveries and present new information revealed through CT imagery.

Three new small-bodied Australian ornithopods have been named—*Galleonosaurus* and *Diluvicursor* (Barremian–Albian) from Victoria and *Weewarrasaurus* (Cenomanian) from New South Wales. *Galleonosaurus* and *Weewarrasaurus* are differentiated from other Australian ornithopods by their craniodental morphologies. *Galleonosaurus* is the first Australian dinosaur represented by an ontogenetic series of maxillae. *Diluvicursor*, known primarily from a partial postcranium, is more robust than other Victorian ornithopod postcranial skeletons. Dental and internal anatomical differences between maxillary specimens revealed through 3D CT imagery further supports high taxonomic richness in the Victorian ornithopods. Remarkably, CT modelling of the *Muttaburrasaurus* cranium suggests morphological convergence with the Laurasian lambeosaurines and a novel bone is identified that is previously unknown in dinosaurs. A new taxon from New South Wales represented by cranial and postcranial remains from several individuals is the first 'mid-sized' Australian ornithopod recognised. Added ecomorphological disparity in the Australian ornithopods is therefore revealed.

Investigations of Australian ornithopods are helping to unravel the phylogeographic history of the clade. Phylogenetic analysis recovers Australian and Argentinian non-hadrosaurid ornithopods within the Gondwanan clade Elasmaria, as sister to Clypeodonta (= *Hypsilophodon* + Iguanodontia). However, the position of *Muttaburrasaurus* shows volatility between Elasmaria and Iguanodontia.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

COMPARATIVE OSTEOLOGY OF ENTOPLASTRA REVEALS THEIR DIAGNOSTIC UTILITY FOR DIFFERENTIATING NORTH AMERICAN HELOCHELYDRID SPECIES

HERZOG, Lisa L., North Carolina Museum of Natural Sciences, Raleigh, NC, United States of America; MAKOVICKY, Peter, The Field Museum, Chicago, IL, United States of America; ZANNO, Lindsay, North Carolina Museum of Natural Sciences, Raleigh, NC, United States of America

Helochelydridae is a distinctive clade of Euramerican stem turtles hypothesized to have originated in Europe during the Late Jurassic and survived until the end-Cretaceous mass extinction event. Europe currently holds the highest species diversity of helochelydrids (seven species), and despite an extensive record on North America (twelve states and provinces, spanning ~50 myr of geologic time), only a singular species has thus far been described from the continent--*Naomichelys speciosa*. Recent surveys in the Cenomanian-aged Mussentuchit Member of the Cedar Mountain Formation have resulted in the discovery of several partial skeletons and isolated elements of a new species of helochylidrid that suggests cryptic diversity within the North American record of helochylidrids. Included in these materials is an isolated, nearly complete helochylidrid entoplastron (NCSM 33526) that can be directly compared to the holotype specimen of *N. speciosa* (AMNH 6136), also an isolated entoplastron. We find NCSM 33526 diagnostically different from that of *N. speciosa* in possessing a distinctive subrhombus shape with subequal margins (78 x 72.5 mm); sulci delininating the presence of three plastral scutes; intergular scute represented by a deep "V" shaped sulcus that culminates at the posterior margin and would have extended onto the epiplastron; and pustulation on ventral surface most pronounced underlying the intergular and reduced underlying the humeral scutes. In contrast, the entoplastron of *N. specisosa* is kite-shaped (~95 x 78mm) with greatest transverse width shifted anteriorly; with sulci delineating the margins of five plastral scutes; and a narrow border free from pustules at hyoplastral margins. To confirm the diagnostic utility of entoplastral morphology and rule out the effect of ontogenetic and individual variation, we examined an ontogenetic series of over 100 species of extant turtles exhibiting an entoplastron (Emydid, Kinsternidae, and Platysternid). We find the general pattern of overlying scutes evident on the entoplastron and entroplastral shape to be conserved, and thereby taxonomically useful. The presence of unique helochelydrids in the Aptian/Albian and Cenomanian of North America suggests the continental diversity of the clade is historically underappreciated and that Turonian through Campanian records may be hiding undescribed helochelydrid species, arguing against the practice of referring framentary NA helochelydrid materials to *N. speciosa.*

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

USING FOSSIL SCIENTIFIC STORIES AS TOOLS TO ENGAGE STUDENTS WITH SCIENTIFIC LITERACY LEARNING OUTCOMES IN A CORE DEPARTMENTAL CURRICULUM

HINIC-FRLOG, Sanja, University of Toronto Mississauga, Mississauga, ON, Canada; REISZ, Robert R., Universityof Toronto at Mississauga, Mississauga, ON, Canada

One of the main goals across different science departments is to engage students in scientific literacy and facilitate scientific literacy among students. At our institution, we have set scientific literacy expectations within our core departmental curriculum with the following learning outcomes: students should be able to identify and discuss scientific content; students should be able to use and evaluate the scientific method; and, students should be able to interpret data and evidence. In this presentation, we will showcase how we use different popular headlines about fossils to help students achieve these scientific literacy learning outcomes. We first present students with popular headlines about a vertebrate fossil in different social media or news platforms across different courses in our department. Students are then tasked with identifying which specific words they would like to explore further. Next, students engage with the content relevant to each of these words to discover the scientific story about the fossil and to evaluate and discuss the science behind the popular headline. For example, for students in introductory classes, we use any vertebrate fossil discovery described next to words the "oldest" or the "largest". Students then choose either the word "oldest" or "largest to discover which scientific evidence is necessary to justify the use of either of these words, to describe the scientific methods necessary to collect data on either the fossil age or body mass, and to determine how these data on age or body mass can be interpreted. In upper year courses, scientific literacy learning outcomes are taught again by presenting headlines about either an environment or a particular behavior attributed to a fossil. This allows students to create scientific discussions about an environmental or behavioral interpretation of a fossil vertebrate. In addition to reiterating identification and discussion or scientific content and use and evaluation of scientific methods, students in upper year classes are building on their data and evidence interpretation skills by analyzing limitation and biases of data interpretation when dealing with the fossil record. Overall, it is through the use of popular fossil stories that we are able to engage students with the scientific literacy and ensure that scientific literacy and scientific communication learning outcomes are both taught and assessed across our core curriculum.

Technical Session XX (Saturday, October 12, 2019, 2:15 PM)

DECIPHERING DEVELOPMENTAL CONSTRAINTS IN LIMB MUSCLES

HIRASAWA, Tatsuya, RIKEN BDR, Kobe, Japan; KURATANI, Shigeru, RIKEN BDR and CPR, Kobe, Japan

Basic pattern of vertebrate limb muscles was established in the lineage toward crown tetrapods, while connections between muscles and skeletal elements have mostly been conserved. Since the musculoskeletal connections are formed in development and unchanged during growth, their evolutionary stasis is likely attributable to developmental constraints. However, developmental mechanisms responsible for the constraints have never been well understood. To solve this problem, we analyzed characteristics of changeable parts in the developmental process of limb muscles through comparative and experimental approaches. We first focused on the exceptional evolutionary change of the pectoralis muscle connection in the evolution of turtles. In chicken and mouse embryos, tendon progenitor cells expressing a transcriptional factor-encoding gene, *scleraxis (Scx)*, develop at

the connection between the sternum and pectoralis muscle. On the other hand, in turtle embryos, the pectoralis muscle is initially connected to the dermis without intervening *Scx*-positive cells, and secondarily attached to the plastron developing within the dermis. At the junction between the developing pectoralis muscle and dermis in turtle embryos, an expression of protocadherin gene, *Fat1*, was observed, as in the skeletal muscles connected to the dermis, such as the cutaneous maximus muscle, in mouse embryos. The same connection was also observed in the tongue muscle of mammals and anurans. From these lines of evidence, the evolutionary reconnection of the turtle's pectoralis muscle was evolvable likely through a developmental exaptation of an existing mechanism connecting a skeletal muscle to the dermis. Furthermore, we identified that the propatagialis muscle of birds, another exceptional evolutionary change, develops along the dermis of the propatagial membrane through the same developmental mechanism. The propatagialis muscle recurrently evolved in theropod dinosaurs and pterosaurs, possibly due to the same developmental exaptation to the turtles' pectoralis muscle. On the other hand, these examples of evolutionary deviations underscore the evolutionary stasis of muscloskeletal connection in tetrapod limbs in the absence of the dermal connection of a skeletal muscle, and its developmental basis should be studied in experimental embryology.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

TYRANNOSAUROID TOOTH FROM THE LATE CRETACEOUS (TURONIAN) OF NORTHERN JAPAN

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The bone bed of the Tamagawa Formation located in Kuji City, Iwate Prefecture, northern Japan, has produced numerous remains of both terrestrial and marine vertebrates of the Upper Cretaceous, with at least 20 taxa, such as turtles, crocodylomorphs, dinosaurs, choristoderan, and Chondrichthyes identified so far. An estimated age of 90.51 ± 0.54 Ma (Late Turonian) is obtained for the bone bed based on U-Pb dating of the overlying volcanic ash bed. In 2018, a fragmentary crown of a left premaxillary tooth of a tyrannosauroid theropod (Dinosauria: Saurischia) was collected from this bone bed exposed at the amber-collecting site for visitors nearby the Kuji Amber Museum. The preserved crown is approximately 9 mm high and possesses a median ridge on the lingual surface with a D-shaped cross-section, a synapomorphy diagnosing Tyrannosauroidea. The crown carina lacks serration as in relatively few tyrannosauroid taxa such as *Moros*. Although approximately 30 genera have been described from the Middle Jurassic through the uppermost Cretaceous in the northern hemisphere, only few named taxa such as *Moros* and *Timurlengia* based on fragmentary materials are hitherto known from the early Late Cretaceous (approximately 100 million to 80 million year ago). Thus, present specimen, from this time interval and with a well-constrained geologic age estimate, is potentially important in analyzing diversity of Tyrannosauroidea by filling in the gap in the evolutionary history of this clade of theropods.

Technical Session XI (Friday, October 11, 2019, 11:15 AM)

COMPARISON OF 'BIG DATA' USES IN PALEOECOLOGICAL MULTI-PROXY MODELS FOR NORTH AMERICAN MAMMALIAN PALEOECOLOGICAL INTERPRETATIONS

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The use of ‘big data’ has rapidly increased in recent years across paleoecology and paleobiology. ‘Big data’ can provide robust statistical analyses and a potential basis for answering broad scale questions, but may also suffer from the homogenization of important detailed information. The purpose of this research is to determine the viability of using the FaunMap (FM) and the PaleoBiology (PBDB) databases for paleoecological reconstructions using multi-proxy models. Holocene North American mammalian data were downloaded from FM and PBDB. FM data consist only of locality information, while the PBDB also has associated trait data. We test the viability of these datasets by evaluating their ability to differentiate among modern and Holocene biomes. Data from PBDB and FM were assigned to biomes based on their geographic occurrences within established ecoregions. Diet, locomotion, and body mass were assigned to taxa as traits. Principle component (PCA) analyses were run with and without small-bodied (<500g) mammals.

Across all analyses, we observe no clear association of traits with biomes. FM analyses show forest and semi-desert significantly separating from each other, yet no clear trait associations within biomes are observed. Combined AMNH historical and FM data show slight biome separation among forest, grassland, and semi-desert. However, separation is not significant since 95% confidence ellipses overlap biomes. Combined occurrence data cover a greater area of North America, as AMNH and FM data has different geographic distributions. While AMNH data show an even distribution, semi-desert and desert biomes appear better sampled in the FM data. Combining these distributions better represents regional biomes and as such, more distinct results are not surprising. PBDB analyses also show significant separation between forest and semi-desert. Without small-bodied mammals, grassland appears separate from forest and semi-desert, though grassland does not have enough points for a confidence ellipse. In the PBDB data, grassland and semi-desert are severely underrepresented, and any results may be products of sampling resolution. The PBDB does not appear to have the resolving power or geographic distribution needed to model modern regional biomes using our methods. Both FM and PBDB cover the full Holocene, including some extinct megafauna and therefore characterize pre-human mammalian communities. To conclude, FM data do a better job at separating biomes, yet the lack of trait association is intriguing and must be further explored.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

TIME IS OF THE ESSENCE: THREE CASE STUDIES FROM QUEENSLAND, AUSTRALIA, DEMONSTRATING RESPONSES TO FOSSIL SITE LOSS THROUGH MINING AND DEVELOPMENT OVER DIFFERING TIME SCALES

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Responding to the potential or impending loss of fossil sites through mining and development can be a difficult and often unsuccessful process. In most cases, the length of time given to respond is the limiting factor. We present three case studies where highly significant fossil sites were discovered during mining and development works, each with different time frames for response, occurring over years, months or weeks. Due to limited legislative control over fossil site protection, the negotiation for successful access, documentation and salvage was undertaken directly between Queensland Museum (QM) paleontologists and the companies involved. Case 1 (2003-2004) occurred over a period of several months and required salvaging and stockpiling of thousands of tonnes of cave deposit exposed during limestone mining at Mt Etna, Rockhampton. These Quaternary-aged fossil deposits have since yielded hundreds of taxa, most new species, and led to the development of regional citizen science programs and events that directly utilise this resource. These deposits are now protected as part of the National Park. Case 2 (2013) occurred over weeks and was in response to a serendipitous discovery of fossil-rich Paleogene-aged oil shale deposits during road construction at Geebung, Brisbane. This deposit was rapidly assessed and stockpiled at QM Geosciences facility. Long-term (5+ years) weathering and sieving of this deposit has yielded a diverse fauna, including new mammals, birds, reptiles, frogs, fish and invertebrates. It now forms the basis for QM Geosciences citizen science program. Case 3 (2008-) has occurred over years and is an ongoing relationship developed between QM and mining company BHP, at South Walker Creek Mine, west of Mackay. The fossils include a rare new suite of tropical megafauna and the world’s tallest kangaroo. Working with the mine since the original discovery by Traditional Owners has led to coordinated site plans and staff involvement. Local and regional science engagement programs, such as *UnEarthed,* held during National Science Week, have evolved from these discoveries. Overall, the key to success in these three case studies was to; 1) rapidly disseminate the fossil site significance and undertake intensive subsampling and site data capture well before research publication; 2) directly involve the local community and company staff with the fossils through citizen science programs, and 3) collectively build a strategy to effectively stockpile the fossil resource (ex-situ) in a way that would allow access for future generations.

Technical Session II (Wednesday, October 9, 2019, 11:15 AM)

ON THE SHOULDERS OF TITANS: INTRODUCING NEW CRETACEOUS DINOSAUR FOSSIL FIELDS FROM SOUTHWEST QUEENSLAND, AUSTRALIA, AND DEMONSTRATING THE UTILITY OF SCANNING (SURFACE AND CT) IN TAPHONOMIC AND ICHNOFOSSIL INTERPRETATION

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Winton Formation (WF) surface fossil records are concentrated in the northern portion of the Eromanga Basin from a small number of sites near Winton and Isisford. This is in spite of the vast areas of mapped WF from western Queensland, eastern Northern Territory (NT), interior South Australia (SA) and northern New South Wales. Isolated faunal remains are known from the NT and SA sections of the WF, however, these sites have yet to yield remains of similar quantity to those from Winton or Isisford. Here we introduce two new fossil fields from southwest Queensland, near the townships of Eromanga and Quilpie, which preserve abundant faunal and floral remains. After 13 years of excavations, the Eromanga sites are dominated by sauropods including isolated dentition, trampled elements and articulated remains from differing body-sizes. Very large specimens represent a new taxon that differs from described taxa known only from Winton. Based on skeletal element dimensions, this taxon represents the largest dinosaur so far found in Australia. Another very well preserved semi-articulated skeleton is preserved within a concretion and includes most of the torso and tail. Confoundedly, a partial turtle and a single poorly preserved unioid bivalve represent the only non-sauropod body fossils. New ichnofossils are compared to northern records using a combination of photogrammetry and CT scanning methods. A cemented linear feature, ~100m long x ~4-5m wide, is interpreted as a 'dinoturbated' layer created by sauropods trampling sediment and underlying bones into a well-trodden 'pathway' or 'pad'. A crush outline on a femur shaft resembles that of a manus with claw imprint. New three-toed bipedal track sites from Quilpie show some differences to tracks from Winton, however, they were likely made by similar track makers. Using CT data, we observe small-sized bipedal dinosaur tracks from both Winton and Quilpie that are dominantly unidirectional across multiple phases of emplacement with each phase showing similar direction to others. This supports hypotheses of gregarious behaviours in small bipedal dinosaurs and evokes speculation about migration. We do not find evidence for swim tracks at these particular sites. Comparisons of the new records with others of similar age reveal that each possess localised depositional, taxonomic and taphonomic peculiarities. These peculiarities are likely governed by localised paleoenvironmental condition. Due to very poor stratigraphic resolution temporal explanations for these differences are limited.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

SKELETAL ONTOGENY OF MASSOSPONDYLUS CARINATUS

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Massospondylus carinatus was a sauropodomorph that lived from the late Triassic to early Jurassic. Thirteen complete or nearly complete skeletons, including two embryos and a juvenile, have been found in the Elliot Formation in South Africa. The goal of this project was to recover the growth series for this species. Six specimens were coded for 12 binary and 2 multistate characters using descriptions in the literature. One specimen, BP/1/4779, was removed from the analysis due to sharing the same coding with BP/1/5241. An artificial embryo was included as the outgroup. An exhaustive search retained one tree with 16 steps, CI of 1.000, HI of 0.000, RI of 1.000 and RC of 1.000. A total of 5 growth stages were recovered: Stage 1: large frontals, contact between the lateral maxillary ramus and the maxilla below the orbit, posterior ramus of the maxilla terminates posteriorly beyond the anterior margin of the orbit, contact between the jugal and quadratojugal is short; Stage 2: frontal has slight emargination for the edge of the fenestra, maxillary ramus is anteroposteriorly long, posterior ramus of the maxilla extends past the ventral midpoint of the orbit, contact between the jugal and quadratojugal increases in length; Stage 3: large nasals; Stage 4: the frontal nearly excluded from the orbital margin and the total number of teeth present is greater than 16 but less than 20; Stage 5: total number of teeth present is being greater than or equal to 20. A Spearman rank-order test showed a significant positive correlation between skull length and maturity with p value less than .001. A correlation coefficient was incalculable due to there being no difference between maturity rank and size values. The size data are normally distributed with a Shapiro-Wilk significance value of p=0.967. No evidence for sexual dimorphism is present in *M. carinatus*, as the ontogram shows no splitting of the specimens into two groups.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

SIZE VARIATION IN POPULATIONS OF *TETRACLAENODON* (MAMMALIA, 'CONDYLARTHRA'), FROM THE TORREJONIAN NALMA OF THE SAN JUAN BASIN, NEW MEXICO, REVEALS NEW INSIGHTS INTO THEIR EVOLUTION AND PALEO-ENVIRONMENT

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After the end-Cretaceous mass extinction, approximately 75% of life on land and in the sea disappeared. The mammals of the early Cenozoic rapidly diversified and dispersed, rising to numerical and ecological dominance beyond their Mesozoic norms. Among those initial groups that ushered in the Age of Mammals, Paleocene and Eocene 'condylarths' are thought to include the ancestors of modern odd-toed ungulates (horses, tapirs, rhinos). *Tetraclaenodon* is the oldest genus of the 'condylarth' group Phenacodontidae and one of the most abundant fossils from the San Juan Basin (SJB) of New Mexico. *Tetraclaenodon* was a medium sized (mean body mass ca. 10kg), terrestrial mammal which was lightly built and had an omnivorous to herbivorous bunodont dentition.

Here we use multivariate and statistical analyses to investigate body mass and dental variation in 110 teeth of *Tetraclaenodon* spanning the Torrejonian (Paleocene) interval of the SJB. The specimens were grouped into six time bins by their biostratigraphical reference, from Tj1 (~63.8 Ma) through Tj6 (~62.7 Ma). Measurements of the length, mesial and distal width of the lower first molars (m1) were subject to principal component analysis (PCA), and m1 area was used to predict body mass using a regression equation. The PCA morphospace ordinates specimens along a PC1 axis that accounts for 90.05% of total variance and is significantly correlated with body size. A PERMANOVA test finds a significant difference in morphospace occupation (non-overlap) between clusters of specimens from Tj1-3 and Tj4-6, but there are no significant differences between the individual time bins within each cluster. This trend is also seen in the body size estimates: Mann-Whitney tests recover significant differences between the two clusters. These results suggest that Torrejonian populations of *Tetraclaenodon* were relatively constant in size throughout Tj1-3, but between Tj3 and Tj4 underwent an increase in body mass and subsequently stabilized (at this resolution) for the remainder of the Torrejonian. A similar trend is seen in contemporary populations of the periptychid 'condylarth' *Periptychus*, suggesting that there were selective environmental pressures acting on these herbivorous species. These body size differences may reflect the emergence of a new, larger *Tetraclaenodon* species in Tj4, or may be associated to an environmental change, perhaps relating to climate or vegetation. In either case, this illustrates dynamic evolution of mammals during the few million years after the extinction.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

ASSESSING THE IMPACT OF SAMPLING BIASES AND TECTONIC CONTROLS ON PALEOGENE MARINE VERTEBRATES FROM THE EASTERN NORTH PACIFIC

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The eastern North Pacific is an active continental margin characterized by accreted terranes and significant movement along long-ranging strike-slip fault systems that have produced a geologically complex coastline. The Paleogene record is poorly known but important for understanding Eocene-Oligocene faunal turnover and transition to colder water environments in the North Pacific.

As part of a broader assessment of geographic and stratigraphic coverage of the eastern North Pacific marine faunas through the Paleogene, a new synthesis of the vertebrate record has been compiled from the published literature and new occurrences from a survey of museum collections. These new records range in age from late Paleocene to early Oligocene and geographically from southern Alaska to southern California. All occurrences were updated to current stratigraphic nomenclature and age assignments, and paleolatitudes estimated based on models developed for specific terranes and

faults. To assess whether vertebrate distribution is primarily controlled by accessible fossiliferous outcrop, number of localities/occurrences are compared with similarly updated molluscan occurrence data at the formation level.
Paleocene sites have a narrow distribution from 34-39°N latitude. Eocene sites expand this range to also include a cluster between 44-49°N and new records from southern Alaska. The latter are at 60°N today but at ~49°N in the Paleogene and transported along the Fairweather-Queen Charlotte fault. Both Paleocene and Eocene faunas are primarily shark teeth, with vertebrates occurring in fewer than 30% of fossiliferous formations. The sand tiger shark *Striatolamia* is the most common taxon. Bony fish are often preserved as scales, and herring are most common. In contrast, Oligocene faunas are dominated by marine mammals. Oligocene vertebrate sites include a cluster at 22-23°N, another at 44-48°N, and an outlier in the Aleutian Islands that likely was deposited well south. The Oligocene is better sampled, with 62% of fossiliferous formations producing vertebrates. The comparatively lower diversity and number of vertebrate sites of the Paleocene and Eocene likely reflects a lack of sampling of available outcrops. No one region or depositional basin has a continuous record of Paleogene deposition. Accessible exposure strongly influences the distribution of faunas and is, in turn, a reflection of the active margin's reorganization of accreted terranes. Analyses of North Pacific faunas require a detailed understanding of the tectonic history of the region.

Grant Information:
This work was supported in part by NSF ADBC award 1503678.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

NEW SPECIMENS REVEAL A HIGH ELEVATION, LOW DIVERSITY MIOCENE TESTUDINOID COMMUNITY IN EASTERN IDAHO, U.S.A.

HOLT, Eric M., U.C. Berkeley, Berkeley, CA, United States of America

Miocene testudinoids have been poorly documented in western North America. Most of the published record of tortoises from the Miocene is either from the Great Plains or the inland valleys of Oregon and California; the record from the Rocky Mountain interior is particularly sparse. No Miocene testudinoids have been reported from Idaho, and only a very few have been recorded from Wyoming and Montana, east of the continental divide.
Here I report on testudinoid materials from six localities in the Railroad Canyon Sequence of the Sixmile Creek Formation in south eastern Idaho, U.S.A. . This sequence spans 4.5 million years between 13-17.5 Ma., and today sits within the North American continental divide. The mammalian biostratigraphy, magnetostratigraphy and fauna have been previously published. Prior studies based on stable isotopes in precipitation estimated a hypsometric mean paleoelevation of 3.7 km (12,139 ft) at 39 Ma for the Sage Creek Basin, which includes the Railroad Canyon region. Leaf physiognomy analyses for the same area estimated a basinal paleoelevation of 2 km (6562 ft) at or around the same time. Railroad Canyon today is located at an elevation of 1.95 km (6410 ft) on the Idaho-Montana border just west of the continental divide, and was almost certainly higher in the Miocene than at present.
These assemblages have yielded one relatively complete shell with postcrania from a site that has been previously dated to the Late Hemingfordian NALMA (North American Land Mammal Age) and fragmented remains from five sites that have been assigned to the Barstovian NALMA. Analysis of the specimens indicates that diversity is low, and only one taxon is present at a given time. For the five Barstovian sites, the taxon present is *Gopherus* sp. based on the shapes of sulci found on fragmentary carapacial remains. This finding is important because it represents one of the highest elevation records for *Gopherus*, and is the first report of that genus from the Miocene of Idaho. This study is significant because it helps to fill a spatiotemporal gap both in the North American testudinoid fossil record generally, and in our understanding of the Miocene distribution of *Gopherus* in particular.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

EXPANDING CETIOSAURID DIVERSITY IN THE MIDDLE JURASSIC

HOLWERDA, Femke M., Utrecht University, Utrecht, Netherlands; POL, Diego, MEF, Trelew, Argentina; LISTON, Jeff, Yunnan University, Edinburgh, United Kingdom

The Middle Jurassic *Cetiosaurus* from the United Kingdom is historically the oldest sauropod described, with numerous phylogenetic and osteological analyses building on its information. Thus far, both *Patagosaurus fariasi* from the Middle Jurassic of Argentina and the contemporaneous Rutland *Cetiosaurus* from Leicestershire, United Kingdom, have been found to be nested within *Cetiosaurus*. However, *Cetiosaurus* is a classic 'wastebasket-taxon', with many specimens traditionally assigned to it, without having been examined in nearly a century. In addition to the holotype and associated material of *Cetiosaurus oxoniensis* from the Bathonian Forest Marble Formation of Oxfordshire, several other specimens from Gloucestershire and Skye have been investigated. The Gloucestershire material comprises several axial elements, including cervical and dorsal vertebrae, as well as pectoral, pelvic and appendicular elements. The Skye material consists of dorsal and caudal vertebral centra, as well as appendicular elements. As the Gloucestershire material originates from the Bajocian Lower Oolite, underlying the Forest Marble, it is possible that it represents different taxa. Indeed, when compared to the holotype material of *Cetiosaurus oxoniensis*, they present significant osteological differences in vertebral and pelvic elements, specifically in cervical, dorsal, and ischial characters. The material from Scotland also originates from slightly older sediments, having been dated to the Bajocian-Bathonian. One character uniting the *Cetiosaurus oxoniensis*, Gloucestershire, Skye and Argentine material, however, is the presence of deep pleurocoels in dorsal vertebral centra, hinting at a degree of vertebral pneumaticity that is basal to that of neosauropods, but more complex for basal sauropods than previously assumed. This pneumaticity has thus far only been investigated for *Patagosaurus*, however, it is here shown to feature more commonly across Cetiosauridae. Specimen-based phylogenetic analyses using an existing datamatrix, adding new characters based on the pneumatic features, retrieve the Gloucestershire specimen as nested within *Cetiosaurus*, and as sister-taxon to *Lapparentosaurus* from the Middle Jurassic of Madagascar. The Skye material is potentially more derived than the latter two. These results suggest a significantly higher diversity in both cetiosaurid and eusauropod taxa in the Middle Jurassic than previously believed.

Grant Information:
FH was supported by an OUMNH Visiting Fellowship

Technical Session VI (Thursday, October 10, 2019, 9:00 AM)

OLIGO-MIOCENE APLODONTIOID RODENTS REVEAL FAUNAL AND ECOLOGICAL RELATIONSHIPS BETWEEN CENTRAL OREGON AND WESTERN MONTANA

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Small mammals show higher levels of endemism and smaller geographic ranges than their larger counterparts, and hence can often reveal details of ecological similarity that aren't evident in whole faunas. Aplodontioid rodents are ecologically, morphologically, and taxonomically diverse in the late Oligocene and early Miocene of North America, and species and their distributions are often geographically narrow. These characteristics offer a good lens through which to examine ecological heterogeneity and faunal connectedness in western North America.
The John Day Formation of central Oregon and Cabbage Patch beds (Renova Formation) of western Montana both preserve some of the best-known Arikareean small mammal faunas; both also have a diverse group of aplodontioids (roughly 10 species in each region) as some of the most common members of the small mammal assemblage. Comparing the material from the two assemblages in a single analysis allows us to recognize that, while the assemblages of aplodontioids in the John Day and the Cabbage Patch both contain multiple species and genera of allomyine and meniscomyine rodents, there are some structured differences between them.
The allomyine assemblages are similar, with *Allomys* and *Alwoodia* both represented in both assemblages, although the John Day assemblage has a slightly greater diversity of *Allomys* species. Allomyines are inferred to be terrestrial or arboreal, and have been suggested to be indicative of closed habitats. The meniscomyines, which are specialized for burrowing habits, are more different between Oregon and Montana and show possible ecological differences between the assemblages, as *Niglarodon* is present only in the Cabbage Patch assemblage, while *Meniscomys* and *Rudiomys* are present in both assemblages. There is a greater diversity of meniscomyines in the Cabbage Patch assemblage, mostly composed of *Niglarodon* species, while the John Day has more different species of *Meniscomys* than the Cabbage Patch.
The abundance and diversity of aplodontioids in the faunas of Montana and Oregon is in contrast with well-sampled Arikareean assemblages from the Great Plains and California, which have far fewer aplodontioid taxa in the rodent assemblages. These diverse groups of species, some of which are shared between the two areas, are shaped by both ecological and biogeographic processes. They add important details to our picture of Arikareean landscapes.

Technical Session XVIII (Saturday, October 12, 2019, 3:30 PM)

COMPOSITION OF NEWLY DESCRIBED EARLIEST TORREJONIAN (TO1) FAUNA FROM NORTHEASTERN MONTANA, U.S.A. REVEALS TAXONOMIC DIFFERENCES AMONG EARLY PALEOCENE FAUNAS IN THE WESTERN INTERIOR OF NORTH AMERICA AND HIGHLIGHTS NORTH-SOUTH PROVINCIALITY

HOVATTER, Brody T., University of Washington, Seattle, WA, United States of America; WILSON, Gregory P., University of Washington, Seattle, WA, United States of America

The Western Interior of North America documents the most complete record of early Cenozoic mammalian evolution following the end-Cretaceous (K/Pg) mass extinction event. Substantial work has been done to describe the taxonomic composition of mammalian faunas throughout the Paleocene in North America, spanning the Puercan, Torrejonian, Tiffanian, and Clarkforkian North American Land Mammal ages (NALMAs). The taxonomic composition of the Torrejonian is perhaps the most poorly known of these four ages, and is divided into three interval zones: the To1, To2, and To3. Few To1 faunas have been described in the literature, specifically from the San Juan Basin in New Mexico, Wasatch Plateau in Utah, Crazy Mountains Basin in Montana, and Williston Basin in Montana. Previous analyses of these faunas have revealed a considerable amount of provinciality, specifically between more northerly and southerly regions. However, it is unclear whether this is an artifact of sampling or reflective of paleoenvironmental differences.

Recent collecting efforts from To1 localities in northeastern Montana (TOM, hereafter) have yielded over 200 mammalian specimens. These sites have been calibrated to a relatively precise chronostratigraphic framework, and may represent the oldest known To1 fauna in North America. Moreover, previous work has shown that these sites may detail an early mammalian taxonomic and ecological radiation. Here, we compare the taxonomic composition of this important To1 fauna with other known To1 faunas from the Western Interior of North America. More specifically, we applied cluster and ordination analyses to presence and absence data from the TOM fauna and published faunal lists from the To1 of the San Juan Basin, Wasatch Plateau, and Crazy Mountains Basin. Our results indicate that the TOM fauna is unique, and contains several taxa previously known only from older time bins. Moreover, the TOM clusters most closely with the Crazy Mountains Basin, further illustrating the provinciality between more northerly and southerly faunas. Additionally, we observe some clustering between archaic ungulate and plesiadapiform genera, with somewhat higher occurrences of the former in more southerly faunas, and higher occurrences of the latter in more northerly faunas. Taken together, these results add substantial detail to the biostratigraphic framework of this poorly sampled time interval, contribute to our understanding of the pattern of mammalian faunal succession in North America, and illustrate the importance of broad geographic sampling.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ALTERNATE PHYLOGENETIC POSITIONS OF FOSSILS EFFECTS BODY SIZE ESTIMATES OF SNAKE ORIGINS

HOWARD, Alexandra F., University of Cambridge, Cambridge, United Kingdom; HEAD, Jason J., University of Cambridge, Cambridge, United Kingdom

Hypotheses of snake origins remain controversial due to conflicting data sets, distinct anatomical and ecological inferences, and problematic fossils. Two alternate ecological specialisations, fossoriality and aquatic swimming, have been proposed to be driving adaptations for the origin of the clade. Although a fossorial habitat has been shown to correlate with a reduction in body size in extant snakes, ancestral body sizes at the origin of snakes have not been investigated. Studies into body size reconstructions in other clades, namely mammals, have shown the importance of including fossil taxa in analyses, as these represent lineages with unique evolutionary histories which can profoundly change ancestral state estimations. To understand the role of fossils in our understanding of body size evolution in snakes and their implications for competing origin ecologies, we used Maximum Likelihood ancestral state reconstruction to model body sizes for Crown Serpentes and the total snake clade for both molecular and morphological phylogenetic topologies. Alternate placements of fossil taxa affected estimates of body size for the most recent common ancestor of all snakes. For example, inclusion of the Late Cretaceous snake *Dinilysia patagonica* as a stem snake greatly increased estimated body size of the most recent common ancestor of all snakes when compared to estimates resulting from analyses on extant snakes alone. Even when included as a stem alethinophidian, *D. patagonica* still increased estimates of ancestral body size for the snake total clade. These results are not consistent with a hypothesis that the ancestor of snakes was small scolecophidian-like burrower, though this does not preclude fossorial habits similar to extant anilioid taxa as an origin ecology. This study highlights the importance of fossil inclusion and placement when reconstructing evolutionary histories of phenotypic traits.

Grant Information:
Trinity Hall Graduate Studentship to AFCH

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

HOW DID MASTODONS GROW? ONTOGENETIC LONG BONE GROWTH IN THE AMERICAN MASTODON (MAMMUT PACIFICUS)

HTUN, Thein, California Polytechnic University, Pomona, Pomona, CA, United States of America; PROTHERO, Donald R., Pierce College, Los Angeles, CA, United States of America; HOFFMAN, Jonathan, Santa Barbara Museum of Natural History, Santa Barbara, CA, United States of America; LUKOWSKI, Stephanie M., Museums of Western Colorado, Grand Junction, CO, United States of America

Proboscideans, much like other terrestrial megafauna, are supported by thick robust limbs, which are necessary to accommodate their larger body mass. How do these limbs grow between different species? Thanks to the large sample of juvenile limb bones at Rancho La Brea, we were able to investigate the growth curves of two different species of proboscideans (the newly described western mastodon, Mammut pacificus, and the Columbian Mammoth, Mammuthus columbi) to determine their ontogenetic patterns, and compared their growth to data from extant African elephants. Contrary to expectations of increasing robustness, analysis of these measurements suggests that elephant and mammoth limbs grew less robust and more gracile as they grew, with slopes of 1.0 to 1.7 favoring the length over the circumference. Only the ulna in some species shows slightly more robust growth, possibly because the huge head of proboscideans requires more robust support in the lower front limbs. However, in the case of the American mastodon, the slopes of the hind limbs (femur slope = 0.761; tibia slope = 0.789) are significantly more robust than expected for isometric growth, while the slopes of the forelimbs (humerus slope = 0.97; ulna slope = 1.09) are not significantly different from the isometric growth pattern. These slopes are tightly constrained, since there are a number of very tiny baby mastodons in the data set (over 30 specimens of each limb were measured), and the correlation coefficients are excellent (r-squared = 0.96 for the humerus; 0.79 for the ulna; 0.84 for the femur; 0.85 for the tibia). This pattern is the complete opposite of that seen in other proboscideans, and we are not certain about the reason for it.

Technical Session XIV (Friday, October 11, 2019, 2:30 PM)

FIRST COMPLETE SKULL THREE-DIMENSIONALLY RECONSTRUCTED FROM EARLY CRETACEOUS BIRDS

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During the evolution of crown Aves from non-avian dinosaurs the architecture of the skull underwent a number of important transformations. The evolutionary advantages imparted by these cranial modifications contributed to the survival of the Neornithes through the end Cretaceous extinction and ultimately facilitated their enormous current success. Although the fossil record of stem birds and their closest relatives has grown enormously over the past three decades, detailed cranial information is lacking due to the crushed, two-dimensional preservation of most specimens. The revolution brought by recent 3D digital visualization technology has the possibility to elucidate the cranial morphology of stem birds. Although widely utilized to study other vertebrate groups, these techniques have rarely been applied to early birds. As a result, details of the early evolution of the avian skull from the rigid non-avian theropod condition remains poorly understood. Using data from a new well preserved specimen we provide the first 3D reconstruction of the skull of the long boney-tailed bird *Jeholornis*, a taxon resolved just crownward to the basalmost avian *Archaeopteryx*. Although the skull of *Jeholornis* certainly holds important clues regarding its early transitional stage in the evolution from non-avian dinosaurs to birds, compared to *Archaeopteryx* it has received little study due to the bad preservation of previously reported specimens. This new skull is exquisitely preserved in 3D such that most elements are complete and articulated. The results of the digital reconstruction clarify several previously equivocal features such as the presence of completely fused premaxillae, the existence of a postorbital, and the presence of maxillary teeth,

indicating a mosaic cranial morphology. Shape and biomechanical analyses comparing *Jeholornis* to representatives of non-avian dinosaurs and extant neornithines provides the first quantitative insight into the early morphological and functional evolution of the avian skull.

Grant Information:
UNE Postdoctoral Research Fellowship; State Key Laboratory of Paleobiology and Stratigraphy, China (183110); National Natural Science Foundation of China (41688103).

Technical Session XV (Saturday, October 12, 2019, 8:00 AM)

CONSTRUCTIONAL MORPHOLOGY OF THE SHOULDER GIRDLE AND OPERCULAR SERIES OF THE UPPER DEVONIAN TETRAPODOMORPH *GOGONASUS* FROM WESTERN AUSTRALIA

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High resolution computed tomography (HRCT) scanning and 3D printing were used to obtain a 3-dimensional digital reconstruction of the shoulder girdle and opercular series of the tetrapodomorph ?sh *Gogonasus* from the Gogo Formation (Frasnian, early Upper Devonian, ~380 million years ago) of Western Australia. The Gogo fossil fishes are acid-etched from limestone nodules, and are exceptionally preserved in three dimensions. However, actual specimens are extremely fragile and difficult to manipulate – we scanned the most complete of four known *Gogonasus* specimens. Our findings show that the opercular series makes a close fit against the upper bones of the shoulder girdle only if the anocleithrum, supracleithrum and post-temporal are aligned more horizontally than previously reconstructed. The lowermost subopercular bone also largely covers the clavicle of the shoulder girdle, unlike all previous reconstructions. The ascending process of the clavicle, and the ventral process of the anocleithrum, do not fit closely inside the cleithrum. We suggest they functioned for ligamentous attachment. A rugose area on the anocleithral process has a similar relative position to muscle ligament attachments on the shoulder girdle of various living actinopterygians. Our work on manipulation of 3D printouts permits functional testing of extremely fragile acid-etched bones, and indicates a new way to investigate the constructional morphology of one or more functional units of the vertebrate skeleton. It is suggested that HRCT scanning and 3D printing techniques will play a major role in future research on functional analysis, testing the highly complex functional systems of fossil vertebrates and providing a much more robust evidential basis for understanding the evolutionary process.

Grant Information:
This research was funded by Australian Research Council Discovery grants-DP0772138 & DP1092870; supported by the Chinese Academy of Sciences (Grant No. XDB26000000).

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ENAMEL SCHMELZMUSTER INFLUENCES ENAMEL FRACTURE PATTERNS AND PROMOTES SHARPENING OF EVERGROWING INCISORS IN *CASTOR* AND *CASTOROIDES*

HUNT, Tyler C., Florida State University, Tallahassee, FL, United States of America; RINALDI, Caroline E., University of Texas--Southwestern, Dallas, TX, United States of America

The masticatory apparatus of the Late Pleistocene giant beaver (*Castoroides*) and the modern beaver (*Castor*) suggest interspecific differences in feeding biomechanics and realized niche. In addition to large size, *Castoroides* differs from *Castor* in incisor morphology, growth and wear patterns, and relative jaw muscle sizes. Specifically, *Castoroides* displays: 1) incisors characterized by longitudinally-oriented enamel ridges corresponding to a corrugated dentin-enamel junction (EDJ) and serrated occlusal cutting edges, 2) extensive wear on medial contact surfaces of lower incisors that honed the pair into a common occlusal point that fit into a bowled-out area on the dentin occlusal surface of the uppers, 3) longitudinal growth and wear rates of uppers exceeding those of the lowers unlike other rodents, and 4) an expanded origin for the internal pterygoid muscles suggesting increased lateral jaw movements. Notably, both genera show an inner enamel layer composed of moderately different Hunter-Schreger banding and an outer layer of radial enamel. We investigated whether the differences in enamel fabrics and loading resulted in variant fracture propagation using Vickers microindentation. In both genera, the outer fabric redirects fractures labio-lingually while preventing crack coalescence and medio-lateral propagation. The inner fabric shows bidirectional cracks localizing strain energy and "block" cleavage. The bipartite composite inhibits cracks from propagating completely through the enamel. Fracture patterns show distinct functions depending on the location along the incisor's long axis. Proximal to the occlusal end, the fabrics promote whole-tooth structural integrity by inhibiting crack formation medio-laterally when placed under tension during biting. This served to prevent spalling of the enamel in conjunction with the corrugated EDJ. The propensity of the inner enamel to fragment relative to the outer enamel promotes wear of the occlusal end into a three-tiered cutting edge composed of the enamel fabrics and the softer dentin. The differences in the enamel microstructure and incisal loading between these taxa are not reflected in the fracture data. However, these findings: 1) show the two-part incisal enamel fabrics in these taxa have similar dual roles for whole-tooth structural integrity and promotion of occlusal sharpness, and 2) further demonstrate that fracture and tribological attributes of teeth are preserved in some vertebrate fossils.

Grant Information:
AFOSR-UNR18-69

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

ADDITIONAL THERIZINOSAUROID BONES COLLECTED FROM THE UPPER CRETACEOUS MIFUNE GROUP, KUMAMOTO, JAPAN

IKEGAMI, Naoki, Mifune Dinosaur Museum, Kumamoto Prefecture, Japan; SCANNELLA, John, Museum of the Rockies; Montana State University, Bozeman, MT, United States of America; TOMIDA, Yukimitsu, National Museum of Nature and Science, Tsukuba, Japan

Therizinosauroids are an enigmatic group of theropod dinosaurs which diversified in the Late Cretaceous of Asia. Here we report additional material representing a therizinosaur taxon collected from the Amagimi Dam fossil site (Loc. 1004) in the Upper Cretaceous Mifune Group (Cenomanian-Turonian) in Kumamoto, Japan. Previously, a partial braincase and isolated teeth were reported from the Mifune Group. The partial braincase possesses a bulbous basishenoid housing multiple internal pneumatic chambers similar to those of *Erlikosaurus andrewsi* and *Nothronychus mckinleyi*. The crowns of the teeth are lanceolate in outline with basal constriction. This shape is different from the teeth of *Segnosaurus galbinensis*. Although additional material collected from Loc. 1004 is fragmentary and isolated in the bonebed, some material is identified as representing a therizinosaur pubis and femur. The pubis has a unique shape in therizinosaurids, namely, the pubic shaft is flattened mediolaterally and the pubic boot projects cranially and caudally. These characters of the pubis aren't known in derived therizinosaurids such as *Segnosaurus*, *Erlikosaurus*, and *Nothronychus*. The pubis from the Mifune Group is relatively small in size (cranio-caudal length of pubic boot is 108 mm) but it is similar to that of the therizinosauroid *Enigmosaurus* from the Bayan Shire Formation in Mongolia; both specimens possess a fused obturator process and cranial and caudal processes which have been considered autapomorphies of *Enigmosaurus*. The head of the partial right femur is dorsally inclined, extending at an obtuse angle from the long axis of femur. The bridging region between the femoral head and the greater trochanter is constricted in dorsal view. The combination of these characters is not found in other theropod groups except for oviraptorosaurs. Although additional specimens are required to resolve whether these elements could belong to a single individual, these additional therizinosaur specimens may provide new insight into the postcranial material of these animals and suggests the occurrence of an adaptive radiation of therizinosaur taxa along the eastern margin of Cretaceous Asia.

Grant Information:
This project is supported by Mifune Dinosaur Museum, Museum of the Rockies, and Sasakawa Scientific Research Grant (No. 16-354G).

Technical Session XIV (Friday, October 11, 2019, 2:15 PM)

FIRST NON-ORNITHOTHORACINE FOSSIL BIRD (THEROPODA, AVIALAE) FROM THE EARLY CRETACEOUS OF JAPAN: INCREASING OUR UNDERSTANDING ABOUT EVOLUTION AND PALEOBIOGEOGRAPHY OF STEM BIRDS

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The Early Cretaceous non-ornithothoracine avialans had been known nearly exclusively from the Jehol Biota of northeastern China. The relatively restricted occurrence contrasts with the worldwide distribution of Ornithothoraces throughout the Cretaceous, and it has been speculated that non-ornithothoracine avialans were endemic to the Jehol Biota. Here, we report an associated, three-dimensionally-preserved skeleton of a fossil bird (FPDM-V-9769) from the late Early Cretaceous of Fukui, central Japan. The specimen represents the first non-ornithothoracine pygostylian outside of the Jehol Biota and increases our understanding about the evolution and paleobiogeographic distribution of these early lineages. FPDM-V-9769 was collected from the Aptian Kitadani Formation, which crops out in Katsuyama, Fukui, central Japan and is interpreted as a lowland meandering fluvial system. By applying the synchrotron x-ray computed tomography technique to FPDM-V-9769, we observed a set of skeletal features comparable to those in other non-ornithothoracine avialans. For example, the pygostyle is robust and craniocaudally long as in confuciusornithids, the furcula is stout and boomerang-shaped as in most other non-ornithothoracine avialans, and the ulna is shorter than humerus as in *Archaeopteryx* and confuciusornithids, resulting in short forelimbs compared to more derived avialans. Absence of lines of arrested growth in a thin cross-section of the ulna indicates that FPDM-V-9769 is skeletally immature and possibly less than one year old at the time of death. Phylogenetic analyses indeed resolve FPDM-V-9769 as a non-ornithothoracine avialan, and suggest that it possibly represents a new, early branching of pygostylians. FPDM-V-9769 appears to have inhabited a lowland, warm-temperate fluvial system near the eastern coast of Asia, based on the paleoenvironmental reconstruction of the Kitadani Formation. In contrast, previous studies interpret the Jehol Biota as a group of organisms inhabiting a highland, cold-temperate lacustrine system in an inland region. Thus, FPDM-V-9769 suggests that the non-ornithothoracine avialans were adapted to a diverse range of environment and more widespread than previously known within East Asia.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

SHAPE TRANSFORMATION MODELS TO PREDICT THE EXTINCTION TIME OF *MACACA NEMESTRINA* IN JAVA ISLAND, INDONESIA

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The chronological point of extinction of *Macaca nemestrina* in Java Island, Indonesia still remains unclear, although the species is considered coexisted with *Macaca fascicularis* 700.000 years ago on the island. In this contribution, we provide allometric scaling approach to predict the appearance possibility of *M. nemestrina* in 4.000 years ago on the island based on fossil macaque teeth found in archaeological cave of Gua Lawa. The occlusal outline of third lower molar of recent *M. fascicularis* (n=60) and *M. nemetsrina* (n=72) were decomposed through Elliptic Fourier Analysis to know the dental size and change differences of both species mainly expressed by Common Allometric Component (CAC) and Residual Shape Component (RSC). Semi-landmarks following the outline were acquired by recording 120 successive equidistant 2D coordinates. Spearman's coefficient of correlation between CAC and RSC ($Rs=0.0369$, $p<0.05$) tested in *M. fascicularis* shows a moderate and significant positive correlation. In CAC, *M. fascicularis* displayed a bucco-lingually narrow, slender occlusal outline with more prominent shape of each cuspid than in *M. nemestrina*, while the RSC demonstrates the protoconid and metaconid are located more bucally in *M. nemestrina* than in *M. fascicularis*. The *nemestrina*-like molars discovered from the Gua Lawa cave suggests the species was existed in the island at least until 4.000 years ago

Technical Session XII (Friday, October 11, 2019, 9:30 AM)

WERE DINOSAUR ORIGINS ASSOCIATED WITH SUDDEN GLOBAL CLIMATE CHANGE DURING THE CARNIAN PLUVIAL EVENT?

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The Late Triassic Period was a pivotal time in Earth history that witnessed the origin of many tetrapod clades that dominated the rest of the Mesozoic, within the context of a hothouse world with high atmospheric CO_2. Recently, some authors have linked the origin and early diversification of dinosaurs to one sudden climate event during this time interval, the Carnian Pluvial Event (CPE) (or Humid Phase/Wet Intermezzo). The CPE began during the middle Julian (>231 Ma), and is associated with warming, increased precipitation, perturbation of the carbon cycle, enhanced weathering, and disruption of the carbonate factory. Most of this evidence comes from marine sections in the Tethys region, so the global extent of the CPE is poorly supported. Furthermore, precise and accurate absolute age constraints for key CPE sections are lacking. Therefore, linking the CPE to global macroevolutionary events such as dinosaur diversification remains difficult given its mostly regional nature and poor geochronologic constraints. Nonetheless, the global footprint record has been used to support a dinosaur-CPE connection.
To help rectify this situation, we present new multiproxy paleoenvironmental evidence from Carnian lacustrine strata in Argentina (~45°S paleolatitude) implicated in the dinosaur-CPE connection, and calibrate this record with a new high-precision U-Pb CA-TIMS zircon age of ~234 Ma from an interbedded tuff. These data (sedimentology, clay mineralogy, carbon and oxygen stable isotopes from carbonates and organic matter, and fossils) indicate that the middle Carnian portion of the section possessed particularly warm and wet conditions associated with a dynamic carbon cycle, consistent with the effects and timing of the CPE. Furthermore, these strata also contain fossil footprint evidence for the presence of early dinosaurs or their closest relatives. However, our re-evaluation of both the Argentine and Tethyan dinosaur fossil evidence suggests they suffer from poor and unequal sampling and ambiguous taxonomic identifications (i.e., they possess no apomorphies unique to Dinosauria). Therefore, the global evidence linking dinosaur origins to the CPE remains weak given that all unambiguous dinosaur fossils either post-date the climate event or are poorly dated. Resolving these issues will require more precise geochronology for both Tethyan marine successions and dinosaur-bearing strata worldwide, detailed paleoenvironmental proxy data from many sequences outside of the Tethys, and fossils with apomorphy-based identifications.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

ANALYSIS OF "OFF-TRACKING" IN THE TURNING TETRAPOD TRACKWAY

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Off-tracking like phenomenon known in the field of vehicle engineering, i.e., a trackway of an inner rear wheel of a turning wheeled vehicle is drawn inside that of an inner front wheel, was observed in some ichnofossil of turning sauropod trackway. For the ichnofossil, there was difference between the manus trackway midline and the pes trackway midline, which can be called "inside off-tracking" when the pes midline lies inside relative to the manus midline.
For the off-tracking, we hypothesized as follows: (1) The animal turns by steering its forelimbs and hindlimbs. (2) Off-tracking arises due to the steer ratio defined by the ratio of the steering angles of the forelimb and hindlimb. (3) The steer ratio between the forelimbs and hindlimbs is the inverse of load ratio of the respective limbs. The third hypothesis means that the projection of the turning center to the anterior-posterior axis is identical to the center of total mass. In this case, the moment of inertia becomes minimum.
We tested the validity of the hypothesis by a geometric analysis for the ichnofossil of turning sauropod trackway. In the case of the large sauropod, as the load is greater on the pes, the steer rate would be greater for the manus, resulting in the inside off-tracking of the turning trackway.
The question how a tetrapod turns while walking has been little studied for not only extinct animals but also extant animals. To verify the validity of the

hypothesis for an extant animal, we obtained a turning trackway of an Asian elephant (Elephas maximus) and analyze the trackway geometrically. The turning trackway of the Elephas maximus showed an outside off-tracking, i.e., the pes trackway midline lies outside the manus trackway midline. This result also follows our hypothesis that the load put on the elephant lies more on the manus, giving a greater steer rate of the pes.
Furthermore, we introduce a dynamic model to analyze a turning tetrapod. The equation of motion was derived for a planar 4-link model simplified a tetrapod. Rotation of the links corresponding to the limbs and frictional force at the ground contact of the leg tip provided locomotion of the tetrapod model. The inside and outside off-tracking were synthesized by numerical simulation, when the steer ratio of the forelimb and hindlimb was changed.

Grant Information:
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Technical Session IX (Thursday, October 10, 2019, 2:45 PM)

SNAKE VERTEBRAL SHAPE AS AN ECOMETRIC METHOD, AND ITS IMPLICATIONS FOR SNAKE DISTRIBUTIONS AT LOCAL TO REGIONAL SCALES.

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Ecometrics examine the community-level relationships between organismal functional traits and environmental factors across geographic and temporal scales. As such, ecometric methods are increasingly useful integrative tools for reconstructing past environments and understanding geologically short- and long-term organismal dynamics in the face of environmental perturbations. With a long (Miocene) history of extant groups appearing regularly in the fossil record of North America, and a particularly close relationship to the environment as limbless poikilotherms, snakes are excellent candidates for developing herpetofaunal ecometrics applicable to modern and paleontological datasets alike. Because snakes employ their vertebrae as the primary skeletal element to pursue prey and move through myriad environments, we elected to investigate the anterior shape of middle trunk vertebrae as an ecometric. We used geometric morphometrics to quantify vertebral shape with 23 homologous landmarks, generalized procrustes superimposition, and a PCA to extract shape scores for 118 extant snake vertebrae representing 118 snake species from the continental United States and Canada. Five of the first six PCs representing different shape variations showed significant relationships to ecology via a combination of phylogeny and ecomorphology, implying potential niche conservatism in North America snake faunas. Multivariate regressions of the first six PCs (~86% of shape variance) and bioclimatic variables suggest that vertebral shape shares closer relationships with temperature-related variables and ecoprovince comparable to mammalian ecometrics ($R^2 > 0.40$) when compared to other bioclimatic variables or vegetation cover. However, maximum likelihood models of AP performed better than those of MAT, suggesting a nonlinear relationship between mean vertebral shape and AP, likely via ecoprovince. Finally, we constructed ecometric spaces consisting of the first six PCs, MAT, and AP, and included case studies of snake populations that experienced different environments over time or across space. We found that both mean and standard deviation changed in those communities for all six PCs, implying that our ecometric is precise enough to capture environmental changes that contribute to changes in the presence/absence of snake taxa. Snake vertebral shape ecometrics therefore have enough resolution to detect environmental changes relevant to conservation and ecology and may act as a proxy for the reconstruction of past environments.

Technical Session VIII (Thursday, October 10, 2019, 3:45 PM)

OLD DOGS AND NEW: HOW DOMESTIC DOG SKULL SHAPE VARIATION MIRRORS THAT OF EXTINCT CANIDS

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As a result of artificial selection, the skulls of domestic dogs display a remarkable amount of variation relative to that of their ancestor, the gray wolf (*Canis lupus*). In fact, the disparity of skull shape in domestic dogs far exceeds that of living species within the entire family Canidae, despite having been generated in a relatively short period of time. However, extant wild canids represent only a fraction of the overall variation in skull shape that has been present over the history of the family Canidae. For example, there are skull shapes among extinct canids, such as those of bone-cracking borophagines, (e.g., Borophagus), or short-snouted hypercarnivorous hesperocyonines (e.g., Enhydrocyon), that represent canid ecomorphs that no longer exist. Can we find these ancient canid skull shapes within today's domestic dogs, or do all breeds fall within a large but limited region of canid skull shape space? To explore this question, we compared skull shape variation across dog breeds and wild canids using landmark data from 117 wild canids, representing both extinct and extant lineages, as well as 40 domestic dog breeds. Landmark data was collected in ImageJ and processed in R 3.5.3 using the package geomorph. Our results confirmed the unique nature of several skull forms among the domestic dogs, including the elongate skulls of greyhounds and the round skulls of chihuahuas. However, other skull shapes seem to be less unique than previously thought. We found that shapes such as that of the Boxer and Rottweiler actually converge on a robust skull form similar to that of extinct bone-crackers such as *Borophagus*. Selection for a stronger bite in both the dogs and extinct canids might contribute to the similarity in form, but it is also possible that the similarity reflects underlying constraints on cranial growth within the family Canidae.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

BONE MICROANATOMY IN KANGAROOS INDICATES DIFFERENT MODES OF LOCOMOTION IN MACROPODINES AND STHENURINES

JANIS, Christine M., University of Bristol, Bristol, United Kingdom; WAGSTAFFE, Amber, University of Bristol, Bristol, United Kingdom; KUNZ, Callum, University of Bristol, Bristol, United Kingdom; RAYFIELD, Emily J., University of Bristol, Bristol, United Kingdom

Hopping locomotion is the characteristic fast gait of extant kangaroos (Macropodidae, Macropodinae); but a maximum body mass of ~150 kg has been estimated for hopping due to tendon safety factors (because hopping mammals maintain a crouched limb posture at larger sizes). The largest extant kangaroos are ~90 kg, but sthenurines (extinct short-faced kangaroos; Macropodidae, Sthenurinae) had body masses ranging up to ~240 kg. Based on these size limitations, and also on aspects of hindlimb anatomy, sthenurines have been proposed to use bipedal striding as an alternative gait.
To further investigate the difference between macropodines and sthenurines data were obtained from micro-CT scans of the extant grey kangaroo, *Macropus giganteus* (~60 kg) and the large sthenurine *Sthenurus stirlingi* (~150-205 kg, above the theoretical weight limit for hopping). Resistance to bending and torsion (estimated from the second moment of area along the length of the bones) and cortical bone distribution were determined in the calcanea, fourth metatarsals (including the fifth metatarsal of *Macropus*), and first and second phalanges of the fourth digits. *S. stirlingi* showed considerably greater hindlimb bone resistance to bending and torsion than *M. giganteus*. This difference might be ascribed the larger size of the sthenurine (although the data were adjusted for body size); but the fourth metatarsal of a sthenurine of similar size to *M. giganteus*, "*Procoptodon*" *browneorum*, showed similar patterns of resistance to *S. stirlingi*, confirming real differences in bone resistance between the two types of kangaroos.
The distributions of cortical bone thickness were also different: in particular, *S. stirlingi* exhibited medial thickening of the bone in the first phalanx and the metatarsal. This may be indicative of a greater degree of weight-bearing on the medial side of the foot, as seen in hominids in the evolution of bipedal walking. These results indicate that *M. giganteus* and *S. stirlingi* were locomoting in different manners, and provide some support for prior hypotheses of alternate leg weight-bearing in *Sthenurus*.

Grant Information:
Support from this study was provided by the University of Bristol's Masters Paleobiology program.

Technical Session XX (Saturday, October 12, 2019, 3:45 PM)

STANDING ON THE FEET OF GIANTS: FINITE ELEMENT ANALYSES OF SAUROPOD DINOSAURS HIND FEET AND THE EVOLUTION OF GIGANTISM

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The capacity of sauropod dinosaurs to withstand the tremendous mechanical forces placed on their feet as a result of their gigantism represents one of the

most challenging biomechanical constraints in the evolution of terrestrial tetrapods. Several qualitative hypotheses have been advanced to explain how the feet of sauropods could bear their massive weight and facilitate their locomotion (e.g.,, changes in bone robustness, posture, or soft tissue). Among these, the presence of a soft tissue pad beneath the bony elements of their hind foot has been proposed as one of the effective means through which excessive mechanical loads could be accommodated. However, quantitative evidence for the presence of a soft tissue pad has never been verified. In fact, the links between foot configurations (i.e., posture) and biomechanical function in sauropods have not yet been tested. In this study, we used finite element analyses to study stress distributions within the hind feet of Late Triassic to Late Jurassic sauropodomorphs. First, we tested the effects of different skeletal postures on the deformations and bending regimes of various sauropod hind feet, and subsequently investigated the effects of a soft tissue pad on identical morphotypes subjected to similar mechanical conditions. The results reveal that our sauropod hind feet models could not have maintained bone stresses that fall within realistic safety factors in the absence of a soft tissue pad. Our findings suggest that a soft tissue pad likely acted as shock absorber, somewhat analogous to the cushion properties found in the foot of extant large-bodied mammals, such as elephants. Most importantly, our findings, coupled with a survey of the fossil record, suggest that sauropods may have evolved a soft tissue pad within their hind foot early in the course of their evolution by the late Early Jurassic–Middle Jurassic. The acquisition of this feature in early sauropods may have represented an initial and decisive evolutionary step, opening one of the pivotal doors for the achievement of gigantic body proportions in these terrestrial giants.

Grant Information:
University of Queensland International Scholarship (UQI)

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

RECONSTRUCTION OF AN ANCESTRAL AMNIOTE TRACKMAKER BASED ON TRACKWAY DATA, TRACKMAKER CORRELATION AND PHYLOGENY

JANSEN, Maren, MfN Berlin, Berlin, Germany; RENAUDIE, Johan, MfN Berlin, Berlin, Germany; VOIGT, Sebastian, Urweltmuseum GEOSKOP / Burg Lichtenberg (Pfalz), Thallichtenberg, Germany; BUCHWITZ, Michael, MfN Magdeburg, Magdeburg, Germany

Trackway measures, such as pace angulation, pace length, stride length, gauge width, manus-pes distance (along track) and imprint orientation vary notably among amphibian, stem-amniote and early amniote tracks from Late Carboniferous to Early Permian deposits. Some of this variability can be attributed to evolutionary changes in trackmaker anatomy and locomotion style close to the origin of amniotes. This variability may be explored through phylogenetic approaches following the assignment of certain track types to distinct producer groups.
Based on trackway averages of various parameters measured for eight tetrapod ichnotaxa from the Early Permian of the Thuringian Forest Basin as well as two additional Late Carboniferous ichnotaxa we infer ancestral states for functionally controlled trackway measures by means of parsimony and maximum likelihood.
We use basal amniote trees from recent literature and consider two alternative trackmaker phylogenies, where: (1) diadectomorphs as probable producers of Late Carboniferous to Early Permian *Ichniotherium* tracks form the sistergroup to all amniotes; (2) they form the sistergroup of more derived synapsids within Amniota.
According to our results the ancestral amniote trackmaker had a body size higher than the sampled amphibian and reptilian track producers but was smaller than diadectomorph and early synapsid trackmakers. Its tracks were characterized by higher pace angulations, somewhat narrower gauges and lower normalized stride lengths than those of its non-amniote predecessors, whereas neither the normalized distance between consecutive manual and pedal imprints nor the orientation of the pedal imprints appear to have changed much on the amniote stem. The manual imprints were more outward positioned and had a more parallel orientation than those made by earlier stem-amniote producers. Early Permian *Ichniotherium* trackways display certain similarities to contemporaneous synapsid tracks whereas other measures, most notably the orientation of manual and pedal imprints, differ considerably, demonstrating their limited use as model tracks of basal amniotes.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

TOOTH ATTACHMENT IN AN ACRODONT AMPHISBAENID (SQUAMATA)

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'Acrodont' tooth implantation has historically been associated with several apomorphies in reptiles, but most often with teeth that are fused to the apices of the marginal tooth-bearing bones. But even reptiles exhibiting 'acrodonty' in the classic sense often display different modes of tooth attachment among clades. For example, acrodontan squamates exhibit dental infilling and no tooth replacement, while other 'acrodont' reptiles lack infilling and may or may not exhibit tooth replacement. Acrodonta and *Sphenodon* are often cited as exemplary taxa for this combination of traits, largely because they are thought to be the only extant taxa with 'acrodont' dentition. However, trogonophid amphisbaenians also possess these traits, although they are often overlooked in studies of reptilian dentitions. Our CT data confirm that *Trogonophis wiegmanni* possesses traits commonly associated with acrodonty, particularly the position of the teeth in relation to the jaw bone, fusion between tooth and jaw, and the lack of tooth replacement. However, *T. wiegmanni* possesses other characters not seen in Acrodonta and *Sphenodon*, particularly the possession of alveolar foramina. The teeth of *T. wiegmanni* possess thicker enamel and dentine than most other reptiles, likely as an adaptation to resist wear. Histological data will confirm whether *T. wiegmanni* attaches its teeth in a similar manner as acrodontan squamates, or whether it displays a unique form of tooth attachment. Tooth implantation within Amphisbaenia varies in both extinct and extant taxa; this variation includes apparent transformations between more or less apical tooth positioning, fusion, and replacement.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW DISCOVERY OF ANKYLOSAUR FOSSILS FROM SHANXI PROVINCE, CHINA

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The ankylosaur fossils of Shanxi Province, China were discovered formerly from the Late Cretaceous Huiquanpu Formation of Tianzhen County. In 1998, two groups of researchers successively erected two genera, i.e., *Tianzhenosaurus youngi* Pang & Cheng, 1998 and *Shanxia tianzhenensis* Barrett, You, Upchurch & Burton, 1998, based on two separate localities which are geographically close. The validity of these two genera was contentious (Sullivan, 1999; Upchurch & Barrett, 2000; Sullivan, 2000). Since 2011, abundant ankylosaur materials have been excavated by Shanxi Museum of Geology around northern Shanxi area. Through painstaking preparation and preliminary research, we have named a new ankylosaurid dinosaur based on specimens found in Zuoyun County: *Jindipelta zuoyunensis gen. et sp. nov.* (Jia Lei et al., 2019, in press). We also discovered a new morphotype of tail club for ankylosaurid dinosaurs. In addition, new materials from Tianzhen are significant for solving the aforementioned 'validity' issues. All these new specimens will bring new insights into regional biostratigraphy and the evolution of Ankylosauridae.

Grant Information:
Our field excavation and indoor preparation are supported by Department of Finance of Shanxi Province.

Romer Prize Session (Thursday, October 10, 2019, 8:30 AM)

WHAT IS TELEOSAURIDAE AND *STENEOSAURUS*? THE TAXONOMY, SYSTEMATICS AND ECOMORPHOLOGICAL DIVERSITY OF TELEOSAUROIDEA (CROCODYLOMORPHA, THALATTOSUCHIA)

JOHNSON, Michela M., University of Edinburgh, Edinburgh, United Kingdom

Teleosauroidea was an extraordinary group of predominately shallow marine crocodylomorphs that thrived during the Mesozoic Era. While they have previously been considered the 'marine gharials' of the Jurassic, teleosauroids were in fact morphofunctionally diverse and evolved a bizarre body-plan (with proportionally enlarged heads and femora). During the Jurassic, they

attained a near-global distribution and became the first crocodylomorphs to grow to truly large sizes (> 7 m in length). Moreover, teleosauroids were the first fossil crocodylomorphs to be described (1758) and named (1814).
Despite increased research over the past decade, particularly for the clade Machimosaurini, the ecology and systematics of Teleosauroidea are still poorly understood and little studied. The question 'what is *Steneosaurus*?', a waste-basket genus that nearly every teleosauroid species has at some point been placed within, is a Gordian knot that has hampered previous attempts to elucidate teleosauroid evolutionary relationships. To rectify these issues, I examined approximately 530 specimens from 12 countries, and using these specimens, I created the largest and most comprehensive teleosauroid phylogenetic dataset to date. My expanded dataset includes 502 characters and 153 crocodylomorph taxa (twenty-seven of which are teleosauroids). This dataset was run in both TNT 1.5 and MrBayes.
The parsimony and Bayesian results are consistent, with two large subclades within Teleosauroidea recovered; these are morphologically distinct, with differing biogeographic distributions (one being Laurasian and the other Sub-Boreal European-Gondwanan) and feeding strategies. There was a significant divergence in ecomorphological characters between these subclades. While the Sub-Boreal subclade attained larger body-sizes (≥ 5 m) and evolved durophagy, the Laurasian subclade was more phenotypically plastic (with an east-Asian freshwater clade, a nascent pelagic clade, and a heavily armoured clade). Based on my first-hand comparative anatomical and phylogenetic results, I propose major taxonomic revisions to Teleosauroidea, including: (1) redefining Teleosauridae; (2) the resurrection of several historical genera; (3) erecting six new generic names; and (4) restricting the 'infamous' *Steneosaurus* to just a single species. With this new phylogenetic framework and updated alpha taxonomy reflecting teleosauroid anatomical and ecological diversity, a new window has opened on our understanding of these historically important crocodylomorphs.

Grant Information:
This research was supported by NSERC, SYNTHESYS, PalAss, the Paleontological Society, the Paleontographical Society and Alberta StudentAid (Sir James Lougheed Award).

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

PHOTOGRAPHS AND FOSSIL FILLINGS: A REVERSIBLE POLYESTER FILL AND UTILIZING NATIVE IPHONE APPS FOR COMPREHENSIVE PHOTO DOCUMENTATION

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When working with fragile fossils, it's normal to encounter missing pieces that endanger the stability of the section or fossil as a whole. To combat this, it's common to fill these sections to provide support, stabilize and to allow for further preparation of the specimen. In working on a small notoungulate jaw, I needed to fill a missing chip of tooth on the inner edge of a crown. Bulked adhesives commonly used offer reversibility but overall were much too soft for my purpose. Epoxy putty would also be too soft on such a small scale. Polyester bulked with talc had the desired rigidity but isn't easily reversible. The solution to this dilemma was the utilization a Paraloid B-72 coating as a separator for the polyester, enabling removal if desired.
In addition, the iPhone's native Camera and Photos apps has proven very useful in reassembling fragmentary teeth. In the iOS 10 update, the "Markup" feature was added to allow the user to draw on images with their finger or a stylus. When reassembling complex projects with multiple fragments, it can be difficult to remember where each individual piece exactly fits over the course of multiple prep sessions. With this tool, it's easy to trace, write notes, number, label and otherwise organize reference images. I utilized this method to photograph in situ pieces of a shattered brontothere tooth through a microscope and number the fragments for easier reattachment after prep. The Markup feature could be helpful with other types of extended projects. For example, it would allow for multiple people working on the same project to easily pick up where another person left off without having to relocate the fits.

Technical Session XV (Saturday, October 12, 2019, 8:30 AM)

THREE DIMENSIONAL SKELETONS OF MIDDLE JURASSIC STEM-GROUP SALAMANDERS FROM SCOTLAND, U.K.

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Salamanders comprise 600+ living species, are crucial components of many terrestrial ecosystems, and are frequent model organisms for investigating toxicity, limb regeneration, and terrestrial locomotion. However, their early evolution and biogeographic history remain poorly known, limiting analyses of lissamphibian origins among Paleozoic tetrapods. Knowledge of early salamander anatomy is highly inadequate. The fossil record has improved in recent decades with both stem and crown group salamanders reported from the Middle and Late Jurassic (~12 taxa). Nevertheless, many of these records are incomplete isolated bones from screenwashing, or slab specimens. Here we report the recovery of six new salamander associations from the Middle Jurassic (Bathonian) of the Isle of Skye (Scotland). These belong to two species: *Marmorerpeton kermacki* and 'Kirtlington salamander A'. Both species were previously known only from isolated bones from the Bathonian of Kirtlington (England) and remained largely undescribed except for the atlas and some other vertebrae. The new specimens collectively comprise much of the skeleton, including partial skulls, atlantes, articulated vertebrae, complete limbs and girdle elements, extracted from micro-CT data. The presence of a possible operculum in one specimen highlights the exceptional nature of this material. These specimens include individuals of both *M. kermacki* and 'Kirtlington salamander A', and thus permit correct allocation of isolated Kirtlington bones to these species. *M. kermacki* has an atlas with an incipient interglenoid tubercle, heavily built skull roofing bones (cf. Karauridae), vertebrae with a deeply ornamented surface texture and no spinal nerve foramina, and a femur with a prominent trochanter. 'Kirtlington salamander A' has low rib facets, gracile roofing bones, and smooth bone texture. The new data suggests that both species are stem-group salamanders (Caudata) that help resolve the sequence of character state acquisition prior to origin of the crown-group (Urodela). Some features of 'Kirtlington salamander A' (e.g., no atlantal interglenoid tubercle; short, widely notochordal vertebrae) suggest that it is both more plesiomorphic than *M. kermacki* and neotenous. This possibility suggests the co-existence of neotenous and non-neotenous species among stem-group salamanders as early as the Middle Jurassic

Grant Information:
Leverhulme Trust Research Project Grant: RPG-2018-381

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

LAST NEANDERTHALS VS. HOMO SAPIENS: NEW PALEOENVIRONMENTAL AND PALEOCLIMATIC DATA USING THE SMALL VERTEBRATE ASSEMBLAGES FROM SERBIA (BALKAN PENINSULA, SE EUROPE)

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Serbia is located at the boundary between the Balkan Peninsula and Central European plains. Northern region of Serbia is a part of the Pannonian Basin, the terrain formed after the retreat of Paratethys. This event had a great influence on the composition of Balkan fauna as retreating sea opened a large plain (Pannonian Basin) that allowed central European species to migrate south and populate mountainous part of the Balkan Peninsula. In early Miocene dramatic tectonic activity gave rise to two mountain ranges. On the East there is a Carpatho-Balkan mountain range, and on the West, there is the Dinarides mountain range, both of which form karst landscape and are favorable for formation of caves. Fossil record in the caves reveals changes in fossil fauna from Pleistocene to Holocene. There is evidence that distinct configuration of the terrain in the Balkans forms many isolated areas, thus allowing large mammal species along with Neanderthals that were living in the area to find refuge and survive longer than in the rest of Europe. Best preserved fossil associations containing both herpetofauna and small mammals come from Baranica, Smolućka, Hadži Prodanova and Pešturina caves, and material that came from these caves is also most studied, best described, and most suitable for applying available methods. Archaeological excavations documented stratigraphical composition of layers within all caves dating from Late Pleistocene to Holocene. For multiple purposes some dates regarding the age of the layers have been obtained using the Accelerator Mass Spectrometry method, so an attempt has been made to create a chronological context within Late Pleistocene using available data which is in some cases very poor. Stratigraphical deposition of layers corresponds from so-called MIS 4 to MIS 2 (i.e., from 70.000 to 14.000 years ago). Results were obtained using Taxonomical Habitat Indexes and Bioclimatic Analysis on small mammals. The Paleontological Statistics program (PAST3) has been used for all statistical approaches, with focus on Hierarchical Clustering, and Correspondence Analysis. The analysis showed that there were no dramatic

climatic oscillations during MIS 2 and MIS 3, and results suggest that the Balkans had milder climate during MIS 2 compared to Central Europe. Data obtained from Quaternary small vertebrate remains can be comprised in context of creating an image of the paleoenvironmental conditions, in that regard obtaining new data would allow us to expand paleoenvironmental reconstruction to MIS 4, for which we currently have insufficient data.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE STRUCTURE OF THE MAMMALIAN AND DINOSAURIAN HERBIVORE GUILD

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Understanding how communities are structured is a fundamental objective of ecology. Theory predicts that similarly sized species within a guild that compete for the same resource will exclude each other from local communities, but species of the same size can co-exist if resources are partitioned using a niche axis other than size. These mechanisms of species co-existence can thus be understood through an analysis of the shape of the body size distribution (BSD) of local ecological guilds. Terrestrial herbivores are diverse components of ecosystems, and occupy a wide variety of sizes, providing an ideal system to study how local environmental and ecological processes shape within-guild BSDs. To date, few models have been developed to predict how niche partitioning and competition will shape the BSD of a guild in a local community. Models based on resource allocation predicts differentially shaped distributions based on the availability and abundance of resources. Whether there is a general pattern in the shape of local herbivore BSDs is yet unknown. It is also to be determined whether mammalian herbivores and dinosaurian herbivores followed the same assembly rules in local communities. In this study, we sample local assemblages of terrestrial herbivores (from individual multitaxon quarries and bone beds) to determine the generalities and variability in the shape of mammalian and dinosaurian herbivore body-size distributions across space and time. Data on fossil assemblages were sourced from the NEOMAP, NOW, and Paleobiology Database. Body sizes of fossil taxa were estimated using allometric equations for skeletal and dental measurements. Sampling only artiodactyls, perissodactyls, and proboscideans, preliminary data from well-sampled North American Arikareen to Rancholabrean assemblages showed a remarkable amount of similarity in the shape of the BSDs among the land mammal ages (LMA). The average skewness of the BSDs for each land mammal age was close to zero, but positive for all LMAs. However, the assemblages did not have significantly different skewness among the LMAs. These results suggest that the terrestrial mammalian herbivore guild in North America is organizing in similar ways irrespective of the species that are occupying it. Further analyses will be conducted on mammalian assmeblages from other continentsand on dinosaurian herbivores.

Technical Session XII (Friday, October 11, 2019, 8:00 AM)

A NEW LAGERPETID ARCHOSAUR FROM THE TRIASSIC OF MADAGASCAR AND THE IMPORTANCE OF MINIATURIZATION IN ORNITHODIRAN EVOLUTION

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The 'basal Isalo II' beds of southwestern Madagascar yield a diverse fauna of latest Middle or early Late Triassic vertebrates, including multiple synapsid (traversodontid and chiniquodontid Cynodontia, Dicynodontia) and archosauromorph (Rhynchosauria, azendohsaurid Allokotosauria) lineages. Here, we present the first crown archosaur from the assemblage, representing a new taxon of lagerpetid ornithodiran. The new taxon is represented by the first confirmed craniodental material known for a lagerpetid (a maxilla) and a partial postcranium. The simple, conical teeth of the new lagerpetid exhibit pitted microwear consistent with a diet of hard-shelled, probably invertebrate, prey. The new taxon's hook-like femoral head with a concave ventral margin identifies it as a lagerpetid, and its medially-angled fourth trochanter resembles that of *Ixalerpeton*. It is distinguished from other members of the group, however, by its exceptionally gracile femur, which at ~38 mm total length makes it one of the smallest non-volant ornithodirans. Osteohistological analysis indicates that this animal was at least 2 years old at the time of death and had reached or neared asymptotic growth, ruling out immaturity as the cause of its small size. The enigmatic probable ornithodiran *Scleromochlus* from the Triassic of Scotland is comparable to the new taxon in its extremely small size. An analysis of ancestral body size in archosaur phylogeny incorporating these two taxa indicates a marked miniaturization event at the base of Ornithodira, with the earliest-diverging ornithodirans being substantially smaller than their nearest outgroups (aphanosaurs, crocodile-line archosaurs) and later ingroup ornithodirans (e.g., early dinosaurs). We propose that ornithodiran miniaturization was an important evolutionary event facilitating the development of bipedality and flight in the group, and may also be implicated in the early origin(s) of filamentous ('proto-feather') body covering.

Grant Information:
Research supported by the National Geographic Society, American Museum of Natural History, and Field Museum of Natural History

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

DISCOVERY OF A NEW RODENT ASSEMBLAGE FROM THE LATE OLIGOCENE IN JAPAN

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Small mammal fossils are efficient indicators of the paleoclimate and are often used in biostratigraphy. However, the Paleogene small mammal fossil record is very rarely identified in Japan. In this study, we report that a new rodent assemblage from Kyushu, Japan, has been found in the Late Oligocene Fukui Formation, Sasebo Group, in Nagasaki Prefecture. The fossiliferous layer is approximately 30-cm thick and contains transgressive lag deposit comprising granule-sized mudstone fragments, which unconformably overlie the coal-bearing nonmarine shale of the Sechibaru Formation of the Sasebo Group. The rodent specimens mainly comprise isolated teeth associated with the fragmental skeletal remains of crocodiles, tortoises, and freshwater fish. The assemblage includes four taxa, Cricetidae, Dipodidae, Sciuridae, and Castoridae. The relative proportions of the taxa based on isolated molar teeth (N=222) are Cricetidae (*Eucricetodon* sp.), 77.5%; Dipodidae, 21.2%; Sciuridae, 0.9%; and Castoridae (*Steneofiber* sp.), 0.5%. Probably, some of the aforementioned are new taxa. This rodent fauna, including abundantly occurring cricetids and dipodids and rare sciurids, resembles the Oligocene faunae of China and Mongolia. In the Late Oligocene, the Japanese Islands were situated in the eastern margin of Asia and, at the time, the Sea of Japan had not yet been widened. Hence, in the Late Oligocene, the Cricetidae- and Dipodidae-dominant faunae were extensively found in East Asia. However, Ctenodactylidae, Eomyidae, and Gliridae are common taxa in the Eurasian Oligocene, they are not included in this rodent assemblage. It must take into account that the assemblage was affected by biases of the depositional and taphonomic setting of fossiliferous layer, but the difference in faunal composition between this assemblage and other East Asian Oligocene rodent faunae implies the difference in paleoenvironments between marginal areas and inner-continental regions of East Asia.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 12:00 PM)

THE APPLICATION OF PHYLOGEOGRAPHY TO INVESTIGATE POSSIBLE ANTHROPOGENIC TRANSLOCATIONS: A PRELIMINARY ANALYSIS OF THE CUSCUS (PHALANGERIDAE).

KEALY, Shimona, Australia National University, Canberra, Australia

The Phalangeridae are a family of arboreal marsupials found throughout Australia, New Guinea, Indonesia and Melanesia. Commonly referred to as cuscuses, the Asia-Pacific phalangerid species have had a number of their island distributions attributed to prehistoric anthropogenic translocations. While some of these possible translocations are supported by archaeological evidence, most are lacking such data and questions regarding the timing and directionality of all these translocations remain. Here we propose a novel method to investigate the likelihood and directionality of these possible cuscus translocations based on phylogeography. We constructed the first dated, total evidence (molecular and morphological) phylogeny of the Phalangeridae incorporating modern, archaeological, and fossil taxa. This phylogeny was then run through the R package BioGeoBEARS to produce a

model of the family's biogeographic history. This biogeographic model, in addition to the divergence estimates obtained from the phylogenetic analysis, were then compared with the archaeological records and paleogeographical reconstructions to determine the likelihood of anthropogenic translocations vs. natural dispersals. We recovered good support for anthropogenic translocations of *Phalanger orientalis breviceps* and *P. o. orientalis* to New Ireland and Timor, respectively. We also found strong evidence to suggest that all other island populations of *P. o. breviceps* originated from the New Ireland population, not from additional translocations out of New Guinea. We find good support for a natural dispersal of *P. ornatus* to the Halmahera island group, rather than anthropogenic translocation. This study demonstrates the potential of this method for future investigation of prehistoric translocations on islands. A number of gaps in the available cuscus data are also identified and discussed as key areas for future research.

Grant Information:
Australian Archaeology Association Student Research Grant (Kealy), ARC Laureate (O'Connor; FL120100156), and ARC Discovery grant (Donnellen & Aplin: DP140103650).

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

CRETACEOUS POLAR MEIOLANIFORM RESOLVES STEM TURTLE RELATIONSHIPS

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Meiolaniforms (Meiolaniformes) are an enigmatic radiation of stem turtles with an exceptionally protracted 100 million-year evolutionary record that spans the mid-Cretaceous (Aptian–Albian) to Holocene. Their fossils have been documented for over 130 years, with the most famous examples being the derived Australasian and southern South American meiolaniids – bizarre horned turtles with massive domed shells and tail clubs that are thought to have been terrestrial and probably herbivorous. Despite a long history of research, the phylogenetic affinities of meiolaniids have proven contentious because of ambiguous character state interpretations and incomplete fossils representing the most ancient Cretaceous meiolaniform taxa. Here, we therefore report the significant discovery of the stratigraphically oldest demonstrable meiolaniform remains, which were excavated from Hauterivian–Barremian high-paleolatitude (around 80°S) deposits of the Eumeralla Formation in Victoria, southeastern Australia. Synchrotron microtomographic imaging of multiple virtually complete skulls and shells provides a wealth of new data, which we combine with the most comprehensive meiolaniform dataset and Bayesian tip-dating to elucidate relationships, divergence timing and paleoecological diversity. Our results reveal that meiolaniforms emerged as a discrete Austral Gondwanan lineage, and basally branching sister group of crown turtles (Testudines) during the Jurassic. We additionally recover a novel dichotomy within Meiolaniformes, which split into a unique Early Cretaceous trans-polar radiation incorporating apparently aquatic forms with flattened shells and vascularised bone microstructure, versus the larger-bodied terrestrial meiolaniids that persisted as Paleogene–Neogene relic species isolated in Patagonia and Australasia. Finally, our analyses resolve the paraphyletic stem of crown Testudines, which otherwise includes endemic clades of Jurassic–Cretaceous turtles distributed across the northern Laurasian landmasses. These had diverged from the Southern Hemisphere meiolaniforms by at least the Middle Jurassic, and thus parallel the vicariant biogeography of crown turtles, which likewise diversified globally in response to continental fragmentation and possibly climate.

Technical Session VII (Thursday, October 10, 2019, 11:15 AM)

FIRST PTEROSAUR (PTERODACTYLOIDEA) SPECIMENS FROM THE ANTARCTIC PENINSULA

KELLNER, Alexander W., Rio de Janeiro, Brazil; RODRIGUES, Taissa, University Fed. Espirito Santo, Vitoria, Brazil; FIGUEIREDO, Rodrigo G., Alegre, Brazil; WEINSCHÜTZ, Luiz C., Universidade do Contestado, Mafra, Brazil; SOUZA, Geovane A., Museu Nacional, Rio de Janeiro, Brazil; COSTA, Arthur S., Museu Nacional, Rio de Janeiro, Brazil; MUELLER, Carsten W., Technical University Munich, München, Germany; SAYÃO, Juliana M., Universidade Federal de Pernambuco, Vitória de Santo Antão, Brazil

Our understanding of the paleobiodiversity of the Antarctic continent is still in its infancy. This limited information is also the case for Mesozoic reptiles, where the record consists mostly of fragmentary material. Concerning pterosaurs, there has been only a brief mention of a small humerus from Jurassic deposits of the continent. In 2006/2007 and from 2016 to 2019, expeditions coordinated by the Museu Nacional and carried out by researchers from several institutions collected a great number of fossils from the Antarctic Peninsula. Hundreds of specimens were recovered, mainly plants and invertebrates, but also isolated vertebrate bones. Among these are pterosaur elements. Two bones with a length of ~65mm that likely belong to the same element were collected in the James Ross Island. They were found isolated and close to each other in a flattened area formed by a moraine located at the Albernethy flats, between the Passo San José and the Crame Col. The sedimentary rocks of this region are regarded as the Lachman Crags Member, the basal unit of the Santa Marta Formation. The age of these deposits is Late Cretaceous (Santonian-Campanian). The most complete is preserved in three dimension and has the typical "boot-shape" of the distal end of pterosaur forth wing finger phalanges. The second bone, essentially comprising a thin bone lamina, was used for osteohistological sections. The bone microstructure is fibrolamellar. The vascular channels have a similar diameter and do not show any sign of anastomoses. They are longitudinal and composed only by primary osteons. No growth marks are perceptible. These osteohistological features are consistent with what has been observed in pterosaurs. Although not diagnostic beyond Pterosauria, compared with other distal ends of wing phalanges, the wing span of this Antarctic flying reptile ranges between 3 and 4 m, what is compatible with the Pterodactyloidea.
A third pterosaur element comes from the nearby Vega Island, more specifically from the López de Bertodano Formation (Maastrichtian). The specimen consists of an elongated bone with a D-shaped transverse section. The cortex is thin (~1mm) and the total preserved length reaches about 140mm. Despite incomplete, this material can be identified as a wing metacarpal IV. It is robust and elongated, allowing its allocation to the Pterodactyloidea. Both specimens demonstrate the presence of derived pterosaurs during the Upper Cretaceous of Antarctica, indicating the cosmopolitan distribution of pterosaur in during the late Mesozoic Era.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

THE PALEOANTAR PROJECT - COMBINATION OF SCIENCE, EDUCATION AND OUTREACH FOCUSING ON ANTARCTICA

KELLNER, Alexander W., Museu Nacional, Rio de Janeiro, Brazil; SAYÃO, Juliana M., Universidade Federal de Pernambuco, Vitória de Santo Antão, Brazil

Antarctica is the continent of superlatives, being the coldest, the windiest, the driest, and the less explored of all. Expeditions to the "white desert" are hard to be carried out, expensive, time consuming and quite challenging from the logistic point of view, what gives any field activity in this region an adventurous and romantic aura, immediately capturing the interest of the public. For all when paleontology, particularly the search for fossil vertebrates, is the main focus of such an endeavor, what is generally associated with camping in an inhospitable region.

Taking advantage of the natural public interest, the project PALEOANTAR (Paleontology in Antarctica) has explored several ways to engage the general public regarding the studies carried out in the "frozen continent". Right from its conception, despite the broad scope that the title suggests, scientific activities were restricted to the Antarctic Peninsula due to limitations of the Brazilian navy. The first version of this project was executed in 2006/2007, when nine researchers and two alpinists have spent around 40 days at the James Ross Island. At that time, this was the southernmost, the largest and the longest camp activity carried out by PROANTAR - the program that is responsible for all Brazilian scientific activities in this region. Two outreach and educational actions of different nature were developed. The first was the documentary "*Expedition Antarctica - a summer of 70 million years*" (55 minutes, in Portuguese) aired in 2008 and freely available on YouTube (http://www.youtube.com/watch?v=I1pZjwBDzTs). It shows scientists and students reporting their individual experience at the island. A second activity consisted in the temporary exhibit "*Fossils of the frozen continent - the Museu Nacional in Antarctica*", opened in December 2010. With all labels in Portuguese and English, the outline of this exhibit was of a ship, one side showing present environment and biota of the James Ross island and on the other plants and animals present in this region some 70 million years ago. With a hiatus of almost a decade, four consecutive field activities (2016-2019)

were implemented in the islands of James Ross, Snow and Vega. Again, a documentary is being produced and a new exhibit was opened recently (2019) entitled "*When not all was ice - new discoveries in the Antarctic continent*". PALEOANTAR has shown how scientific projects can also provide ways of education and outreach to the general public, strengthening the perception of the importance of Science.

Grant Information:
Funding for this project was provided by CNPq (PROANTAR #407670/2013-0 and #442677/2018-9; #) and FAPERJ (#E-26/202.905/2018).

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 11:15 AM)

A UNIQUE ARTICULATED FOSSIL SHEDS LIGHT ON THE TAXONOMY OF TWO PLEISTOCENE SPECIES OF GIANT KANGAROO FROM THE GENUS *PROTEMNODON.*

KERR, I. A., Flinders University , Eden Hills, Australia

Prior to the extinction of the genus around 40 000 years ago, kangaroos of the genus *Protemnodon* Owen, 1873 (Marsupialia: Macropodidae) were common members of mammalian herbivore assemblages across Australia and New Guinea. Of these, the mixed-feeding and grazing species *Protemnodon brehus* and *P. roechus*, found in open woodland and forest deposits from the Australian Pleistocene, were some of the largest kangaroos ever at between ~120 kg and ~170 kg. These two taxa are poorly delimited, with morphological descriptions relying heavily on variable dental characteristics, leaving significant grey-areas and lacking postcranial descriptions despite a wealth of postcranial material. Although *P. brehus* is described as smaller than *P. roechus* and differing in certain features of the cheek teeth, preliminary data from this study have suggested that these taxa may represent a single spatiotemporally widespread species. This study will utilise visualisation of craniodental and postcranial measurement data, morphological descriptions and geometric morphometric analyses of taxonomically significant areas, taken from a large sample of *P. roechus* and *P. brehus*, to test the taxonomic definitions of these taxa. An articulated fossil specimen in this study, that of a mother *Protemnodon brehus* with a joey preserved while still held within the pouch, presents the rare opportunity to be certain of the sex of a fossil marsupial. With this unique fossil it will be possible to visualise the degree of sexual dimorphism in size in *Protemnodon brehus*. It is possible that, given the significant size sexual dimorphism among medium- to large-sized extant kangaroo species, the perceived difference in size between *P. brehus* and *P. roechus* is an artefact of sexual dimorphism within a single species.

Grant Information:
Supported by the Royal Society of South Australia Student Research Travel Grant and the Flinders University College of Science and Engineering HDR Student Travel Grant.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

MIDDLE MIOCENE BOVIDS (MAMMALIA) FROM POTWAR PLATEAU, NORTHERN PAKISTAN

KHAN, Muhammad A., University of the Punjab, Lahore, Pakistan; ASIM, Muhammad, University of the Punjab, Lahore, Pakistan

New fossil bovids are collected, described and discussed from the Middle Miocene of the Siwalik Group in northern Pakistan. The new material is collected from seven localities: Dhok Bun Amir Khatoon, Chinji Rest House, Parrewala, Lawa, Bhilomar, Rakh Wasnal and Jand. The fossiliferous localities, having the age of the Middle Miocene, are located in district Chakwal, Potwar Plateau, northern Pakistan. The taxa are consistent with a Middle Miocene age of the deposits. The specimens are classified on the basis of morphometric features and are assigned to eight bovid species, namely *Miotragocerus gluten, Tragoportax salmontanus*, *Helicoportax tragelaphoides, Eotragus* sp., *Elachistoceras khauristanensis,* Boselaphini sp. indet., *Gazella* sp. and *Sivaceros gradiens*. Quantitatively, the specimens of *Gazella* and *Miotragocerus* are the most predominant. The smallest bovid *Elachistoceras* is uniformly rare. The new findings include the deciduous premolars of *Miotragocerus gluten* and *Gazella* sp. from the Chinji Formation of Pakistan. The specimens add substantial knowledge of the anatomical and metrical features of the described species. The bovid remains increasingly indicate both taxonomic and adaptive diversity. Biostratigraphically, the faunal composition suggests a Middle Miocene age (14.2-11.2 Ma). Based on the recovered faunal elements of Bovidae, it is proposed that the riverine and forest settings was found in the Siwalik Chinji Formation during the Middle Miocene.

Grant Information:
Subject: Request for Award/Grant of Scientist from Economically Developing Nation (SEDN)

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

THE FIRST DISCOVERY OF REDFIELDIIFORM FISH (ACTINOPTERYGII) FROM THE UPPER TRIASSIC AMISAN FORMATION OF KOREA AND ITS PALEOBIOGEOGRAPHIC IMPLICATIONS

KIM, Su-Hwan, Seoul National University, Seoul, Korea, Republic of (South); LEE, Yuong-Nam, Seoul National University, Seoul, Korea, Republic of (South); PARK, Jin-Young, Seoul National University, Seoul, Korea, Republic of (South); LEE, Sungjin, Seoul National University, Seoul, Korea, Republic of (South); LEE, Hang-Jae, Geological Museum, Korea Institute of Geoscience and Mineral Resources, Daejeon, Korea, Republic of (South)

A new genus and species of redfieldiiform fish, *Hiascoactinus boryeongensis* gen. et sp. nov., is described based on a nearly complete specimen from the Upper Triassic Amisan Formation of South Korea. Redfieldiiforms are freshwater fishes which have been reported from the Early Triassic to Early Jurassic deposits of many continents including Australia, Africa, North America, and South America, and have a fusiform body covered with ganoid scales, a hatchet-shaped preopercle, a single plate-like branchiostegal ray, caudally positioned dorsal and anal fins, and a heterocercal caudal fin. This new specimen is distinguished from other redfieldiiforms by having a barely ornamented dermal skull surface except for the snout region, two heteromorphic suborbitals arranged vertically behind the postorbital, a pistol-shaped suprascapular, and dorsal and anal fins with divided fin membranes between rays. The morphological features of the snout region and dorsal and anal fins of *Hiascoactinus* provide important clues to understand its feeding and swimming behavior. The snout tubercles of *Hiascoactinus* seem to be used for a sensory organ based on comparisons to modern fishes having odontodes although they were considered to support the flesh upper lip before. Another remarkable feature of *Hiascoactinus* is that the fin membrane is not fully developed but finely segmented between each rays of the dorsal and anal fins. This fin structure suggests that *Hiascoactinus* did not have efficient turning maneuvers. All previously proposed Asian redfieldiiform fossils are inaccurately classified, and consequently, *Hiascoactinus* is regarded as the only valid redfieldiiform taxon in Asia. *Hiascoactinus* is assigned to the basal group of redfieldiiforms primarily based on the presence of an antopercle. The basal phylogenetic position of *Hiascoactinus* indicates that basal redfieldiiforms dispersed from the southern Gondwanaland to the easternmost Laurasia through the terrestrial water system, and these two landmasses were connected to each other during the Late Triassic. This study represents the first scientific report of fossil fish from the Daedong Supergroup in Korea and gives new insight into the paleobiogeographic distribution of redfieldiiforms during the Late Triassic.

Grant Information:
This work was supported by the National Research Foundation of Korea (grant number 2016R1A2B2015012) to Yuong-Nam Lee.

Technical Session VI (Thursday, October 10, 2019, 10:45 AM)

ISOTOPIC VARIATION IN MODERN HOMINOID DIETARY NICHES: IMPLICATIONS FOR INTERPRETING THE FOSSIL PRIMATE RECORD

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The utility of stable isotopic analyses of fossil material to reconstruct foraging strategy and habitat preferences of extinct taxa ultimately hinges on developing modern analogs to explore the complex biogeochemical links between diet, climate, and biogenic tissues. As isotopic research on fossil hominoids in tropical Africa has been extended into the middle and early Miocene, it has become increasingly critical to characterize and partition isotopic variability in potentially C_3 dominated paleohabitats. To address this need, we systematically analyzed the isotopic signature of 228 well provenienced extant hominoid teeth to establish sources of variation and isotopic ranges for differential niches. Multiple teeth of specimens of *Pan*, *Gorilla*, *Pongo*, *Hylobates*, and *Symphalangus* were bulk sampled to document inter-tooth variability related to life history patterns, intra-population variability linked to variable foraging strategies, intra-species variability that reflects habitat differences, and inter-species variability

reflecting niche partitioning. Within these hominoid taxa inhabiting exclusive C_3 habitats, there was significant interspecific variation ranging from a median $\delta^{13}C_{enamel}$ value of -16.7‰ for *Hylobates muelleri* in Borneo to -13.3‰ for *Gorilla beringei* in DRC, in part reflecting a general trend of ^{13}C enrichment linked to increasing folivory. The isotopic composition (both $\delta^{13}C$ and $\delta^{18}O$) of the enamel of sympatric hominoids provided clear evidence of niche partitioning in some cases. At the highly seasonal site of Abai in Borneo, for example, orangutans (*Pongo pygmaeus*) had more variable $\delta^{13}C_{enamel}$ values averaging over 2‰ more positive than the enamel of gibbons (*Hylobates muelleri*), reflecting frugivory differences and possibly greater water stress in the larger diameter and taller trees where Orangutans feed. $\delta^{18}O_{enamel}$ values, however, were 5‰ more positive for gibbons, potentially reflecting increased drinking from terrestrial water sources by Orangutans. Intertooth variation in $\delta^{13}C_{enamel}$ of >4‰ and >6‰ in $\delta^{18}O_{enamel}$ in some individuals indicate either seasonal shifts in foraging strategy or variable diets linked to life history patterns. Collectively these data provide critical perspectives on the range of isotopic variation at the level of the individual to interspecific differences that will greatly increase the interpretive value of isotopic analyses of isolated teeth of fossil hominoids and other primates.

Grant Information:
Funding from NSF BCS-1241811, BCS-1208369.

Technical Session XVII (Saturday, October 12, 2019, 8:00 AM)

OBSERVATIONS ON THE MORPHOLOGICAL SUPPORT FOR ORNITHOSCELIDA HUXLEY, 1870

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Early dinosaur radiation has been a controversial topic for years, and new discoveries constantly change the understanding of the area. Recent studies have reignited the debate on the relations of the major dinosaur groups and the anatomic traits that characterize them. The traditional Ornithischia and Saurischia (Sauropodomorpha + Theropoda + Herrerasauridae) scheme was challenged in favor of an Ornithoscelida (Ornithischia + Theropoda) and Saurischia (Sauropodomorpha + Herrerasauridae) hypothesis. The main objective of this work is to review the putative diagnostic features of Ornithoscelida Huxley, 1870, which will be done with the redefinition and rescoring of the characters recovered as synapomorphic for the group, aiming at a better understanding of their distribution. One of the most consistent findings so far is that most evaluated characters do not encompass the full gamut of morphologies present in the dinosaur lineage. For example, the acetabular wall is completely closed in forms such as *Lagerpeton;* has a straight margin in *Saturnalia;* is partially excavated in *Herrerasaurus;* is almost fully opened, with only a small round margin, in taxa such as *Coloradisaurus;* and fully opened in *Eocursor*. Therefore, scoring the acetabular wall simply as present or absent does not represent the full variability of the trait and misses relevant information. Some characters have unclear homology series, such as the post temporal fenestra, as it remains unclear which of the reduced apertures of modified taxa represents the large plesiomorphic element. As for the femoral anterior trochanter, the plesiomorphic anatomy is unclear, as the element is absent in lagerpetids. Its blade-like shape seen in ornithischians and neotheropods may not be homologous, as the structure in taxa such as *Tawa* differs not only from that of those modified forms, but also from those of sauropodomorphs, which have a possibly apomorphic diminutive trochanter. In the end, the observed morphology of the anterior trochanter does not support an unequivocal grouping of theropods and ornithischians. Moreover, when the so far modified scorings are included in the data matrices, Ornithoscelida is not recovered, with a large polytomy uniting the major dinosaur groups being found instead. We hope that, with more compressive observations and scorings, the actual distribution of characteristics will be elucidated, and their phylogenetic signal made clear.

Grant Information:
São Paulo Research Foundation – FAPESP, Nbrs. 2018/19178-8 & 2019/02167-6 and CAPES PROEX Nbr. 88887.198954/2018-00 to J.P.S.K. FAPESP Nbr. 2014/03825-3 to M.C.L.

Technical Session II (Wednesday, October 9, 2019, 10:30 AM)

HIGH-LATITUDE NEONATE AND PERINATE ORNITHOPODS FROM THE MID-CRETACEOUS OF SOUTHEASTERN AUSTRALIA

KITCHENER, Justin L., University of New England, Armidale, Australia; CAMPIONE, Nicolas E., University of New England, Armidale, Australia; SMITH, Elizabeth, Australian Opal Centre, Lightning Ridge, Australia; BELL, Phil, University of New England, Armidale, Australia

Dinosaurs were remarkably climate-tolerant, thriving from equatorial to polar latitudes. In the Northern Hemisphere, eggshells and hatchling material confirm that hadrosaurid ornithopods were capable of reproducing in polar regions and remained resident throughout the winter season. However, similar examples and interpretations are lacking from Gondwanan landmasses. Here we present on two hatchling-sized non-iguanodontian ornithopod femora from the Griman Creek Formation (Cenomanian) in New South Wales, Australia. These two incomplete proximal femora represent the first perinatal ornithopods described from Australia, supplementing examples of neonatals and slightly older 'yearlings' from the Aptian–Albian Eumeralla and Wonthaggi formations in Victoria. Although histological examination of these femora is obviated by opalization (i.e., pseudomorphic preservation), gross anatomical and size comparisons with Victorian specimens, which underwent previous histological work, support a perinatal interpretation for the Griman Creek Formation specimens. Both Griman Creek Formation specimens (reconstructed femoral lengths = 37 mm and 45 mm) are estimated to have been shorter in length than those from the Eumeralla and Wonthaggi formations (minimum length = 47 mm). Mass estimations for the two femora were 148–252 g, and 209–353 g based on their respective femoral circumferences. The small size and limited development of features (e.g., a low, crescentic fourth trochanter; absence of a distinct *fossa trochanteris*; absence of insertion scars for the *M. iliotrochantericus* and *M. caudofemoralis brevis*) in the smallest femur suggests that it may have been embryonic. Despite a period of rapid growth during the first few years of life, low body masses (<1 kg for 'yearlings' and ~20 kg at skeletal maturity) would have precluded such small-bodied ornithopods from undertaking long-distance migrations, even as adults. As a result, these specimens support high-latitudinal breeding in a non-iguanodontian ornithopod in Gondwana during the early Late Cretaceous. High-paleolatitude ornithopod nesting sites from both hemispheres reveals an apparent preference for wet, lowland settings suggesting the presence of constraints on egg incubation temperatures at high paleolatitudes, although preservational biases must also be considered.

Grant Information:
This work was funded through the University of New England and an Australian Research Council Discovery Early Career Researcher Award (project ID: DE170101325) to PRB.

Romer Prize Session (Thursday, October 10, 2019, 10:15 AM)

MOLECULAR AND MORPHOLOGICAL PATTERNS OF SURVIVAL, NOT EXTINCTION, OF SNAKES THROUGH THE CRETACEOUS-PALEOGENE MASS EXTINCTION

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Mass extinctions have played a vital role in shaping patterns of biodiversity throughout the Phanerozoic. The Cretaceous-Paleogene (K-Pg) mass extinction is the most recent and therefore the most influential on modern patterns of biodiversity. Recent advances in molecular clock methodology and discoveries of new fossils have permitted renewed evaluations of patterns of extinction and diversification of clades over the boundary. This has revealed the recovery and diversification of mammals, birds, frogs, and teleost fishes shortly after the K-Pg boundary. However, it remains unclear how this event affected small poikilothermic reptiles, such as snakes. Here we investigate their survival and recovery through the K-Pg mass extinction using morphological disparity and molecular clock methods. We reveal a gradual increase in the disparity of snakes from the mid-Cretaceous to the Late Eocene, with increasing specialisation of marine paleophiids towards extreme lateral compression following the K-Pg, together with a concomitant shift in the region of the morphospace occupied. A molecular clock with up to 42 fossil calibrations demonstrates that snake diversification continued throughout the extinction event, with no marked shifts in rate. However, we highlight the importance of the calibration and model choices underpinning these results, as recovered ages vary significantly. Our results suggest that poikilothermy and burrowing or aquatic habitats increased the survival of snakes through the boundary. Niche use may therefore explain the differential impact of mass extinctions across major groups.

Grant Information:
This project was funded by the Fonds National de la Recherche Luxembourg AFR grant 10142968

Technical Session XIII (Friday, October 11, 2019, 2:45 PM)

NEW TRILOPHOSAURID SPECIES DEMONSTRATES EXTINCTION-DRIVEN DROP IN ALLOKOTOSAUR DIVERSITY ACROSS THE ADAMANIAN-REVUELTIAN BIOZONE BOUNDARY IN THE LATE TRIASSIC OF WESTERN NORTH AMERICA

KLIGMAN, Ben, Virginia Tech, Blacksburg, VA, United States of America; STOCKER, Michelle R., Virginia Tech, Blacksburg, VA, United States of America; NESBITT, Sterling J., Virginia Tech, Blacksburg, VA, United States of America; MARSH, Adam D., Petrified Forest National Park, Petrified Forest National Park, AZ, United States of America; PARKER, William, Petrified Forest National Park, Petrified Forest National Park, AZ, United States of America

Archosauromorph reptiles are the most diverse clade of tetrapods from the Upper Triassic Chinle Formation of western North America, and they display the breadth of morphological evolution achieved by this group in its radiation after the end-Permian extinction. Allokotosaurs, including trilophosaurids, azendohsaurids, and *Pameleria dolichotrachela*, are an extinct archosauromorph clade of small to medium body size which reached a global distribution in the Late Triassic and evolved a broad range of cranial and dental morphologies. Allokotosaurs span the Norian-aged Blue Mesa (Adamanian biozone) and Sonsela (Revueltian) members of the Chinle Formation biozones. These biozones are punctuated by the Adamanian-Revueltian faunal turnover, which is characterized by extinction and faunal turnover in large-bodied archosauromorphs, but poor sampling has obscured any similar patterns in tetrapods <1m from those same localities. *Trilophosaurus* (Trilophosauridae) is the most common small herbivore taxon found in Adamanian biozone (224–215 Ma) microvertebrate sites, with three species present (*Trilophosaurus buettneri, T. jacobsi,* and *T. dornorum*). The presence of two other allokotosaur taxa in Adamanian microsites, a close relative of *Malerisaurus* and an unnamed trilophosaurid, demonstrate the diversity of this group in the Adamanian.

Here we describe a new species of trilophosaurid found in microvertebrate-bearing horizons in the Jim Camp Wash beds of the Sonsela Member (Chinle Formation) that is the first trilophosaurid species reported from the Revueltian biozone. Unlike in other trilophosaurids, the teeth are bicuspid, and the presence of four cingula on each tooth represents an increase in cingulum complexity for trilophosaurids. The occurrence of this new taxon shows the extent of allokotosaur extinctions at the Adamanian-Revueltian boundary with a drop in diversity from five taxa to one. The pattern of faunal turnover and extinction seen in allokotosaurs is similar to patterns in other archosauromorph clades including aetosaurs and phytosaurs across the Adamanian-Revueltian boundary in Arizona. These local patterns of extinction in both large- and small-bodied tetrapod clades demonstrate the magnitude of the Adamanian-Revueltian faunal turnover. The Manicouagan bolide impact (~215 Ma), which is coincident with the Adamanian-Revueltian turnover, has been linked to marine invertebrate extinctions, and our findings add to the evidence for possible global ecological disruption associated with this event.

Grant Information:
Petrified Forest Museum Association
Petrified Forest National Park
David B. Jones Foundation

Technical Session XII (Friday, October 11, 2019, 10:45 AM)

GEOMETRIC MORPHOMETRIC EVIDENCE FOR RAPID EVOLUTION AND STRONG DIVERSIFYING SELECTION OF PUTATIVE SIGNALLING TRAITS IN HORNED DINOSAURS

KNAPP, Andrew, Queen Mary University of London, London, United Kingdom; ALVAREZ-CARRETERO, Sandra, Queen Mary University of London, London, England; KNELL, Robert J., Queen Mary University of London, London, England; HONE, David W., Queen Mary University of London, London, England

Discoveries over the past few decades have greatly increased our knowledge of the morphological diversity of the horned dinosaur clade Ceratopsidae. This clade is known for the diverse and often complex arrangement of nasal and postorbital horns, and the shape and epiossifications of the parietal-squamosal frill. The Late Cretaceous experienced an apparent rapid increase in diversification of ceratopsian taxa, with diversity particularly notable in these putative display structures of ceratopsid skulls. Because the arrangement of these features is unique to each taxon, it has been suggested that the evolution and diversification of ceratopsian crania, particularly in the Late Cretaceous, is driven by these features. This points to a role in intraspecific socio-sexual interactions driving a form of runaway selection for increases in size and/or complexity for these traits. If this assertion is correct, quantifying the relative rates of evolution of different skull elements will allow us to test the hypothesis of accelerated evolution of 'display' traits, and help us to better understand patterns of evolution within this clade.

Here, for the first time, we conduct a three-dimensional geometric morphometric analysis of ceratopsian skull morphology using high density landmarks sampled from over 80 specimens in more than 20 taxa. Using a maximum likelihood approach, we show that the ceratopsian skull shows a high degree of modularity, with the putative display structures forming distinct phenotypic modules. Morphological diversity in ceratopsians is largely a result of the diversity of phenotypic modules typically associated with display.

Using the Bayesian approach implemented in MCMCtree to deal with quantitative characters, we were further able to estimate divergence times of ceratopsian taxa under the Brownian diffusion model. We found that phenotypic modules and whole-skull data returned different estimates for branch lengths, and that those for the unique 'display' traits of ceratopsians are considerably higher than modules not considered to be associated with display.

These findings suggest that putative display traits did indeed undergo rapid evolution in ceratopsians and that they were under consistent and strong selective pressure, which both maintained their presence in ceratopsids and drove their diversification. This is consistent with the proposed runaway selection hypothesis of Fisher, adding support for the suggestion that these traits were important in socio-sexual interactions of ceratopsians.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

PALEONEUROLOGY OF A NEW THEROPOD SPECIMEN FROM THE 'ARGILES DE L'IRHAZER', MIDDLE JURASSIC OF NIGER

KNOLL, Fabien, ARAID—FCPTD, Teruel, Spain; LAUTENSCHLAGER, Stephan, University of Birmingham, Birmingham, United Kingdom; SERRANO-MARTÍNEZ, Alejandro, UNED, Madrid, Spain; ORTEGA, Francisco, UNED, Madrid, Spain

In 2006, a partial middle-sized dinosaur braincase was discovered at the Azenak site (Aderbissinat, Niger). The specimen comes from the 'Argiles de l'Irhazer', which are possibly late Middle Jurassic in age. Although it was initially determined as belonging to a sauropod, a number of characters (such as a well-developed basisphenoidal recess) indicate that it pertains to a theropod. We CT-scanned this specimen and generated 3D renderings of the cranial endocast and inner-ear system. The endocast is characterized by a prominent floccular lobe. This strengthens the identification of the specimen as a theropod, which was already apparent from observation of the external braincase morphology. Due to the incompleteness of the fossil, only the cranial nerves V to XII could be reconstructed. Large venous structures as well as the endosseous labyrinth could also be traced. Preliminary comparisons of the paleoneurology of the new dinosaur from Azenak with a variety of theropods for which the endocast is known shows resemblances with *Allosaurus fragilis* (Late Jurassic, U.S.A.). The Azenak theropod and *Allosaurus* display similar configurations of the caudal middle cerebral vein and blind dural venous sinus of the hindbrain. In both taxa, the vestibular system appears triangular with a fairly vertical *crus commune* in lateral view of the endocast. From this perspective, the horizontal semicircular canal and the caudal middle cerebral vein are parallel in both the Azenak theropod and *Allosaurus*. Most of these characters were previously brought to light as well in an isolated braincase of probable megalosauroid affinities from the latest Middle Jurassic of France. The combination of features shared by the Azenak theropod, *Allosaurus* and the Norman purported megalosauroid suggests that the Nigerien dinosaur may be a basal Tetanurae. The presence at Azenak of a megalosaurid close to (or identical with) *Afrovenator abakensis*, a Nigerien megalosaurid of possibly latest Middle Jurassic age (Tiourarén Formation), has been recently put forward on the basis of a few isolated teeth. Unfortunately, comparisons of the new specimen with *Afrovenator* cannot be made as no part of the braincase of the latter is known.

Grant Information:
This is a contribution to the research project CGL2017-89123-P funded by FEDER/Spanish Ministry of Science, Innovation and Universities-State Research Agency.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE LAZARUS DICYNODONT – REASSESSING AUSTRALIAN CRETACEOUS MATERIAL

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The often tusked, edentulous, and beaked non-mammalian therapsid dicynodonts were amongst the most abundant terrestrial herbivores during the latter half of the Permian and throughout the Triassic periods. Assumed extinct at the Triassic-Jurassic boundary, the discovery of a possible Cretaceous dicynodont (QMF990) by a grazier in Queensland Australia, in 1914, potentially extended the longevity of the dicynodont lineage by nearly 100 million years. However, the very fragmentary nature of the specimen and the lack of information on its geological provenance, has so far prevented a definitive identification of the taxonomical and temporal affinities of the material. Through recent reviews of museum correspondence archives and the use of synchrotron microtomography and geochemical analysis, new information has become available shedding light on the geographical and geological background of the specimen, as well as revealing anatomical details facilitating a better understanding of the material's biological origins. These new findings impact on our knowledge of dicynodont evolution and biogeography, but also highlight the importance of specimen metadata and museums' roles as custodians of these.

Grant Information:
The synchrotron microtomographic imagery was produced at the Australian Synchrotron facility in Melbourne, Australia as part of grant proposal ID AS182/IMBL/13304.

Technical Session II (Wednesday, October 9, 2019, 11:30 AM)

A NEW CRESTED HADROSAURINE (DINOSAURIA: HADROSAURIDAE) FROM THE MARINE DEPOSITS OF THE LATE CRETACEOUS HAKOBUCHI FORMATION (MAASTRICHTIAN), YEZO GROUP, JAPAN

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A nearly complete skeleton of a hadrosaurid dinosaur was discovered from the outer shelf deposits of the Upper Cretaceous Hakobuchi Formation (early Maastrichtian) of the Yezo Group in the Hobetsu area of Mukawa town in Hokkaido, Japan. This Hokkaido Hadrosaurid (HH) is important for understanding the diversity of hadrosaurids in marine-influenced environments because hadrosaurid materials from marine deposits are rarely reported. Given the completeness of this skeleton, this dinosaur also sheds light on understandings of the diversity of hadrosaurids in the Far East as well as spatial and environmental significance for the hadrosaurid evolution during the Late Cretaceous.

HH is a new taxon in having some unique characters (the midpoint of the quadratojugal notch positioned at roughly three-quarters of the total length of the quadrate from the dorsal end, short ascending process of the surangular, high average height/width ratio of dentary tooth over 3.30, anterior inclination of neural spines of sixth to twelfth dorsal vertebrae). Our phylogenetic analysis shows that HH belongs to Edmontosaurini (a sub-clade of Hadrosaurinae) and forms a clade with *Laiyangosaurus* and *Kerberosaurus* from the northern Far East. HH has a long frontal platform for the nasofrontal sutural surface, indicative of the presence of a moderate-sized supracranial crest, similar to a sub-adult form of *Brachylophosaurus* based on the extension of the nasofrontal sutural surface. The histological section of the mid-shaft of the tibia exhibits at least nine lines of arrested growth (LAGs). The last few LAGs of the outermost circumference are closely apposed, and the growth curve reconstruction indicates that this individual had virtually reached its asymptotic body size. The Dispersal Extinction Cladogenesis analysis with the 50% Majority Rule consensus tree suggests that the clade of HH, *Laiyangosaurus*, and *Kerberosaurus* may have separated from the hadrosaurines in the rest of Asia prior to the early Campanian and that the clade was endemic for more than a million years in the northern Far East. The results of both Dispersal Extinction Cladogenesis analysis and ancestral state reconstruction on depositional environments with the 50% Majority Rule consensus tree imply that the marine-influenced environments in North America during the Campanian may have played an important role for the hadrosaurid diversification in its early evolutionary history.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

GEOCHEMICAL CHARACTERIZATION OF LATE CRETACEOUS MARINE REPTILES AND FISH FROM ANTARCTICA AND PATAGONIA

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Mosasaur, plesiosaur and *Enchodus* fish remains from Antarctica (Isla Marambio – López de Bertodano Fm., late Maastrichthian), as well as mosasaur and shark teeth from Patagonia, Argentina (Los Bajos de Trapalco and Santa Rosa, Río Negro – Jagüel Fm., late Maastrichthian) have been analyzed for their stable isotope ($\delta^{18}O_{PO4}$, $\delta^{13}C_{CO3}$, $\delta^{18}O_{CO3}$) and trace element compositions in order to trace possible ecological and taphonomical information of their bioapatite. Enamel-derived $\delta^{18}O_{PO4}$ values of the fishes from Antarctica are 1 ‰ higher on average than the Patagonian population, which could reflect expected latitudinal seawater temperature differences between the two regions during the Late Cretaceous (paleolatitude of 64°S versus 45°S, respectively). In contrast, the marine reptiles have a higher variation in their $\delta^{18}O_{PO4}$ values and average isotopic compositions 3 to 4 ‰ lower than those of the fishes. This result is compatible with earlier studies and collectively suggests that these reptiles were able to maintain higher body temperature than ambient conditions. The $\delta^{13}C_{CO3}$ values are also different between fishes and reptiles with higher values for the fishes. Both mosasaurs and plesiosaurs have very low $\delta^{13}C_{CO3}$ values (–11.2 ± 2.2 ‰, n=12 and –11.8± 0.9 ‰, n=5, respectively), which cannot only be explained by their trophic level (i.e., diet) but are also linked to their respiratory physiology relating to their diving habits. The two oxygen isotopic values, $\delta^{18}O_{PO4}$ and $\delta^{18}O_{CO3}$, derived from enamel/enameloid correlate for the Antarctica samples (R^2=0.79), which may be taken as a sign of good preservation. Complete isotopic re-equilibration between the two oxygen bearing phases is highly unlikely in the view of preserved ecological differences between fishes and marine reptiles in their $\delta^{18}O_{PO4}$ and $\delta^{13}C_{CO3}$ values. Commonly the $\delta^{18}O_{CO3}$ can be overprinted in the structural carbonate of the apatite, which is probably the case for the Patagonian samples. In view of the trace element content, especially the early diagenetic rare earth elements (REE) and uranium (U), all samples may have had a complex diagenetic history, indicated by their large variation in REE concentrations and distributions. Enamel/enameloid seems to be better preserved and reflect early depositional conditions, while in some cases dentine probably affected further by late trace element exchange maybe even during weathering processes.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

SMALL MAMMAL AND MOLLUSC FAUNAS FROM THE MIDDLE PLEISTOCENE OF CENTRAL RUSSIA

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The Middle Pleistocene deposits of the Central Russian Plain include three major moraines with an extensive series of alluvial deposits, fossil soils, and loesses between them that produced rich small mammal and mollusc faunas. The main glacial stages on the Central Russian Plain correspond with marine isotopic stages (MIS) 18 (Setunian), 16 (Donian), 12 (Okian), and 6 (Moskovian) and correlate well with the glacials known from Central and Western Europe. Tiraspolian (=Cromerian) faunas of the Early Middle Pleistocene are known from the deposits of Petropavlovian, Pokrovian, Ilyinian, and Muchkapian horizons (MIS 20-15). Tiraspolian faunas known from below the Donian till (MIS 20-17) are characterized by the dominance of the vole *Mimomys pusillus*. Mollusc faunas of the lower part of the Tiraspolian complex are characterized by the presence of *Tanousia krasnenkovi*, *Viviparus diluvianus*, and *Parafossarulus*. The upper Tiraspolian faunas (MIS 15) are characterized by the dominance of the vole *Mimomys intermedius*, the presence of the gastropod *Borysthenia intermedia*, and the absence of *Tanousia* and *Parafossarulus*. Transition between the Tiraspolian and Ikoretsian faunas, which corresponds with the final stage of the Cromerian (MIS 13), was characterized by a significant faunal turnover with the disappearance of *Mimomys* and the first appearance of *Arvicola*. The dominant rodent species in the Ikoretsian faunas are *Arvicola mosbachensis* and *Microtus* voles. The evolutionary level of the latter corresponds with that

of Western European voles from the final stage of the Cromerian. The occurrence of archaic *Arvicola* in the fauna of Mastuzhenka indicates that in the evolutionary lineage of *Mimomys-Arvicola* the loss of cheek tooth roots and, thus, the differentiation of the genus *Arvicola* occurred prior to the Okian glacial stage during the final phase of the Cromerian. The Likhvinian (Holsteinian) molluscan faunas (MIS 11) are characterized by the disappearance of *Borysthenia intermedia* and high terrestrial mollusc diversity. These faunas are similar to modern Central European faunas in the presence of *Acicula polita* and several clausilid species. New data from numerous localities on the Central Russian Plain show a complex history of evolution of small mammal and mollusc faunas during the Middle Pleistocene, characterized by the appearance and disappearance of several taxa. The new data contribute to the development of a more detailed stratigraphic scale of European Quaternary continental deposits.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 10:15 AM)

WHAT IS AN 'EXCEPTIONAL' FOSSIL? ASSESSMENT OF THE MICROSCOPIC PRESERVATION OF A JEHOL BIOTA FEATHERED DINOSAUR

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At the macroscopic scale, there is a clear range in fossil quality, and specimens which preserve soft tissues are typically considered exceptional. There is also a range in preservation quality on the histological scale; some environments preserve the fine details of single cells in phosphate or the structure of melanosomes on feathers. Some fossils even contain putative osteocytes and blood cells, which would be truly exceptional if valid. The molecular level is more difficult to assess preservation of as most organic molecules do not survive fossilization, and it is difficult to confidently identify even the most durable (i.e., collagen and lipids). The Jehol biota of Northeast China is composed of many classically exceptional specimens including well-feathered avialians with melanosomes preserved. These features make them clearly exceptional on the macroscopic level, and at least notable for their cytological-scale preservation.
We have studied the Yixian Formation's *Beipiaosaurus inexpectus*, a feathered therizinosaur from the Early Cretaceous, to assess whether exceptional detail at a macroscopic scale is necessarily indicative of high-quality cytologically and molecularly. To accomplish this assessment, we used a suite of analytical tools including Raman Spectroscopy, Energy Dispersive Mass Spectroscopy, and Time-of-Flight Secondary Ion Mass Spectrometry in addition to light microscopy of thin sections. These tools reveal some signs of high quality on the histological scale – fine details of canaliculi and little-altered apatite – and other indications of poor preservation conditions on the cytological scale including clay minerals in the vasculature. The purported blood cells are indistinguishable from other vessel fills chemically and do not contain any unique biomolecules. Extrapolating from this data, we conclude that the fine sediments of the Yixian Formation which preserve many of the exceptional Jehol fossils are not particularly well suited for preservation of blood cells or biomolecules.

Grant Information:
Geological Society of America Graduate Research Grant

Technical Session III (Wednesday, October 9, 2019, 1:45 PM)

AN EARLY 'CAT GAP'? AN EVALUATION OF OXYAENIDS AS ECOLOGICAL ANALOGUES OF FELIDS

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Oxyaenids were among the largest carnivorous mammals during the early Eocene. Their short-faced skulls and large carnassials resemble those of cats, characteristic of a hypercarnivorous diet. Oxyaenids became extinct in North America by approximately 43 Ma before the diversification of crown-group carnivorans, including true cats and other cat-like carnivorans. The gap between the extinction of oxyaenids and the first appearance of cat-like carnivorans approximately 39 Ma can therefore be considered analogous the later period between 23 – 17.5 Ma commonly referred to as the "cat gap" due to the absence of cat-like carnivores in North America. Whether this earlier period can be considered analogous to the 'cat-gap' depends on whether oxyaenids filled the same ecological role as cats. That the skull and dentition have similarities is established, but the function of oxyaenid postcrania needs to be resolved to completely compare their ecological role with cat-like forms. I made observations and measurements on the postcrania of a *Patriofelis ulta* from a nearly complete specimen (UMNH 550), as a representative oxyaenid to assess locomotor specializations in oxyaenids in comparison with felids. The humerus of *P. ulta* resembles that of felids in having an expanded deltopectoral crest and wide capitulum. The expanded deltopectoral crest increases attachment area for adduction and abduction muscles, and the wide capitulum allows for supination of the forearm. In cat-like carnivores, strong, flexible forelimbs are used to grapple with prey, and it is likely this was the function in *P. ulta*. However, the lumbar vertebrae and feet of *P. ulta* differ from those of cat-like forms. The lumbar of *P. ulta* have revolute articulations with a restricted range of motion when compared with the lumbar of cats. The feet of *P. ulta* would have been plantigrade and lacked retractable claws, unlike the digitigrade feet in modern felids. While flexible forelimbs indicate that *P. ulta* could have been an ambush hunter that grappled with prey, *P. ulta* would have lacked the range of motion in lumbar spine and longer digitigrade limbs that allow for short, rapid pursuits like in some extant cats. Thus, *P. ulta* may have filled a similar niche as cat-like carnivores but would have been more restricted in locomotion. Regarding the period between the extinction of oxyaenids and the appearance of nimravids 43 – 39 Ma as an early "cat gap", while accounting for differences in locomotion, could provide useful comparison to the later "cat gap" in understanding patterns of extinction in carnivores.

Grant Information:
Robert R. Shrock Fund, Department of Earth and Atmospheric Sciences, Indiana University

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

TOOTH MORPHOMETRICS CAN DIFFERENTIATE MORRISON FORMATION DIPLODOCIDS

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The teeth of diplodocine sauropods are often deemed undiagnostic to species or genus level. To test this hypothesis we conducted morphometric studies on the teeth of three diplodocine specimens (likely representing at least two species, one including a hypothesized juvenile) and two outgroup sauropod taxa (*Camarasaurus lentus* and material assigned to *Brachiosaurus* sp.) from the Late Jurassic Morrison Formation of North America, and performed principal component (PCA) and Linear discriminant analyses (LDA) of the data. We measured all available teeth within each specimen, capturing the variation evident in dental morphology across the tooth row. All taxa are recognized as significantly different in the LDA, except for a *Camarasaurus* tooth originally assigned to *Brachiosaurus* sp. (USNM 5730). PCA was able to differentiate early-diverging macronarians (*Camarasaurus* and *Brachiosaurus*) from the diplodocids, and the juvenile diplodocine (CM 11255) emerged as significantly different from all other specimens.
To test the impact of dental data on the differentiation of diplodocine taxa in morphospace, we contrasted our dental-only data analyses with analyses using solely cranial morphometric data, and analyses on a combined dataset. PCAs of these same taxa using only cranial morphometric data related to the feeding apparatus were unable to significantly discriminate between operational taxonomic units (OTUs) except for the diplodocine USNM 2672. Due to the small sample size for the cranial values, we caution against reading this as a failure of cranial morphometrics. Greatest differentiation between OTUs was achieved with a combination of dental and cranial morphometric data. With this dataset all diplodocines (USNM 2672, CM 11161, CM 11255) emerged as significantly different from each other and the macronarians, indicating that dental morphometric data was a key contributor to the differentiation observed. Dental measurements are able to differentiate between diplodocines, and we advise future research on sauropod feeding ecology and evolution to include dental morphometric data (even capturing variation within the tooth row), in addition to cranial characters to improve ontogenetic, phylogenetic, and ecological signal related to the feeding apparatus.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

WHAT CAN MORPHOLOGICAL CHANGES THROUGH TIME TELL US ABOUT DIET & HUMAN-DRIVEN HABITAT CHANGES? THE CASE OF THE ETRUSCAN SHREW IN CORSICA

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The Anthropocene is an epoch defined by accelerated environmental changes driven by humans. These changes have a substantial impact upon all aspects of living organisms worldwide, including their morphology. Understanding

the mechanisms behind such changes is essential for predicting and preventing future effects on organisms. We focus on the micromammal assemblages of a high-resolution stratigraphic sequence of 12 layers from the French island Corsica, covering approximately 600 years (14th–19th century AD) of intensified anthropisation. More specifically, we focus on *Suncus etruscus*, the smallest and most abundant shrew of these assemblages. We use 2D geometric morphometrics to study the shrew's mandible shape through time and evaluate shape differences between stratigraphic layers by calculating Euclidian distances. We also calculate the Mechanical Potential (MP) of the two primary masticatory muscles. For both muscles, we use simple biomechanical models that already exist in the literature and introduce new enhanced models. We perform a Procrustes ANOVA, Pearson's correlations and regressions to test the relation between shape, size and MP. We also study the integration patterns (if and how the shapes of different anatomical parts or modules co-evolve). We do this for the two modules of the mandible: the body and ramus. We then test whether there is a relationship between shape and MP, and with changes in vegetation and human-activity through time. The distance tree shows a distinction of layers that correspond to different vegetation and anthropic conditions. The Procrustes ANOVA shows that morphological changes had functional consequences, with 6.5% of shape variability explained by MP of the temporalis, and 4.2% from MP of the masseter. The negative statistical correlation between the MPs of those muscles, as well as their relation with vegetation and anthropic changes (shown by the regression results), suggest rapid changes in the shrew's diet over time. We also find strong integration in our sample; however, we find similar integration patterns in layers of different environmental and human conditions. This suggests that integration is not a good indicator of rapid environmental changes and/or human impact, at least in this instance. It remains to be shown whether integration could be an indicator of longer-term environmental changes related to human activity, and whether the morphological changes found in this study are the result of natural selection or of phenotypic plasticity of the shrew mandible.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 8:45 AM)

MUSCLE RECONSTRUCTIONS AND HUMERUS AND FEMUR FINITE ELEMENT ANALYSES OF *CRYPTOCLIDUS EURYMERUS* (PLESIOSAURIA) SUPPORT UNDERWATER FLIGHT AND FLIPPER TWISTING

KRAHL, Anna, RUB and University of Bonn, Bochum, Germany

Plesiosaurs (Sauropterygia) are secondarily aquatic diapsids. They evolved, uniquely amongst Tetrapoda, a locomotor apparatus that employed two pairs of hydrofoil flippers. However, whether plesiosaurs rowed, flew underwater, or combined both locomotory styles remains debated. Tetrapod long bones experience temporary bending, compressional, and torsional loads, but superposition of load cases shows that in total bones are loaded mostly by compression. Thus, hypothetical muscle attachment surfaces and muscle lines of action (MLA) can be tested by optimizing for minimal bending and a homogenous compressive stress distribution in finite element analysis (FEA). This approach was applied to the forelimb and hindlimb of the Middle Jurassic plesiosaur *Cryptoclidus eurymerus* in order to investigate locomotion in plesiosaurs. First, *Cryptoclidus* foreflipper and hindflipper musculature was reconstructed using the extant phylogenetic bracket. Second, results were refined by comparison to recent functional analogues, including dissection of cheloniid humerus muscles. Functional analogues inform on potential muscle reductions in the distal fore- and hindflippers and on crucial muscle wrappings. Third, muscle lines of action (MLA) were obtained for all reconstructed muscles by spanning threads along the *Cryptoclidus* skeleton. Fourth, total muscle length changes between maximum flipper elevation and depression were measured for all glenoid- and acetabulum-spanning muscles. Fifth, MLA were implemented in finite element humerus and femur models, muscle forces were stochastically approximated, and compressive stress distribution was computed in ANSYS to test two load cases, upstroke and downstroke, describing an underwater flight limb cycle for each bone. A homogenous compressive stress distribution was obtained after a muscle-driven flipper twisting mechanism was reconstructed and those extensors and flexors arising from humerus and femur that contribute to flipper twisting were implemented in the finite element models. FEA model muscle forces are highest in humeral and femoral depressors and elevators indicating plesiosaurs flew underwater rather than rowed. High humeral extensor and flexor forces corroborate the flipper twisting mechanism neccessary for underwater flight which had been predicted by hydrodynamic studies.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

DIETARY RECONSTRUCTION OF PLEISTOCENE DEER *CERVUS ASTYLODON* USING DENTAL MICROWEAR TEXTURE ANALYSIS

KUBO, Mugino O., The University of Tokyo, Chiba, Japan; FUJITA, Masaki, National Museum of Nature and Science, Ibaraki, Japan

Microwear is microscopic scars left on tooth surface during mastication. Because microwear reflects physical property of food eaten by animals, it has been used for dietary reconstruction of extinct animals. In the present study, we investigated tooth microwear of extinct deer *Cervus astylodon*, excavated from Late Pleistocene archaeological sites of the Okinawa Island. *C. astylodon* is estimated to have migrated into the Okinawa Island during the Early Pleistocene and became extinct at the end of the Late Pleistocene. This species is also known as a representative island dwarf, with the body size is estimated to be ca. 15kg. In order to examine its evolution on islands and the causes of extinction, paleoecological reconstruction of *C. astylodon* has been conducted. We applied three-dimensional surface texture analysis to evaluate microwear features quantitatively. By analyzing 300 individual sika deer (*Cervus nippon*) from 14 populations of Japan with quantitative dietary data, we found significant correlations between surface texture parameters and diet (proportion of graminoids in diet). Deer consuming a greater amount of graminoids showed rougher tooth surface than those consuming tree browses, because graminoid leaves contain a significant amount of silica, which abrades tooth surface. From the regression equation of surface roughness parameter and percentage of graminoids in diet, we estimated that *C. astylodon* might have consumed graminoids approximately 40-60% of their total diet. The current results were concordant with the previous stable carbon isotope analysis indicating *C. astylodon* was C_3 plant feeder, but additionally clarified that they were not pure C_3 browser but mixed feeder.

Grant Information:
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Technical Session XVII (Saturday, October 12, 2019, 12:00 PM)

BIOGEOGRAPHICAL NETWORK ANALYSIS OF CRETACEOUS NON-AVIAN DINOSAURS AND BIOGEOGRAPHICAL CONNECTIONS OF AUSTRALIA TO OTHER CONTINENTS

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A biogeographical network of Cretaceous dinosaurs was constructed using a new method that utilizes phylogenetic relationship. This method estimates a biogeographical region of all internal nodes of a given phylogeny based on biogeographical information of the terminal taxa using ancestral state reconstruction via maximum parsimony. Then, each sister relationship in the phylogenetic tree is converted to an edge in the biogeographical network.
For this presentation, continents were set as biogeographical regions and the phylogeny of dinosaur was analysed with its internal nodes which estimated age were within the Cretaceous period were used. The biogeographical regions were grouped using community detection algorithms that were used to partition networks. The dinosaur network that utilize all Cretaceous internal nodes was partitioned into three groups of continents: (1) North America, Asia, and Australia; (2) Europe and Africa; (3) India, Madagascar, and South America. When Early and Late Cretaceous dinosaurs were analysed separately, the dinosaur networks were divided into (1) North America, Asia, and Australia; and (2) Europe, Africa, India, and South America for the Early Cretaceous and (1) North America, Asia, and Europe; (2) India, Madagascar, and South America for the Late Cretaceous.
Surprisingly, Australia was grouped with Laurasian continents, that may be due to small number of Australian species included in the analysis, namely *Wintonotitan, Australovenator*, and *Kunbarrasaurus* and many plesiomorphic features retained in these taxa that placed them as a sister taxon of Laurasian taxa. Biogeographical relationship of Australia with other continents during the Cretaceous period was further investigated by adding more Australian dinosaur taxa, such as *Qantassaurus*, *Savannasaurus*, *Diamantinasaurus* and *Weewarrasaurus*, to the phylogeny and importance of finding new Australian taxa in understanding biogeography is discussed.

Grant Information:
This study was supported by JSPS KAKENHI grant number 17K14411.

Technical Session III (Wednesday, October 9, 2019, 2:30 PM)

BURIED PRIDE: MULTIPLE INDIVIDUALS RECOVERED FROM SINGLE FOSSIL DEPOSIT, BOLT'S FARM, SOUTH AFRICA

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Panthera fossils in the South African context are rare. Where they have been recovered, they tend to be isolated teeth, cranial elements or individual post cranial bones. Large deposits of *Panthera* fossils have been reported from sites across the northern hemisphere and have been attributed to cave lion (*Panthera spelaea*) in Europe, the Urals, the Caucasus and Siberia; and *Panthera atrox* in North America. Recent discoveries at the Bridge Cave loci of the Bolt's Farm Karst System, Cradle of Humankind, South Africa, have yielded an unprecedented number of Pantherine fossils. To date more than 1300 fossils have been recovered from a deposit approximately 1.5 meters across, half a meter high and half a meter deep. Of these 1300+ fossils, 507 have been attributed to *Panthera.* Nearly every bone in the skeleton has been identified and we can say with confidence that there are at least seven individuals. Many of the post cranial remains are extremely large, suggesting that at least one of the individuals may have been a male, and well outside the size realm of modern *Panthera leo.* The presence of juvenile remains suggests that we may have an example of a fossil lion pride in a single depositional event. Other morphological variants suggest the possibility that we have identified a new species or sub-species of *Panthera*. The presence of *Phacochoerus modestus* as well as *Metridiochoerus andrewsi* indicates an age of approximately 1.8 million years.

Grant Information:
LIA 1041, CNRS-NRF and the MPFSA (Mission Paléoanthropologique Franco-Sud-Africaine)

Technical Session XV (Saturday, October 12, 2019, 11:15 AM)

MORE THAN ONE WAY TO BE A BOSS: HISTOLOGICAL PERSPECTIVES ON CRANIAL BOSS DEVELOPMENT AND ITS EFFECT ON SUTURE MORPHOLOGIES

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Cranial bosses, or elaborately thickened regions of the skull, convergently evolved in several amniote clades including dinosaurs, basal archosauriforms, and nonmammalian synapsids. Thickened domes encompassing most of the skull roof typify burnetiamorph and dinocephalian skulls, whereas other therapsid clades like dicynodonts and therocephalians sometimes developed more restricted bony protuberances on the nasal or maxilla. To begin assessing differences in the tissue construction and development of cranial bosses, we histologically sampled thickened cranial elements in burnetiamorphs and *Oudenodon* (Dicynodontia). We also compared the pachyostotic, or unusually thickened tissue from these skulls to similar regions of the nonpachyostosed skulls of a gorgonopsian and *Diictodon* (Dicynodontia). Our sample includes a juvenile burnetiamorph (estimated skull length = 10 cm), the postorbital region of *Diictodon* (estimated skull length = 14 cm), and fragmentary nasal bones from a gorgonopsian and *Oudenodon* of larger size (approximately 30 cm).
In thin section, dermal bones typically consist of two compact layers surrounding a cancellous interior, regardless of cranial element thickness. We found this same organization in dicynodont and gorgonopsian coronal sections. By contrast, the burnetiamorph skull consists of four histological zones that differ markedly from typical dermal bone construction. Here, much of the skull roof is made up of radial fibrolamellar bone. This predominantly woven-fibered tissue is highly vascularized, suggesting rapid cranial expansion. Radial fibrolamellar bone is also seen in rapidly expanding, juvenile pachycephalosaur skulls, which led us to expect it in *Oudenodon* nasal bosses. Instead, coronal thin sections of *Oudenodon* nasal bosses reveal an expanded cancellous interior with only a slightly thicker dorsal compact layer.
Differences in cranial boss structure and organization between *Oudenodon* and burnetiamorphs indicate at least two developmental pathways for cranial expansion. Radial fibrolamellar expansion convergently evolved in burnetiamorphs and pachycephalosaurs and affects suture morphologies such that they obliterate completely, in even a very small burnetiamorph. In *Oudenodon*, sutures remain open but are elongated due to cranial expansion. Future work should investigate whether sutures are obliterated or maintained in the thickened and ornamented skulls of other synapsids (e.g., dinocephalians).

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

THE POSTCRANIAL MORPHOLOGY AND PHYLOGENY OF TAENIODONTS (MAMMALIA: TAENIODONTA); DETERMINING LOCOMOTOR ADAPTATIONS IN PALEOGENE MAMMALS

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After the Cretaceous-Paleogene (K-Pg) mass extinction mammals, which originated during the Mesozoic, managed to survive and thrive. However, the tempo and mode of evolution for eutherians (placentals and close relatives) after the extinction are still unclear. An ideal group to investigate the post K-Pg evolution of mammals is the taeniodonts, as they are among the few taxa to purportedly cross the boundary. They then underwent a radiation in the early Paleogene and are defined primarily by their unusual dentition which is suited to chew an abrasive and tough diet. Ten genera of taeniodonts are currently recognized and are commonly arranged into two families. The Conoryctidae is usually considered to have a more generalized body plan while Stylinodontidae possess relatively extreme digging adaptations and more highly derived dentitions with enlarged canines. We conducted a phylogenetic analysis by applying parsimony and Bayesian techniques to a dataset of characters gathered from extensive observation of new specimens. We found limited support for the conoryctid-stylinodontid division and the genera *Conoryctes* and *Onychodectes* are placed as key basal taxa outside the clade of the more robust derived taxa (*Wortmania*, *Ectoganus*, *Psittacotherium*, *Stylinodon*). We then assessed postcranial bones to determine functional modes for taeniodonts and to test changes across phylogeny. Qualitatively, most taeniodonts, including *Onychodectes*, possess indicators of digging, i.e., a well-developed deltopectoral crest and broad distal end of the humerus for increasing flexion, pronation and supination, a long olecranon process of the ulna and enlarged manual unguals. Then we conducted quantitative multivariate analyses (linear discriminant analysis), using 9 forelimb linear measurements and 29 tarsal ones, comparing taeniodonts to a suite of extant mammals with known locomotor mode and other Paleogene taxa. Our results suggest *Onychodectes* to be terrestrial/semi-fossorial and comparable with the numbat (*Myrmecobius fasciatus*). *Ectoganus* and *Stylinodon* are semi-fossorial and fall out near the gopher, *Pappogeomys merriami* and the aardvark (*Orcyteropus afer*). Therefore, our study indicates that digging behaviors are ancestral for taeniodonts, and suggest that burrowing may have been integral to their survival across the K-Pg boundary and their subsequent radiation.

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Technical Session XVII (Saturday, October 12, 2019, 8:30 AM)

A NEW AND WELL-PRESERVED EARLY-DIVERGING ABELISAURID (THEROPODA: CERATOSAURIA: ABELISAUROIDEA) FROM THE EARLY LATE CRETACEOUS OF NORTHERN PATAGONIA

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Abelisaurid theropods were the most diverse and abundant medium-sized to large-bodied carnivorous dinosaurs in many Gondwanan and European paleoecosystems during the Late Cretaceous, frequently occupying the apex predator niche in these environments. Although several derived abelisaurids (e.g., the Patagonian brachyrostrans *Ekrixinatosaurus novasi*, *Skorpiovenator bustingorryi*, *Viavenator exxoni*, *Aucasaurus garridoi*, and *Carnotaurus sastrei* and the Madagascan majungasaurine *Majungasaurus crenatissimus*) are represented by well-preserved skeletons, earlier-diverging members of the

clade (e.g., the African *Kryptops palaios* and *Rugops primus*) are known from much less complete material. Consequently, the early evolutionary history of Abelisauridae remains poorly understood. Here we report a new taxon of medium-sized (body length ~5 m) basal abelisaurid collected from an exposure of the lowermost Upper Cretaceous (Cenomanian) Candeleros Formation in an area known as Aguada Pichana near the town of Añelo in Neuquén Province, northern Patagonia, Argentina. The new form is known from two individuals, one of which is represented by a largely complete, partially articulated skeleton (including much of an articulated skull and multiple teeth plus dorsal, sacral, and caudal vertebrae, dorsal ribs, hemal arches, a scapula, the forelimb lacking the manus, the pelvis, and several hind limb elements); the second individual is known only from a partial skull (consisting of the maxilla, lacrimal, jugal, quadratojugal, quadrate, pterygoid, ectopterygoid, palatine, and dentary with teeth). Notable osteological features include: (1) maxilla with 14 tooth positions (as in *Carnotaurus* and some generically unidentified abelisaurids but 3–5 fewer than in *Rugops*, *Skorpiovenator*, and *Majungasaurus*); (2) lacrimal with prominent anterior process; (3) postorbital with 'inflated' dorsal terminus and suborbital flange; (4) anterior caudal transverse processes with well-developed anterior projection at distal end; (5) humerus and metatarsals proportionally slender, recalling those of non-abelisaurid abelisauroids; and (6) radius and ulna ~34% length of humerus (proportionally longer than in *Aucasaurus*, *Carnotaurus*, and *Majungasaurus*). Phylogenetic analysis using two independent datasets recovers the new Candeleros form as a basal (i.e., non-brachyrostran, non-majungasaurine) abelisaurid. As such, the new taxon is herein regarded as the earliest-branching abelisaurid that is known from the greater part of the skeleton.

Technical Session I (Wednesday, October 9, 2019, 8:45 AM)

EARLY DISPERSAL FOR QUADRUPEDAL CETACEANS: AN AMPHIBIOUS WHALE FROM THE MIDDLE EOCENE OF THE SOUTHEASTERN PACIFIC

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Cetaceans originated in south Asia more than 50 Ma (early Eocene), from a small, four-limbed artiodactyl ancestor. Amphibious whales gradually dispersed westward along North Africa, eventually reaching North America before the end of the Lutetian (41.2 Ma). However, because the fossil record on both sides the Atlantic is fragmentary, when, through which pathway, and under which locomotion abilities these early whales made it to the New World remains debated.

Marine deposits dated to 42.6 Ma (Lutetian) from the locality of Playa Media Luna (Pisco Basin, coastal Peru) yielded the associated skeleton of a new protocetid cetacean, including mandibles, teeth, vertebrae, scapulae, pelvis, and many fore- and hind limb elements. The study of this unique material led to the description of a new genus and species *Peregocetus pacificus*. It constitutes the first indisputable quadrupedal whale skeleton described from the whole Pacific Ocean and Southern Hemisphere, possibly the geologically oldest from the Americas, and the most complete outside Indo-Pakistan.

Fused sacral vertebrae, the pelvis being firmly attached to the sacrum, an insertion fossa for the round ligament on the femur, fore- and hind limb proportions being roughly similar to geologically older quadrupedal whales from Indo-Pakistan, and the retention of small hooves with a flat anteroventral tip at fingers and toes indicate that *Peregocetus* was still capable of standing and even walking on land. Caudal vertebrae display bifurcated and anteroposteriorly expanded transverse processes, like those of semiaquatic mammals (e.g., marine sloth *Thalassocnus*, beavers, and otters). Although this feature suggests a more significant contribution of the tail during swimming (lift-based propulsion) than in geologically older protocetids, the large, most likely webbed feet bearing long toes indicate that strokes from hind limbs may also have contributed to underwater locomotion (drag-based propulsion), as in otters.

Sharing similarities with some western African protocetids, this new taxon from the Lutetian of the southeastern Pacific further supports the hypothesis that early quadrupedal whales crossed the South Atlantic from Africa to South America, and nearly attained a circum-equatorial distribution with a combination of terrestrial and aquatic locomotion abilities less than 10 million years after their origin in south Asia. Assisted by the paleo-South Equatorial Current, this westward oceanic migration was followed by a northward dispersal towards higher North American latitudes.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

ON THE HISTOLOGY AND DEVELOPMENT OF DINOSAURIAN POST-CRANIAL SKELETAL PNEUMATICITY

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At least since the 18th century it is known that diverticula of the air sacs – bellows-like protrusions of the lungs – penetrate and invade the avian skeleton, a process which is referred to as pneumatization. Similarly, also the morphological diversity of this post-cranial skeletal pneumaticity is relatively well understood on a comparative level. This, in fact, even extends to numerous non-avian dinosaurs, many of which also possessed pneumatized bones. Given the apparent functional importance and evolutionary significance of this trait – not only for extant birds, but rather for at least the entire lineage of saurischian dinosaurs – it is astonishing how little is known about the underlying mechanisms of pneumatization. Only very recent histological studies, for instance, revealed that pneumatized bones exhibit a characteristic osseous tissue: pneumosteum. Such pneumosteal bone is found in regions where the epithelium of the air sacs contacts the skeleton, is characterized as secondary trabecular or secondary endosteal bone containing numerous very fine fibers, and can be found both in extant birds as well as in non-avian dinosaurs. The aim of the present poster is to provide an overview of the histological characteristics of post-cranial skeletal pneumaticity, with a special focus on ongoing research on its developmental aspects, namely what happens when the air sacs first extend their diverticula into the bones in extant dinosaurs (i.e., birds). The poster furthermore intends to serve as a discussion forum on how this work can be expanded to extinct non-avian dinosaurs, in order to add an evolutionary dimension to understanding the origin and formation of post-cranial skeletal pneumaticity in general.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

A RE-EVALUATION OF 'FURO' MICROLEPIDOTES (NEOPTERYGII, HALECOMORPHI) FROM THE UPPER JURASSIC SOLNHOFEN ARCHIPELAGO OF GERMANY

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The extinct halecomorph fish genus *Furo* has long been recognized as a 'wastebasket taxon' into which a number of unrelated species of uncertain taxonomic and phylogenetic affinities have been thrown. This has become especially problematic among '*Furo*' from the Upper Jurassic plattenkalk regions of Germany (Solnhofen, Nusplingen) and France (Cerin), which include '*F.*' *longiserratus*, '*F.*' *latimanus*, '*F.*' *angustus*, '*F.*' *aldingeri*, '*F.*' *microlepidotes*, and *Ophiopsis* (formerly *Furo*) *muensteri*. Of these, '*Furo*' *microlepidotes* stands out as one of those most morphologically distinct from the type species (*Furo orthostomus* from the Lower Jurassic of southeastern England). Preliminary results appear to confirm speculation by previous authors that '*Furo*' *microlepidotes* is phylogenetically closer to Caturidae than it is to *Furo*. '*Furo*' *microlepidotes* is characterized by a slender, bar-like maxilla similar to that of caturids (*Caturus*, as exemplified by the type species *C. furcatus*, as well as *Amblysemius* and *Liodesmus*) in which the ventral dentigerous border is downturned and ventrally expanded posteriorly. Other characters that '*Furo*' *microlepidotes* shares with caturids include a large difference in size between the left and right parietals; well-developed sclerotic ring; deeply forked caudal fin with a symmetrical outline; and short splint-like supramaxilla occupying less than half the length of the maxilla. As in caturids, the maxilla in '*Furo*' *microlepidotes* lacks the broad triangular dorsal expansion and posteroventral extension observed in *F. orthostomus* and morphologically similar forms (such as *Furo normandica* and *Ophiopsis muensteri*). However, unlike caturids, '*Furo*' *microlepidotes* retains the more primitive halecomorph character of having ganoin-covered rhomboid scales, indicating a phylogenetically more basal position than other Caturidae. Preliminary results of phylogenetic analysis using PAUP place '*Furo*' *microlepidotes* at the base of Caturidae (including *Caturus furcatus*, *Amblysemius pachyurus*, and *Liodesmus gracilis*), within the Amiiforms (a clade that also includes the extant bowfin *Amia calva* and its extinct relatives); whereas *Furo orthostomus* and *Ophiopsis muensteri* are basal to *Ophiopsiella*. This reevaluation sheds new light on the taxonomy of '*Furo*' *microlepidotes*, distinguishing it from *Furo*. This study was supported by Volkswagen Foundation grant I/84 636 and by SYNTHESYS grant GB-TAF-950.

Grant Information:
This study was supported by Volkswagen Foundation grant I/84 636 and by SYNTHESYS grant GB-TAF-950.

Technical Session VI (Thursday, October 10, 2019, 9:45 AM)

ENDOCRANIAL SHAPE VARIATION WITHIN EUARCHONTOGLIRES USING 3D GEOMETRIC MORPHOMETRICS

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Landmark based 3D geometric morphometrics have been widely applied in analyses of skeletal morphological variation, with recent analyses successfully expanding their use to virtually constructed endocasts. This study examines endocranial shape variation within Euarchontoglires. Twenty-seven landmarks were captured for virtual endocasts produced from X-ray CT data for 130 extant members of Euarchontoglires: Scandentia (n = 14), Dermoptera (n = 2), Primates (n = 37), Lagomorpha (n = 10), and Rodentia (n = 67) and two primitive fossil primates (*Microsyops annectens*, *Ignacius graybullianus*). Principal Components Analyses on Procrustes shape variables indicate that phylogeny plays a major role in euarchontogliran endocranial shape variation. Principal Component (PC) 1 represents variation in the relative size of the neocortex and olfactory bulbs, and the degree of flexion of the endocast, with taxa at one extreme of this axis having a large neocortex, small olfactory bulbs, and a more flexed endocranium, and taxa on the other extreme having a small neocortex, large olfactory bulbs, and a less flexed endocranium. Within this sample, Primates plot in a distinct morphospace while Dermoptera, Scandentia, Lagomorpha, and Rodentia generally overlap. A subordinal pattern is identifiable within Primates across PC1, as the highly encephalized haplorrhines group near the extreme margin of this axis while strepsirhines plot near the centre, closer to the non-primates in the analysis. Principal Component 2 is associated with variation in the shape of the olfactory bulbs and the neocortex, with taxa at one extreme having short, narrow olfactory bulbs, and a maximum neocortical height located more rostrally, and taxa on the other extreme having longer, wider olfactory bulbs, and a maximum neocortical height located more caudally. All orders overlap across PC2.
The primitive fossil primates *M. annectens* and *I. graybullianus* plot at the extreme of PC1, on the opposite end of that axis from the haplorrhine primates. This is likely related to their shallow neocortices relative to paleocortices, and large olfactory bulbs, which is consistent with previous inferences about the importance of neocortical expansion and reduction in olfaction in primate brain evolution. This analysis provides a framework that can be used to identify morphological commonalities within Euarchontoglires to provide an approximation of what is primitive for the group, and to explore variation in both evolutionary and ecological contexts.

Grant Information:
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Technical Session XVII (Saturday, October 12, 2019, 8:45 AM)

A NEW DESERT-DWELLING NOASAURINE THEROPOD FROM THE CAIUÁ GROUP, CRETACEOUS OF SOUTH BRAZIL

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Noasaurines form an enigmatic group of small theropod dinosaurs known from the Late Cretaceous of Gondwana. They are relatively rare, with notable records only in Argentina and Madagascar, and more incomplete remains reported for Brazil, India, and continental Africa. In south-central Brazil, the Bauru Basin has yielded a rich fauna of terrestrial tetrapods, most of which is known from the fluvial deposits of the Bauru Group. The mainly aeolian deposits of the Caiuá Group, on the contrary, bear a scarce fossil record composed of rare lizards, turtles, and pterosaurs. We report here the first dinosaur of the Caiuá Group, which also represents the best-preserved theropod so far recovered from the entire Bauru Basin. The identified skeletal parts (vertebrae, girdles, limbs, and scarce cranial elements) show that the new taxon was just over 1 m long, with unique anatomical traits among theropods. Metatarsals II and IV have very lateromedially compressed shafts, as are the blade-like ungual phalanges of the respective digits. This implies that the new dinosaur could have been functionally monodactyl, with a main central weight-bearing digit, flanked by neighboring elements positioned very close to digit III or even held free of the ground. Such anatomical adaptation is formerly unrecorded among archosaurs, but was previously inferred from footprints discovered during the 1970s in the same beds that yielded the new dinosaur. A phylogenetic analysis nests the new taxon within Noasaurinae, which is unresolved because of the multiple alternative positions that *Noasaurus leali* can take. The exclusion of that taxon results in positioning the new dinosaur as the sister-taxon of the Argentinean *Velocisaurus unicus*.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 11:15 AM)

DEVELOPING A NEW HABIT: ONTOGENY TRACKS THE EVOLUTION OF FILTER FEEDING IN BALEEN WHALES

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Baleen whales (Mysticeti) represent an excellent candidate for integration of a developmental perspective in the study of macroevolutionary transitions. They possess a detailed fossil record that tracks the transition from tooth-bearing taxa, best adapted to raptorial feeding, to the modern toothless whales, which use keratinous structures called baleen to filter feed. Remnants of their toothed ancestry are preserved in the development of living species, such as the presence of unerupted tooth germs that are replaced by baleen plates before birth. However, the influence of ontogenetic changes on the evolution of skull adaptations related to filter feeding in Mysticeti has yet to be tested. This study aims to highlight how shifts in developmental timing of anatomical features, such as teeth and baleen, and in skull growth rates in modern taxa are related to the evolution of filter feeding.
Using CT scanning, morphological data were collected to qualitatively describe the developmental changes in skull anatomy of prenatal specimens of living species of Mysticeti. Adult specimens of fossil stem-mysticetes, representing major steps in the transition from raptorial to filter feeding, were then added to this dataset and variation in skull shape was quantitively analyzed using 3D geometric morphometrics. Results show that toothed stem-mysticetes share similar rostral and braincase shape with neonatal and late fetal specimens of modern taxa. This suggests that living species go through additional ontogenetic steps compared to their ancestors to obtain their distinctive head shape, such as an elongated rostrum and marked overlapping of the neurocranial bones (telescoping). As early diverging toothless specimens possess a long rostrum but lack complete telescoping, it can be inferred that the rostrum increased the tempo of its development before the braincase, resulting in different rates of shape evolution in these two skull components. This is mirrored by the relatively divergent growth patterns of these regions observed in the ontogeny of living species. The progressive replacement of teeth with baleen might have also been caused by a gradual acceleration of developmental rate of these features.
This study presents the first hypotheses regarding the developmental processes driving the evolution of feeding adaptions in baleen whales. Incorporating more fossil taxa and closely related toothed whales in future studies will allow to test of these conclusions and broaden the understanding of how ontogeny shaped the evolution of this lineage.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

ONTOGENETIC CHANGES IN THE WOOLLY MAMMOTH (*MAMMUTHUS PRIMIGENIUS*)

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The woolly mammoth, *Mammuthus primigenius*, is a well-known late Quaternary proboscidean found throughout northern North America and Eurasia. Many well-preserved remains have been found and described. This study seeks to identify ontogenetic changes in the woolly mammoth through a quantitative cladistic analysis. Previous studies of woolly mammoth ontogeny have limitations, as they have not used rigorous statistical analyses or they have only examined a specific area of the skeleton. 10 specimens described in the literature were coded for their state of epiphyseal fusion, dental stage, and fusion of the radius with the ulna. This was then analyzed using PAUP to generate a strict consensus of 27 trees with a length of 45, a CI of 0.9556, an HI of 0.0444, an RI of 0.9444, and an RCI of 0.9025. Six growth stages were identified in the strict consensus tree, with stage one defined by the presence of dp2 teeth, the presence of dp3 teeth, and the presence of deciduous tusks; stage two by the removal of dp2 teeth, the removal of deciduous tusks, the presence of dp4 teeth, and the presence of unerupted permanent tusks; stage three by the removal of dp3 teeth, the

presence of m1 teeth, the presence of m2 teeth, and the eruption of permanent tusks; stage four by the removal of dp4 teeth, the removal of m1 teeth, the presence of m3 teeth, and the fusion of the epiphyses of the distal end of the humerus, proximal end of the tibia, and distal end of the tibia; stage five by the fusion of the epiphyses of the proximal end of the ulna, and the distal end of the femur; and stage six by the removal of m2 teeth, and the fusion of the epiphyses of the proximal end of the femur, distal end of the radius, distal end of the ulna, proximal end of the humerus, and proximal end of the scapula. This data is consistent with the current literature on woolly mammoth dental progression and epiphyseal fusion and shows that the epiphysis of the proximal end of the scapula fuses at the final growth stage, which was not included in previous research on epiphyseal fusion in the woolly mammoth.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A SMALL THEROPOD TOOTH ASSEMBLAGE FROM THE ST. MARY RIVER FORMATION OF SOUTHERN ALBERTA, CANADA: IMPLICATIONS FOR IDENTIFYING ISOLATED THEROPOD TEETH AND NORTH AMERICAN THEROPOD BIOGEOGRAPHY

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The St. Mary River Formation at the Scabby Butte locality is significant in being one of three formations preserving latest Campanian to Early Maastrichtian terrestrial vertebrate assemblages in Canada. Since the initial description of the assemblage, new material has been collected from the locality, and a greater understanding of the systematics of theropod teeth in North America now allow for a redescription of the material and a revision of the theropod taxa present in the assemblage. To identify the teeth, comparisons were made to other well-sampled small theropod tooth assemblages in Alberta. Linear discriminant analysis of small theropod teeth from the Horseshoe Canyon and Dinosaur Park formations show that teeth differ morphologically between the units, with varying degrees of quantitative morphological overlap, indicating that isolated teeth can be identified in some instances. Morphologic comparisons between these units with the specimens from the St. Mary River (in southern Alberta) and Wapiti (in northern Alberta) formations show notable biogeographic differences between species present. In both the troodontid and dromaeosaurine comparisons, the St. Mary Formation theropod teeth were consistent with those in the Horseshoe Canyon Formation, likely *Albertavenator curriei* and an unnamed dromaeosaurine. However, both saurornitholestine and avialan teeth from the St. Mary River Formation were consistent with teeth from the younger Dinosaur Park Formation rather than the Horseshoe Canyon Formation, representing *Saurornitholestes* rather than *Atrociraptor* and bird teeth not present in the Horseshoe Canyon Formation. The Wapiti Formation teeth, in contrast, were entirely consistent with the penecontemporaneous Horseshoe Canyon Formation. This suggests diachronous species turnover of small theropod dinosaurs in the latest Campanian of western North America, with some elements of more archaic assemblages persisting further south.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

OBSERVATIONS ON THE MESOZOIC CHIMAEROID, *ELASMODECTES* NEWTON 1878

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The purpose of this study is to elucidate the morphology and soft tissue anatomy of the Mesozoic chimaeroid, *Elasmodectes*; a genus originally raised for *E. willetti* from the Cenomanian of southern Britain. Since the original description, a total of 7 species have since been identified, ranging in age from the Aalenian (Middle Jurassic) to Maastrichtian (latest Cretaceous). *Elasmodectes* is mostly known from isolated cutting toothplates and incomplete specimens with calcified cartilage and dorsal fin spines. However, complete and fully articulated specimens are recorded from the Late Jurassic of Eichstätt (Germany) and Late Cretaceous of Jebel Tselfat (Morocco).

Around 20 holomorphic specimens of *Elasmodectes* are known, but two exceptionally well-preserved specimens; *E. avitus*, LF 2322, housed in the Lauer Foundation Collection (Chicago, U.S.A.) and *E. willetti*, NHMUK PV P73270 (Natural History Museum, London, U.K.) are the focus of the present study and show soft tissue preservation. The former is of interest since it appears to be a rare male individual. The latter is the only holomorphic chimaeroid so far recorded from Africa.

Both species are known from anoxic deposits which have allowed outlines, cartilages and soft tissue preservation. From these two specimens, it is obvious that *Elasmodectes* possessed a fusiform body outline, with a single characteristic fin spine supporting the dorsal fin, and long median fins. The tail is homocercal with expanded dorsal and ventral lobes, in contrast to the long, whip-like condition in Recent genera. The sensory canal system is represented by articulated lengths of semi-circular cartilage rings and circular calcifications are present in the notochordal sheath. Elements of the musculature are present in both specimens; phosphatised representations of myotomic muscle fibre blocks, arranged in a zig-zag pattern, can be clearly distinguished, as can occasional parts of the dorsolateralis musculature. The sectorial dentition comprises paired vomerine tooth plates, together with labio-lingually compressed mandibular and palatine tooth plates with beaded tritors along the crest of the occlusal surface. The frontal tenaculum in *E. avitus* is relatively long, compared to those in Recent chimaeroids, with a spatulate proximal end and an armature of posteriorly-directed denticles distally opposite a number of frontal denticles on the head forming a "tenacular complex". The scroll-like pelvic clasper is preceded by a triangular pre-pelvic tenaculum.

Grant Information:
RFBR 18-05-01045 (to EVP)

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

A COMPARISON BETWEEN THE EDUCATIONAL OUTREACH PROGRAMS DEVELOPED BY THE LAUER FOUNDATION, CHICAGO, U.S.A. AND THE FOSSIL FISH SECTION OF THE NATURAL HISTORY MUSEUM, LONDON, U.K.

LAUER, Rene L., Lauer Foundation PSE, Wheaton, IL, United States of America; BERNARD, Emma L., The Natural History Museum, London, U.K. , London, United Kingdom; WARD, David J., The Natural History Museum, London, U.K. , LONDON, United Kingdom; LAUER, Bruce H., Lauer Foundation PSE, Wheaton, IL, United States of America; WARD, Alison E., The Natural History Museum, London, U.K. , LONDON, United Kingdom

The Lauer Foundation (LF) curates and provides permanent access to the Foundation's collections of scientifically important paleontological specimens and provides educational outreach programs to schools (grades 2-7). The public Earth Science educational outreach programs are customized to fit the audience.

The Natural History Museum, London (NHMUK) attends fossil festivals with scientific staff and volunteers where members of the general public can interact with scientists and participate in enrichment activities.

Both the LF and NHMUK programs provide hands-on learning experiences to people who do not normally have access to fossil specimens or visit museums. The programs are designed to be fun and engaging but also to inform, educate and provide interaction. Their aim is to supplement and complement the educational curriculum. As people learn differently, the use of visual, auditory and tactile teaching methods are utilized. Accommodations are made to facilitate those with special educational needs and disabilities.

Both the LF and NHMUK have found that hands-on experiences and visual aids are beneficial in order to increase the comprehension of unfamiliar concepts such as stratigraphy, deep time, fossilization and index fossils. Both provide program content designed to demonstrate why scientific data is important and how it is utilized. In addition, handouts and labeled specimens help to reinforce the retention of program information.

The LF and NHMUK differ in terms of student participation. The LF programs are presented primarily in schools as either a supplement to the curriculum, or as an enrichment program. Therefore, a more visually engaging, interactive experience is required to differentiate it from their regular classrooms. In contrast, NHMUK's participants at fossil festivals chose to participate, often returning yearly and relish the opportunity to meet and talk to experts.

Post activity reflections via self-critiques, reference to learning outcomes and participant feedback are utilized to measure effectiveness of the program and refine it as needed. This valuable data identifies what was learned and what they most enjoyed from the program.

Both the LF and NHMUK provide an opportunity for children and the general public to engage in an interesting, fun, interactive learning experience to improve their understanding of the importance of science and how it applies to the past, present and future of the world. Forging a connection with young people and the community is vital for support of science initiatives.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

COMPARATIVE ANALYSIS OF PARALOID B-72 AND BUTVAR B-76 DISSOLVED IN ACETONE SOLUTIONS

LAUTERS, Brian A., South Dakota School of Mines and Technology, Rapid City, SD, United States of America

Despite the incredible importance of solution adhesives and consolidants in the preparation and conservation of fossil material, very little empirical work has been done to compare the effectiveness of one brand of polymer over the other. It is currently unknown if there is an advantage to using Paraloid B-72 or Butvar B-76 polymers dissolved in acetone in any given situation. Current anecdotal knowledge holds that low viscosity, low concentration consolidants will have better penetrative and consolidative capabilities than a high concentration, high viscosity consolidant, and Paraloid has superseded the use of Butvar B-76 in many institutions. The results of this experiment should help preparators and fossil conservators choose which polymer-based solution adhesive/consolidant to use in a given situation.
In order to compare the penetrative and consolidative capabilities of these two solution adhesives/consolidants, 20ml treatments of each adhesive/consolidant prepared in varying concentrations using the weight by volume method and were applied to 200ml well sorted sand samples in varying concentrations, and the effectiveness of each consolidant was determined by directly comparing the results of volumetric, resistivity, and diffusion measurements. After the experimental data was collected, it was analyzed using the statistical program PAST.
Qualitative analysis of the data confirmed the expected results that of Paraloid B-72 in low concentrations (5, 10, and 15%) showed greater penetration and mass consolidated than Paraloid B-72 in high concentrations (40, 45, and 50%) and Butvar B76 (in 5%, 10%, and 15% solutions). Statistical analysis using Kruskal-Wallis and Dunn's Post Hoc tests confirmed the initial analysis, but also showed that high concentration Paraloid B72 showed no significant difference from the Butvar B-76 test group.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ENGAGING THE PUBLIC WITH SMALL VERTEBRATE FOSSILS AND UTILIZING CITIZEN SCIENCE TO MAXIMISE SCIENTIFIC DISCOVERY AT CAPRICORN CAVES, CENTRAL EASTERN QUEENSLAND, AUSTRALIA

LAWRENCE, Rochelle A., Queensland Museum, Brisbane, Australia; HOCKNULL, Scott, Queensland Museum, Brisbane, Australia

The Capricorn Caves (CC) Fossil Open Day is a paleontologically-themed citizen science event that engages the public in an authentic program of scientific exploration. This program focuses on the fossil record of The Caves region near Rockhampton, central eastern Queensland, Australia, connecting the tourism industry with scientists and the public with science. CC is the only privately owned cave system in Australia, and is positioned as a coastal gateway to Queensland's 'Dig the Tropic' geo-tourism trail, linking regional communities to more science-based programs. These experiences are unique because they occur in direct context of the original natural history resource, the caves. CC is also the only accessible cave system in Australia to showcase a series of fossil deposits representing different paleoenvironments, transitioning from rainforests (>500 kya) to xeric habitat (<280 kya) and into the present-day vine thicket refugia, all of which have been influenced by environmental changes, both climatic and human induced. While the deposits preserve a unique suite of extinct species, including megafauna, the fossils themselves are small. Unlike large dinosaur bones, the interpretation of these small fossils has overcome the challenges of being both hard to find and see with the use of 3-D technology and tactile display. These small fossils tell extraordinary stories that transpire into discussions focused on modern issues facing the public today, with species and habitats under threat from climate change and human impact. The collaboration between CC and scientists has allowed these ongoing research projects, and their results, to be directly incorporated into guided tours, community programs and events. By working with Queensland Museum and National Parks and Wildlife, nearby salvaged cave fossil deposits have also been made accessible for supervised citizen science programs at CC. The annual, free event invites the public to become citizen scientists for the day and literary literally get their hands dirty as they experience the excitement of scientific discovery by working with real fossils from unprocessed deposits. Over 3000 participants, annually, have sorted through tonnes of fossil-rich cave sediment, adding new specimens and species to an evolving map of northern Australia's unique fauna. In this case, citizen science is covering more ground and speeding up the process of discovery. This experience also supports open science, and creates positive and immediate engagement between scientists and the public.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

LOST IN SPACE AND TIME: NEW QUATERNARY SMALL VERTEBRATE RECORDS FROM THE FITZROY RIVER BASIN OF TROPICAL QUEENSLAND, AUSTRALIA

LAWRENCE, Rochelle A., Queensland Museum, Brisbane, Australia; HOCKNULL, Scott, Queensland Museum, Brisbane, Australia; CRAMB, Jonathan, Queensland Museum, South Brisbane, Australia

New Quaternary-aged deposits within the Fitzroy River Basin (FRB) of tropical Queensland, Australia preserve an exceptionally diverse faunal record. The FRB is both the largest river system to drain Australia's east coast and the largest water catchment to flow into the Great Barrier Reef lagoon. These new sites within the FRB include deposits formed in closed-cave systems near the Fitzroy River mouth at Capricorn Caves, The Caves Region, near Rockhampton and open-alluvial sites at the northern-most headwaters of the catchment at South Walker Creek Coal Mine (SWC), near Nebo, west of Mackay. This paleobiogeographic study between The Caves region and SWC compares the distribution and diversity of fauna through space and time within the FRB to determine the relative impacts of past environmental changes across the catchment. Although all fauna are used, small-sized mammals are the focus, including members of Petauroidea (Petauridae, Acrobatidae and *Petauroides*), in determining their usefulness as proxy indicators of paleoecology. At Capricorn Caves, the new faunal assemblages indicate two paleoenvironments that correlate with dated faunas from nearby Mount Etna Caves National Park. One deposit is characterised by a distinctive rainforest fauna and is estimated to be older than 280 kya based on biocorrelation with Mount Etna sites. Some taxa are closely related to living species now only found in tropical rainforests of New Guinea, while many are new extinct species. The other deposit is estimated to be less than 280 kya, representing a period of time when rainforests were driven locally extinct and replaced by a mostly xeric-adapted fauna. These new deposits expand the only Quaternary record of Australian rainforest species and provide the most easterly records of some xeric-adapted species. The northern SWC localities preserve the remains of a unique suite of Late Pleistocene tropical megafauna along with small aquatic and terrestrial fauna. The small fauna includes a probable new species of bettong (*Bettongia* sp.) and several dry-adapted species (e.g., *Notomys* sp.). Together, these new records demonstrate a diversity of small faunal species across the FRB throughout the late Quaternary that are now either locally or entirely extinct. These changes in species level diversity and paleobiogeography since the Middle Pleistocene provide additional evidence for major periods of faunal turnover and extinction in northern Australia.

Technical Session XII (Friday, October 11, 2019, 11:30 AM)

MORE THAN *MINMI*: A NEW AUSTRALIAN ANKYLOSAURIAN DINOSAUR FROM THE LOWER CRETACEOUS (ALBIAN) OF QUEENSLAND, WITH IMPLICATIONS FOR UNDERSTANDING GLOBAL THYREOPHORAN DIVERSITY.

LEAHEY, Lucy G., The University of Queensland, Brisbane, Australia; MOLNAR, Ralph E., University of California, Berkeley, CA, United States of America; SALISBURY, Steven W., The University of Queensland, Brisbane, Australia

Gondwanan ankylosaurian research has been conceptually dominated by the genus *Minmi.* Subsequent to the description of *Minmi paravertebra* in 1980, all ankylosaurian material from Queensland has provisionally been placed within this genus. However, the description of the Richmond ankylosaur (formerly *Minmi* sp.) and the erection of *Kunbarrasaurus ieversi* to encompass it, as well as the recent discovery of ankylosaurian material from the Upper Cretaceous part of the Winton Formation, indicates that there is more to the diversity of Queensland ankylosaurs than just *Minmi.* In 1994, another partial ankylosaurian dinosaur skeleton was discovered and informally assigned to *Minmi* pending a detailed description. Collected from the Albian Toolebuc Formation, northeast of Julia Creek in north-western Queensland, this specimen represents the second most complete ankylosaurian specimen from Gondwana. It comprises the axial elements of the trunk, parts of the pectoral and pelvic girdles, fore- and hindlimbs, as well as the cranial part of the tail. The preservation of the specimen is similar to the holotype of *K. ieversi*, in that ossified tendinous elements as well as in-situ dermal elements are fossilized. Comparisons with other ankylosaurians indicate that the specimen represents a new taxon that can be distinguished from both *Minmi* and *Kunbarrasaurus* based on the morphology of elements within both the body and dermal skeletons. Notably, the specimen lacks paravertebral elements. The new taxon is of comparable size to both *M. paravertebra* and *K. ieversi,* and, also in common with both the latter taxa, has a relatively simple dermal skeleton. Phylogenetic analysis indicates that like *M. paravertebra* and *K. ieversi*, the new taxon is a basal ankylosaurian.

Chronologically, it is older than *K. ieversi* but younger than *M. paravertebra. Minmi* has often been regarded as a 'relictual' taxon. However, evidence for a greater diversity of thyreophorans in Australia, and thus Gondwana, is not unexpected when earlier records of thyreophorans from the Lower Cretaceous (Broome trackways, WA; isolated material, VIC) and Middle Jurassic (Balgowan trackways, QLD) are considered. The discovery and description of any new thyreophoran material from Australia has the potential to significantly alter our understanding of the taxonomic diversity of the continent's dinosaurian fauna, as well as the latent diversity of Gondwanan thyreophorans with implications for understanding global thyreophoran evolution, diversity and paleobiogeography.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

USING FOSSILS TO UNDERSTAND THE IMPACTS OF CLIMATE CHANGE ON HERPETOFAUNA IN CENTRAL TEXAS

LEDESMA, David T., University of Texas, Austin, TX, United States of America; KEMP, Melissa, The University of Texas at Austin, Austin, TX, United States of America

Relatively little is known about the magnitude of climate change's impact on extant herpetofaunal populations over long timespans, due in part to challenges in conducting the necessary long-term ecological studies. Paleontological evidence can address the need for long-term data by extending our temporal study interval to investigate the responses of biota to climate change over long timescales. Here, I use fossils from Hall's Cave, located on the Edward's Plateau in Kerr County, Texas, to reveal changes in the herpetofauna during the late Quaternary. Hall's Cave represents an excellent locality for studying late Quaternary biota as it has an abundant amount of fossil material, a relatively continuous stratigraphic sequence encompassing the last 20,000 years, and numerous radiocarbon dates distributed throughout the sequence. I assembled a count of the minimum and maximum number of individuals for different reptile and amphibian taxa within 5-centimeter intervals. My preliminary results show an overall correlation between the maximum and minimum abundance metrics during the last 3,500 years suggesting that the two are in accordance with one another. A correlation was found between the abundances of frogs, snakes, and lizards through time. Abundances of these taxa have a peak at 2,000 years ago, corresponding to wetter and cooler conditions as indicated by existing paleoclimate reconstructions from other north-central Texas localities. Herpetofaunal abundances decrease after 1,500 and between 2,500-3,500 years ago, which correspond to a warmer and drier time intervals, according to published speleothem records. These preliminary results suggest that changes in herpetofaunal abundances from Hall's Cave may reflect responses to climatic change. My ongoing research provides insight into the changes experienced by Texas' herpetofaunas during the late Quaternary and contributes to our understanding of the impacts of climatic change on extant and fossil biota.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

A NEW HALSZKARAPTIRINE FROM THE BARUUNGOYOT FORMATION OF MONGOLIA: PRELIMINARY DESCRIPTION AND PHYLOGENETIC ANALYSIS

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The Halszkaraptorinae is a recently erected subfamily of the Dromaeosauridae and comprises only three known taxa from the Late Cretaceous of Mongolia. They have been interpreted as semiaquatic animals based on extremely long necks, forelimbs possibly capable of swimming, and relatively short tails. The paleoecology of halszakaraptorines is thus different from other non-avian maniraptorans. Despite their unusual characters, however, it has been very difficult to study these dinosaurs due to their rare fossil record. In addition, only *Halszkaraptor escuilliei* is represented amongst halszkaraptorines by a nearly complete skeleton. A new halszkaraptorin specimen from the Baruungoyot Formation of Mongolia was found at Hermiin Tsav during the Korea-Mongolia International Dinosaur Expedition (KID) in the southern Gobi Desert in 2008. It is a nearly complete skeleton with a skull. The specimen is only slightly smaller than the holotype of *H. escuilliei*. The new specimen (KID275) has synapomorphies of dromaeosaurids such as an elongate pre-antorbital part of the maxilla, cheek teeth with concave posterior margins; subparallel dorsal and ventral margins of the dentary; ginglymoid distal ends of metatarsals II and III, and a short and stout pedal phalanx II-1. It is further diagnosed as a halszkaraptorine by a long neck, horizontal zygapophyses; prominent zygodiapophyseal laminae of the proximal caudal vertebrae, and because the shaft of metacarpal III has a similar mediolateral width as that of metacarpal II. KID275 is distinguished from other halszkaraptorines by the following set of characters: premaxilla has an anterodorsal depression at the anterior end, the internarial process of the premaxilla overlies the nasal, there are more than 12 premaxillary teeth, the external naris is anteroposteriorly elongate, there is a sinusoid suture between the frontal and parietal, none of the cervical vertebrae have pleurocoels, each anteroposteriorly expanded proximal chevron articulates with most of the length of each centrum, and the proximodistally elongate pedal phalanx IV-1 exceeds the length of pedal phalanx II-1. Our phylogenetic analysis recovered KID275 as the basalmost halszkaraptorine. Investigation of the paleobiology of KID275 will provide clues to better understand how halszkaraptorines lived and diversified.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE FIRST CHORISTODERAN TRACKWAY?

LEE, Yuong-Nam, Seoul National University, Seoul, Korea, Republic of (South); KONG, Dal-Yong, National Research Institute of Cultural Heritage, Daejeon, Korea, Republic of (South); JUNG, Seong-Ho, National Research Institute of Cultural Heritage, Daejeon, Korea, Republic of (South)

The fossil record of choristoderes shows the highest diversity in the Early Cretaceous of eastern Asia, especially in China as well as in Japan and Mongolia, suggesting that these regions including Korea were an important center for choristoderan evolution. While abundant crocodyliform tracks have been reported in the Jurassic and Cretaceous in the world, however, there is no single report thus far on the choristoderan tracks. Recently, a new quadrupedal trackway with hetropody was discovered in the Daegu Formation (Albian, Early Cretaceous), Ulsan City, South Korea. It consists of nine manus-pes sets of footprints. The manus tracks are pentadactyl, digitigrade with slender and slightly recurved digits. Their length and width are 29.4 mm and 53.0 mm on average, respectively. Five manual digits are separated from the proximal base and terminating in claws. Digits I and V are opposed with more than 180° and are oriented anteromedially and posterolaterally, respectively with respect to the trackway axis. The fourth digit is the longest, being ectaxonic. All manus tracks are located medially in front of pes tracks. The pes tracks are also pentadactyl with opposed digits I and V. They are plantigrade with slender digits with claw marks. Digit III and IV imprints are much longer than digit II imprint and the digit I imprint is the shortest, being distinctly ectaxonic. There is an indication of webbing between the pedal digits. The elongate heel is oval and almost symmetrical with respect to the central axis of the foot. The average length and width of the pes footprints are 98.8 mm and 69.3 mm, respectively. There is no belly mark nor tail trace. Although seven choristoderan genera were reported in the Early Cretaceous of Asia, well-preserved hands and feet are known only in *Hyphalosaurus* and *Monjurosuchus* among them. While long-necked and fully aquatic *Hyphalosaurus* inhabited exclusively in deep water lakes, short-necked and semiaquatic *Monjurosuchus* lived in a more shallow water ecosystem. New quadrupedal tracks are fairly well matched with foot skeletons of *Monjurosuchus* such as the hind foot much larger than the forefoot, long metatarsals, the shortest pedal digit I with similar length of digits III and IV, webbed hind feet, and the hindlimb much longer than the forelimb. In addition, the average of glenoacetabular length of the trackway is 228.8 mm, which is concordant with the body size of *Monjurosuchus* whose snout-vent length is up to 300 mm. Therefore, Ulsan new trackway could be made by a *Monjurosuchus*-like choristoderan.

Grant Information:
The National Research Foundation of Korea (grant number 2016R1A2B2015012)

Technical Session XX (Saturday, October 12, 2019, 1:45 PM)

USING TRABECULAR ANISOTROPY TO DETERMINE THE POTENTIAL FOR WALKING LIMBS IN A DIVERSE ARRAY OF EARLY TETRAPODS FROM BLUE BEACH, NOVA SCOTIA

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A historical explanation of the fin-to-limb transition suggested fish moving across land to get from one drying pool of water to another drove the evolution from aquatic to terrestrial lifestyles. However, it has become clear that digits likely arose well before the transition into terrestrial environments. Previous research on terrestriality has focused on descriptions of external limb and cranial morphology, but few have examined microanatomy to determine whether limbs could bear the animal's weight on land. Those that did studied internal bone structure focused on the midshaft profile created from a single histological slice of a long bone, which does not reflect the full extent of directional forces that may act on a bone. This study uses the entire 3D volume of trabecular (spongey) bone in long bones of early tetrapods to test if bone microstructure reflects forces associated with aquatic or terrestrial locomotion.

Long bones remodel in response to intermittent loading; here we look specifically at how trabecular bone structurally aligns with the forces acting on the bone. Anisotropy, a measure of structural organization, is analyzed from the trabecular bone to infer the location, orientation, and potentially strength of intermittent forces from musculature or gravity. The limb bones used in this study come from Blue Beach Nova Scotia, an early Tournaisian locality with a diverse array of early tetrapod bones thought to include both aquatic and terrestrial tetrapods. We expect this diversity to include bones with low anisotropy as expected in aquatic animals, and high anisotropy as in terrestrial long bones.

Bones representing all available tetrapods from this locality display low anisotropy in the trabecular region, in contrast with predictions derived from taxonomy and morphological proxies. Areas of higher organization are scattered throughout the trabecular bone closest to the compact bone layer, but these few anisotropic regions are small, suggesting that forces acting on the bone were weak and not constrained to specific areas. We conclude that a greater variety of tetrapods from the earliest Carboniferous than previously thought had limbs better adapted to an aquatic rather than terrestrial lifestyle, further supporting the idea that limbs evolved in an aquatic context for a prolonged period and the fin-to-limb transition is not contemporaneous with the water to land transition.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

DENTAL TOPOGRAPHIC CHANGE AND DIETARY INFERENCE IN *HOMUNCULUS PATAGONICUS* AMEGHINO, 1891 (MAMMALIA: PRIMATES)

LI, Peishu, Duke University, Durham, NC, United States of America, 27708; MORSE, Paul E., Duke University, Durham, NC, United States of America; KAY, Richard F., Duke University, Durham, NC, United States of America

Molar occlusal surfaces in extant primates correspond with the physical properties of food items those teeth are most efficient at chewing. Insectivores and folivores generally have molars with long shearing crests and tall cusps for slicing tougher foods; frugivores have molars with blunt cusps for better crushing and grinding performance. Dental topographic metrics are homology- and landmark-free methods that measure functionally relevant qualities of the tooth crown, such as sharpness (Dirichlet normal energy [DNE]), complexity (orientation patch count rotated [OPCR]), and relief index (RFI). These metrics are ideal for comparison of worn teeth—the most common element in the mammalian fossil record—both within and between taxa. A recent analysis of DNE in the extant folivorous platyrrhine *Alouatta* found that this species increases occlusal sharpness as the teeth wear, whereas sharpness was maintained but did not increase with wear in the frugivore *Ateles*. This diet-specific modality of dental macrowear offers a novel pathway to interpret primate dietary ecology in the fossil record.

Homunculus patagonicus is a stem platyrrhine from the Early Miocene, high-latitude Santa Cruz Formation, Argentina. Prior analysis of shearing quotient in *Homunculus* suggested a mixed diet of fruit and leaves, but its heavy postcanine tooth wear and large root size are more similar to extant folivorous platyrrhines. We measured DNE, OPCR, and RFI in 21 μCT-generated 3D digital models of variably-worn first and second lower molars of *Homunculus*, and compared them with the wear series of *Alouatta* and *Ateles*.

DNE, OPCR and RFI do not vary significantly between *Homunculus* M_1 and M_2 (Mann-Whitney U test $p > 0.05$). DNE and OPCR of unworn *Homunculus* molars are more similar to those of *Alouatta* than *Ateles*. However, *Homunculus* DNE does not change significantly with macrowear, and was statistically indistinct from the relationship between crown sharpness and wear observed in *Ateles* (ANCOVA $p = 0.238$) vs. a significant difference from that in *Alouatta* (ANCOVA $p < 0.001$). As in *Ateles*, OPCR of *Homunculus* has a significant positive linear relationship with macrowear ($p = 0.009$), whereas no significant linear correlation was observed between OPCR and macrowear in *Alouatta*. Despite the folivore-like topography of unworn *Homunculus* molars, wear-induced changes in crown sharpness and complexity are more consistent with a frugivorous diet. The degree and pattern of wear observed in *Homunculus* is consistent with a primarily frugivorous diet with leaves as a fallback resource.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

LOCOMOTIVE IMPLICATIONS OF THE 7.4 MA HIPPARIONINE FOSSILS FROM THE MIDDLE REACHES OF THE YELLOW RIVER AND THEIR PALEO-ECOLOGICAL SIGNIFICANCE

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The Late Miocene landscape in the middle reaches of the Yellow River was deemed to be an arid and semiarid grassland or steppe, which is analogous to that of the African savannah. This view contradicts the mainstream recognition regarding the paleoecology of the Loess Plateau. The ecomorphology of fossil equids plays an important role in paleoecological and paleogeographic interpretations, particularly through locomotive function. The morphologies of the 7.4 Ma hipparionine fossils (*Hipparion chiai*) from the Lamagou Fauna in northern Shaanxi reveal "pristine" features; however, the limb bones indicate that their motor abilities were adapted to an open environment. By comparing this finding with the Neogene paleozoogeographical boundary of northern China, we conclude that the Lamagou Fauna inhabited a temperate steppe. However, *H. chiai* should be a grassland dweller that was adapted to open habitat.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

SKULL REMAINS OF A SMALL FELINE (CARNIVORA, FELIDAE) FROM THE LATE MIOCENE DEPOSITS OF LINXIA BASIN (GANSU PROVINCE, CHINA)

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The Linxia Basin of Gansu Province, in northwest China, is notably enriched with abundant and well preserved Late Cenozoic fossil mammals. Among them, numerous materials of felids have been discovered from the "red clay" deposits of the late Miocene Liushu Formation. After preliminary identification, at least five genera have been recognized, including large-sized *Machairodus*, *Paramachaerodus*, *Metailurus*, medium-sized *Yoshi*, and small-sized *Pristifelis*. Here we report two almost complete skulls of caracal-sized feline from the upper Miocene deposits of the Linxia Basin. They are attributed to *Pristifelis attica* (Wagner 1857) based on the size and several cranial and dental characters. While skulls, dental and postcranial elements of *P. attica* have often been reported from Turolian localities in Spain, Greece, Turkey and Iran, the new fossil skulls represent the first discovery of *P. attica* from the Linxia Basin. They provide supplementary information to this species and further illustrate its morphological variability, as referred to the presence of P2, the mesial cusp on P3 and ectostyle on P4. In addition, personal observations on other late Miocene materials previously reported as *Felis* sp. from China confirm the existence of *P. attica* in Shanxi Province. The fossil records of *P. attica* indicate that it is a widespread late Miocene small felid, who has an almost continuously distribution in paleogeography, probably spread from the whole southern Europe to the eastern Asia and could inhabit various environment like the living species *Felis sylvestris*.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

BRAZILIAN CRETACEOUS FISHES DISTRIBUTION SHED LIGHT ON ECOSYSTEMS IN THE WESTERN GONDWANA

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In north-eastern South America, the biogeographical history of Gondwana has been directly affected by the formation of the South Atlantic and Equatorial oceans. Eustatic sea elevation associated to the warming ocean floor spreading during the Early Cretaceous originated a temporary epicontinental seaway in the Northeastern Brazil. Hypotheses regarding its possible route of ingression have not been consistent. However, recent paleontological data concerning Aptian-Albian fossil fish assemblages in Brazilian Northeastern Marginal and Interior Basins (BNMIBs) have suggested a biotic relation with Tethyan ichthyofaunas. The Lower Cretaceous Santana Formation of the Araripe Basin has provided the best known fossil fish record in South America. The oldest fishes occur under brackish/hipersaline conditions but with intermittent marine connections, which is indicated by species of the genera *Vinctifer*, *Rhacolepis*, *Notelops*, and *Araripichthys*. The fossil fishes of the Santana, Codó and Riachuelo formations show a greater similarity to each other than to assemblages from other BNMIBs. This suggests greater connectivity between the depositional environments dominating the Araripe, Parnaíba and Sergipe-Alagoas basins during the late Aptian. However, a recent reassessment of fossil fishes from the Codó Formation (Aptian; Parnaíba Basin) revealed distinct species among some of the genera shared with other BNMIBs (e.g., mawsoniids, aspidorhynchids, and clupeomorphs). This suggests a degree of separation between the depositional environments in these basins. Except for a few works concerning the Santana Formation, controlled excavations have not been conducted in strata containing these fossil fishes. The fossil fish distribution patterns in BNMIBs probably result from vicariance and/or dispersal events, related to transgressive/regressive episodes that controlled sedimentation within the basins. Thus, an understanding of the evolution of the ecosystems of western Gondwana requires a comprehensive understanding of stratigraphic and tectonic provincialism in order to refine biostratigraphic significance and correlation of the fossil fish assemblages.

Grant Information:
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Technical Session X (Friday, October 11, 2019, 10:15 AM)

THE BEAST OF MÜHLHEIM: FIRST EVIDENCE OF A SOLNHOFEN MEGAPLANKTIVORE

LISTON, Jeff, BSPG, Munich, Germany; HEYNG, Alexander, BSPG, Munich, Germany

As the first animals to successfully occupy the large (> 1 m Standard Length, SL) vertebrate suspension-feeding niche, pachycormid osteichthyans were the Mesozoic ecological forerunners of today's cetacean (mysticetes) and chondrichthyan (*Rhincodon* and *Cetorhinus*) planktivores. At their acme in the Callovian (Middle Jurassic), suspension-feeding pachycormids were growing to sizes in excess of today's whale sharks (*Leedsichthys*, estimated SL 16 metres), achieving a scale of growth unequalled by subsequent osteichthyans. Until recently, the largest suspension-feeding pachycormid in the Upper Jurassic Plattenkalk fauna was the 1.9-2.3 metres long *Asthenocormus*, although occasional discoveries had suggested that there might be something larger. Anomalous pectoral fins in the BSPG, Munich, since 1951 were >3x any recorded specimen of *Asthenocormus* (0.5x *Leedsichthys*), with a highly non-asthenocormid shape. In 2009, a tail ray specimen was found in the Mühlheim quarry (Upper Jurassic, Mörnsheim Fm), exhibiting the classic pachycormid characteristic of bifurcating without segmentation, to a length of around 90cm, 3x longest recorded for *Asthenocormus* (0.5x *Leedsichthys*). In 2015, the pit also yielded highly elaborate gill rakers more than twice the length of those commonly seen in *Leedsichthys*, and substantially more robust.
Although virtually meaningless to estimate the size of such an animal from these small components of its gill basket, it is the first evidence that the Upper Jurassic in Southern Germany may have had a significantly larger suspension-feeding pachycormid than the Middle Jurassic *Leedsichthys*, indicating that the Plattenkalk deposits preserve even more of a diversity hotspot than previously suspected, with the apex of Mesozoic suspension-feeding unexpectedly represented in this ecosystem.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

PROGRESS IN THE STUDY OF PALEOGENE ICHTHYOFAUNA FROM ONSHORE BASINS AROUND BEIBU GULF OF CHINA

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Paleogene sediments are well developed in the onshore basins, including Ningming, Nanning, and Baise Basins of Guangxi, Sanshui and Maoming Basins of Guangdong, and Changchang Basin of Hainan, China, around the Beibu Gulf (Gulf of Tonkin). As fieldwork and research activities progressed, the picture of the Paleogene ichthyofauna of this region is gradually unveiled. Cypriniforms were the dominant fish in terms of specimen numbers and taxonomic diversity, which
spanned from the Paleocene to the Oligocene and occurred in every basin of this region, including: (1) Cyprinidae: *Eoprocypris maomingensis* from late Eocene Youganwo Formation (Fm.) of Maoming
Basin, *Cyprinus*-like cyprinid from late Eocene Nadu Fm. of Baise Basin, *Huashancyprinus robustispina* and *Ecocarpia ningmingensis* from Oligocene Ningming Fm. of Ningming Basin, *Nanningocyprinus wui* from Oligocene Yongning Fm. of Nanning Basin, and some undescribed new forms; (2) Jianghanichthyidae (the only fossil family of the order Cypriniformes and only occurred in South China): *Jianghanichthys sanshuiensis* from Paleocene Buxin Fm. and a new species of the same genus from early Eocene Huachong Fm. of Sanshui Basin; and (3) Cobitidae: *Cobitis nanningensis* from Oligocene Yongning Fm. of Nanning Basin. These fishes are among the oldest cypriniform fossils, which provide critical information on the origin and evolution of the order Cypriniformes. Along with cypriniforms, there are osteoglossiforms, siluriforms, and perciforms from Sanshui Basin; siluriforms and sharks from Maoming Basin; siluriforms and clupeomorphs from Nanning and Baise Basin; and ellimmichthyiforms, siluriforms, and gobiiforms from Ningming Basin. The Oligocene ellimmichthyiforms from Ningming represents the youngest member of the order so far. The Oligocene gobiiforms from Ningming is the first occurrence of fossil gobiiforms in China. Furthermore, shark materials and possibly marine ellimmichthyiform and siluriforms are discovered in this region alongside abundant cypriniforms, a group of primary freshwater fishes, which indicate that the freshwater bodies of this region were invaded occasionally by marine water during the Paleogene.
To sum up, the Paleogene ichthyofauna from onshore basins of Beibu Gulf consists of oldest fossils of major clades of Cenozoic fishes and a relict of typical Mesozoic fish taxa, which suggest that this region is an evolutionary hotspot of Cenozoic freshwater fishes, especially of cypriniforms.

Grant Information:
NNSF of China (41862001), NSF of Guangxi (2017GXNSFAA198291), and State Key Laboratory of Paleobiology and Stratigraphy (173116).

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

NEW TETRAPODS FROM THE SUNJIAGOU FORMATION AND SHANGSHIHEZI (UPPER SHIHHOTSE) FORMATION, SHANXI, CHINA AND ITS IMPLICATIONS

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In China, the outcrops of the Sunjiagou Formation and Shangshihezi Formation have most widespread distribution among synchronous terrestrial late Permian deposits. However, only pareiasaurs among tetrapods have been reported from the Sunjiagou Formation, and only one tetrapod fossil locality is known for the Shangshihezi Formation. Up to now, the tetrapod diversity from two formations is low, and dicynodonts, one common Permian tetrapod group, have never been reported from them. In contrast, dicynodonts are abundant and the tetrapod diversity is much higher for the Naobaogou Formation, which only distributes within a small basin.
In 2017, a partial pareiasaur skeleton was discovered from the upper portion of the Shangshihezi Formation at Shouyan, Shanxi, China. In 2018, three dicynodont specimens and one pareiasaur specimen were collected from the Sunjiagou and Shangshihezi formations. These dicynodonts show closely relationship with those from the Naobaogou Formation. One mandible displays some unique features among dicynodonts, such as long retroarticular process with anteroposterior length roughly equal to the height of articular, midline trochlea directs posterolaterally rather than posteromedially. Furthermore, one skull shows close relationship with one dicynodont species

from Laos. It supports the form of a land-bridge by the end of Permian on the eastern margin of Pangea.
The current clues indicate a diverse tetrapod assemblage could be recovered from the Sunjiagou Formation and Shangshihezi Formation of Shanxi, China.

Grant Information:
National Natural Science Foundation of China (Grant No. 41572019)
Excavation Funding of Chinese Academy of Sciences

Technical Session I (Wednesday, October 9, 2019, 10:30 AM)

BUT DID IT EAT OTHER WHALES? NEW ENAMEL MICROSTRUCTURE AND ISOTOPIC DATA ON *LIVYATAN*, A LARGE PHYSETEROID FROM THE ATACAMA REGION, NORTHERN CHILE

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Livyatan was a macroraptorial extinct genus of sperm whale, with records from the Neogene of Peru, Chile and Australia. Like other Neogene-age physeteroids, *Livyatan* had large functional upper and lower teeth, which likely reflects a hypercarnivorous feeding style. We examined the morphology, enamel microstructure, and isotopic composition of a putative lower *Livyatan* tooth from the Bahia Inglesa Formation, northern Chile. The subcylindrical tooth is 322 mm long and 109 mm in diameter, comparing favourably to holotype teeth from Peru. This Chilean specimen is slightly smaller than the largest of the type series teeth, which were 362 mm long. The crown is curved lingually, approximately 30 degrees from the main axis. The root apex is open and a thick cementum layer covers the root. A rugose enamel tip covers part of the crown. Enamel fragments were removed from the crown base for scanning electron microscopy (SEM) and isotopic analyses. SEM images revealed a moderately thick enamel (600 µm) with prominent Hunter-Schreger bands (HSB) throughout the whole thickness, with both open and closed prisms present. HSB are implicated in resisting and limiting enamel crack propagation, being considered a biomechanical response to increased occlusal loads sustained during feeding. The carbon and oxygen isotopic compositions of structural carbonate from enamel and dentine samples were analysed as a proxy of diet and habitat information. We observed an extremely low $d^{13}C$ value in enamel ($\delta^{13}C$ = -16.5‰), which suggests feeding at southern latitudes greater than 40° S. Based on isotopic analysis of fossil mysticetes from the same rock unit, it seems unlikely the *Livyatan* specimen analysed here was exclusively macrophagous; however, it could have fed on mysticetes from higher latitudes. The presence of HSB in *Livyatan* suggests a reduction in enamel complexity in physeteroids over time, as extant sperm whales have thin, prismless enamel that is often worn away. Further analysis considering more specimens will help elucidate the feeding ecology of these poorly known cetaceans.

Grant Information:
C Loch acknowledges a Sir Thomas Kay Sidey Research Grant

Technical Session X (Friday, October 11, 2019, 8:30 AM)

EXCEPTIONALLY WELL-PRESERVED FISHES, INCLUDING A NEW POROLEPIFORM AND NEW ARTHRODIRES, FROM THE LATE DEVONIAN GOGO FORMATION OF WESTERN AUSTRALIA

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The Gogo Formation of Western Australia is renowned for its exceptional 3D preservation of both bone and soft tissue in fossil fishes that inhabited an ancient reef environment. It is also one of the most diverse vertebrate assemblages of this age (Frasnian) with over 50 species of placoderms, osteichthyans and rare sharks and acanthodians that once inhabited the algal-stromatoporoid reef environment.
The earliest expeditions (1963,1967) led by the British Museum of Natural History, working with Western Australian Museum and Hunterian Museum staff managed to collect about half the known taxa of Gogo fishes, and these were methodically described between 1971-1995. Field expeditions lead by the author and other Australian teams systematically collected at the sites from the early 1970s (ANU Geology, BMR, WA Museum, Museum Victoria, Curtin University teams) which added a significant number of new taxa plus better specimens of poorly described taxa, representing groups not previously known or incomplete from the initial collections.
These included the first records of complete tetrapodomorph fishes, many new lungfish and actinopterygian taxa, and the first record of coelacanth, shark and acanthodian taxa. More significantly these later expeditions found the first evidence of well-preserved soft tissue, embryos and sexual organs in certain groups of placoderms.
Recent collecting from the site keeps yielding high quality 3D new taxa from the formation. Here we report the first occurrence of a porolepiform (Osteichthyes; Dipnomorpha, Porolepiformes), known from relatively complete skull remains, indicating that a *Glyptolepis* grade taxon was present. The new specimen under CT scanning and neutron beam analysis shows remarkable anatomical details of the porolepiform braincase and other cranial features.
In addition, new placoderm taxa keep being uncovered, including a new large predatory genus of arthrodire related to the eastmanosteid group, but with well-developed pointed teeth along all gnathal plates. New smaller taxa of torosteid arthrodires indicate that micro-predatory niches were occupied by fishes of the reef system.

Grant Information:
ARC DP 140104161

Technical Session VI (Thursday, October 10, 2019, 8:15 AM)

DENTAL TOPOGRAPHY ANALYSIS AND DIETARY INFERENCE OF THE MIOCENE NEOTROPICAL BAT *NOTONYCTERIS MAGDALENENSIS* FROM LA VENTA, COLOMBIA

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The fossiliferous locality of La Venta contains the richest Cenozoic vertebrate fossil community of northern South America. It includes over 70 mammals and covers a poorly-represented time span in the middle Miocene, helping to define the Laventan South American Land Mammal Age (SALMA).
Best known for its diverse primate community, La Venta has yielded 14 Miocene bat species, including the oldest plant-visiting bat in the world, and some of the earliest fossil evidence of extant families Phyllostomidae, Thyroptera and Noctilionidae. *Notonycteris magdalenensis* is an early phyllostomid that has been instrumental for phylogenetic and systematic analyses. It has been described as an early relative of the modern subfamily Phyllostominae, a group of Neotropical animalivorous and omnivorous bats. Despite its importance for the study of the evolution of Neotropical bats, the biology of *N. magdalenensis* remains mostly unknown.
N. magdalenensis is represented by several complete molars, providing an opportunity to study possible ecological adaptations. Using 3D computational modelling, we implemented dental topography analysis to infer the diet of *N. magdalenensis*. We compared the dental complexity in two lower first molars of *N. magdalenensis* with 19 modern phyllostomid species, covering a wide range of diets. We performed multivariate analysis based on three measures of dental complexity: Dirichlet Normal Energy (DNE), Relief Index (RFI), and Orientated Patch Count Rotated (OPCR).
Based on our sample, species with liquid diets (nectarivorous and sanguivorous) had lower DNE and OPCR values, whereas frugivorous species had lower values of RFI. Based on Principal Component Analysis (PCA), DNE and OPCR explained the highest amount of variability in our results. Our PCA separated species with different diets, with some overlap between insectivores and omnivores. Discriminant Function Analysis (LDA) better discriminated between diets, and classified both *N. magdalenensis* specimens as omnivorous species. Our results, coupled with previous ecological studies on other bats from La Venta, indicate a generalist phyllostomid paleocommunity with an ample morphological diversity.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

FIRST MYOCRICETODONTINAE (RODENTIA) FROM THE MIOCENE OF LEBANON

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Recent excavations in the lacustrine Late Miocene of Lebanon resulted in the discovery of several new fossiliferous localities near the city of Zahleh. They are the first Late Miocene sites with micromammals in Lebanon and the second ones in the whole Arabian Peninsula. Several isolated molars of a Myocricetodontinae have been recovered from one of these localities. The

Myocricetodontinae are a group of rodents, which is supposed to have originated in the Middle East during the Early Miocene. Their evolutionary history, systematics and stratigraphic range are debated. The Lebanese myocricetodontine has low crowned cheek teeth. Its upper molars are characterized by a normal longitudinal crest with the posterior mure somewhat reduced, strong labial and lingual cingula surrounding the valleys, absent or incipient accessory cusps and no mesoloph. The third upper molars are slightly reduced in size but not as much as in other myocricetodontines, such as *Myocricetodon*. The lower molars show a single anteroconid with well-developed labial and lingual anterolophids, labial cingula surrounding the valleys and a large posterolophid. They lack the mesolophid. The size and overall morphology of these teeth are strongly reminiscent of *Mellalomys*. We determine the Lebanese myocricetodontine as belonging to this primitive genus. Some features, such as the presence of a single anterocone on the first upper molar, suggest that it does not pertain to any species of the genus already known. *Mellalomys* has been recorded so far from the Early and Middle Miocene of South Asia and the Middle Miocene of North Africa. The discovery of a new species of *Mellalomys* in Lebanon suggests that the dispersal of this genus from South Asia to North Africa took place through the Levant. This extends the temporal range of this genus into the early Late Miocene.

Technical Session X (Friday, October 11, 2019, 10:30 AM)

THE ENIGMATIC *AINIA ARMATA* WAGNER AND ITS SIGNIFICANCE FOR ACTINOPTERYGIAN SYSTEMATICS

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Ainia is a rare fish in the late Jurassic limestones of Europe, which has been known from some specimens from Cerin (France) and very few specimens from the Solnhofen Archipelago (Germany). The species was erected based on a complete specimen from Solnhofen with the name *Lepidotus armatus* Wagner, while the French material was described as *Callopterus agassizi* Thiollière, name that prevailed after the synonymy of the specimens from both countries. However, according to the ICZN Wagner's species name has priority. Also, the generic name *Callopterus* is a nomen nudum and it was replaced by *Ainia* Jordan. Therefore, the correct name of the species is *Ainia armata*.

New specimens from Germany triggered a new anatomical and systematic study of this taxon, which is easily distinguished by its very [illegible] of squamation limited to numerous rows of tiny [illegible] covering the dorsum and ventrum of the caudal peduncle. The [illegible] are not oriented in [illegible] dorsal to the [illegible] ventral sectors of the [illegible] body scales of the [illegible] and ventral [illegible]. To explore the phylogenetic relationships of *Ainia*, we [illegible] a matrix [illegible] 21 morphological characters, 32 [illegible] 3 chondrichthyans, 5 teleosts, and 4 more distant [illegible].

As [illegible] more taxa and characters will be added to our cladistic analysis, the results obtained so far support the monophyly of three clades corresponding to the Amiiformes, Ionoscopiformes including caturids, and Ophiopsiformes, but the Panxianichthyformes are paraphyletic in the strict consensus tree. Interestingly, the new anatomical information led to the revision and reinterpretation of some hypotheses of homology, in particular regarding the formation of the vertebral centra in several Jurassic neopterygians. Moreover, this information is being incorporated into a broader project meant to achieve a general phylogeny of Actinopterygii based on combined morphological and molecular data and including as many as possible living and fossil species. As a starting platform, we produced a data set encompassing 602 morphological characters plus cured public amino acidic data for 47 DNA markers with information for 16289 species as terminal taxa. Results and progress of this mega project will be also presented.

Grant Information:
Deutsche Forschungsgemeinschaft (DFG) LO1405/6-1; Fondo para la Investigación Científica y Tecnológica (FONCYT) PICT-2016-0275.

Withdrawn

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

FIRST VIRTUAL RECONSTRUCTION OF THE INNER EAR OF A FOSSIL RABBIT: LOCOMOTOR BEHAVIOUR AND HEARING SENSITIVITY OF *MEGALAGUS TURGIDUS* (EARLY OLIGOCENE OF NEBRASKA)

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The inner ear can be highly informative about locomotor agility and hearing sensitivity. Having larger semicircular canals (SCCs) relative to body mass implies faster, jerkier locomotion compared to having smaller SCCs. Cochlear and oval window dimensions are associated with low- and high-frequency hearing sensitivities, respectively. In this study, agility and hearing sensitivities are reconstructed from the inner ear of the stem lagomorph *Megalagus turgidus* (UC 1642) from the early Oligocene of the Brule Formation of Nebraska. UC 1642 includes an almost complete cranium with both zygomatic arches largely missing, as well as some damage around the left external auditory region and lateral portion of the cranium. It preserves the right inner ear, including both the SCCs and the cochlea. The cranium was micro-CT scanned, and the ear was segmented using Avizo 9.0.1. A comparative sample of inner ear metric data taken from scanned crania of extant lagomorphs was created, including representatives of the two modern lagomorph lineages: leporids (N = 8) and ochotonids (N = 3). *Megalagus* has proportionally small SCCs with respect to its body mass (estimated at 2.3 kg), suggesting that it had less agile locomotion than most modern lagomorphs. *Megalagus* only surpasses the arctic hare (*Lepus arcticus*) in agility, which is not surprising given the arctic hare's rather strenuous locomotion through thick layers of snow. *Megalagus* is closer in proportional SCC size to the volcano rabbit (*Romerolagus diazi*), which dwells in dense zacaton grass. A level of agility for *Megalagus* within the range of modern rabbits agrees with the evidence from postcranial elements.

The hearing sensitivities for *Megalagus* are reconstructed as 45.2 and 12.1 decibels (dB) for low- (250 Hz) and high-frequency (32 kHz) sounds, respectively. Overall, the reconstructions for *Megalagus* are in the range of extant lagomorphs for both low- and high-frequency sensitivity. However, it is worth noting that *Megalagus* has one of the highest values for low-frequency sensitivity among the sample, suggesting that this animal was better adapted for detecting some range of low-frequency sounds.

In sum, these data show that, by the early Oligocene, stem lagomorphs already had fundamentally rabbit-like hearing sensitivity and locomotor behaviour, even though *Megalagus* was not a particularly agile species within the context of lagomorphs. This is consistent with the idea that *Megalagus* was more of a woodland dweller rather than an open-habitat runner.

Grant Information:
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Symposium: Quarternary Extinctions (Friday, October 11, 2019, 2:45 PM)

QUATERNARY EXTINCTION OF LARGE RAINFOREST HERBIVORES ON INDONESIA'S LARGEST ISLAND, SUMATRA

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Sumatra is the world's sixth largest island, and Indonesia's largest. It hosts 201 mammal species, of which nine are endemic to mainland Sumatra, fourteen to Mentawai islands, and 22 found nowhere else in Indonesia. Unlike other major islands in Southeast Asia, it records very few Quaternary extinctions. Here, we report the first globally extinct taxon from the island. *Hexaprotodon,* the Asian hippo, is represented by the anterior portion of a second lower molar as well as some canine fragments. These were recovered from Ngalau Gupin, a cave site in the Padang Highlands. A tapir molar from the same site has been dated to at least 45,000 years old by uranium series dating. Other than the hippo, the banteng, the buffalo, and the Javan rhino became extirpated from the island, probably sometime in the historical period. Examination of carbon and oxygen isotope values from fossil and modern large mammal communities show no significant differences in either isotope

(Mann-Whitney U: carbon U=1666, p=0.1704; oxygen U=1855, p=0.759). This suggests there have been no significant ecological shifts over the Pleistocene at the resolution of these proxies. Unlike other Quaternary extinction events on islands, the largest herbivore on the island is still extant, suggesting that anthropogenic overkill alone is unlikely to be responsible. We suggest that an interplay between decreased carrying capacity, increased hunting, and separation from Southeast Asian source populations may have adversely affected the large, but not medium or very large, herbivores on this island.

Grant Information:
Australian Research Council Future Fellowship (FT160100450)

Technical Session X (Friday, October 11, 2019, 9:00 AM)

MACHINE LEARNING BASED EARLY DEVONIAN VERTEBRATE MICROFOSSILS TOMOGRAPHY SEGMENTATION AND RECONSTRUCTION

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A large part of early vertebrate history is evidenced by microfossil fish scales and teeth abundant globally. However, fully appreciation of these important evidences is often hampered by the labor and time intensive nature of extracting information from the large number of samples, complicated to prepare. Here, we develop a novel open source machine learning approach based on Python, to automate the segmentation and reconstruction of the three-dimensional virtual models of microfossils from tomographic image stack. The current dataset includes the tomographic data of microfossils from the lower section of the Xishancun Formation (Lochkovian, Lower Devonian) of Yunnan, China. Each scanned rock, one or two centimeters cubic, contains hundreds of microfossils, and is almost impossible to prepare using traditional methods. To achieve an automated digital preparation of these fossils, we firstly apply Otsu-thresholding, a global thresholding technique, on the smoothed tomography images to obtain a set of object candidates. Small-sized candidates are often mixed with noises and hard to separate in a single slice. However, unlike noises, the 3D structures of actual fossil continually exist across slices. Accordingly, we utilize the spatial-slice coherence of adjacent frames to classify and merge the objects from candidates. Also, the pre-processing that smooths the noises blurs the sharp boundaries, making it difficult to accurately segment the narrow-shaped objects. To address it, we propose a simple linear iterative clustering (SLIC) based strategy for precise adherence of boundary. Specifically, we use SLIC algorithm to generate superpixel. Then, we apply Otsu-thresholding method again on individual superpixel to preserve the details of a narrow shape. Finally, we merge the detailed boundary shape to the previous segmentation for an accurate segmentation. After that, we could use interpolation method to reconstruct the 3D virtual models of these microfossils. An accompanying website will be provided for other users to test and improve our approach using new data, assumptions or methods. In perspective, we believe our attempt will surely fuel further collaborations between paleontology and computer vision approaches.

Grant Information:
Strategic Priority Research Program of Chinese Academy of Sciences (Grant No. XDB26000000); the National Natural Science Foundation of China (41872023)

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW POSTCRANIAL MATERIALS OF *ACERORHINUS YUANMOUENSIS*, AND THE PHYLOGENY OF ACERATHERIINAE

LU, Xiaokang, Henan University of Chinese Medicine, Zhengzhou, China; TAO, Deng, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China

Compared to other groups within Rhinocerotidae, Aceratheriinae is less specialized in having a hornless or small horned skull. However, the taxonomy of Aceratheriinae is consfused, and the group is absolutely non-monophyletic. A recent discovery of fully preserved skeleton of early Miocene *Diaceratherium shandongense* sp. nov., from the Shanwang Basin in China, provide us an opportunity to re-evaluate the phylogeny of Aceratheriinae. This is the first discovery of *Diaceratherium* in East Asia, and the first study to investigate the phylogenetic of Aceratheriinae and whose position relative to other rhinocerotids subfamilies. The new specimen is characterized by the large-sized body, short and horned nasal bones, moderately retracted nasal notch with a posterior edge above P2, very large-sized lower and upper incisors, higher-crowned but less specialized cheek teeth, and less massive metapodials. Our phylogenetic data matrix includes all genera currently regarded as acerathers *sensu lato* (i.e., *Mesaceratherium*, *Protaceratherium*, and *Diaceratherium*). The characters used in the present analysis includes some that have been used previously in addition to 105 new ones, resulting in a data matrix of 387 characters scored for 50 rhinocerotid species and one extant tapir outgroup. Codings have been reviesd for several characters, both in the light of recent observations and also in order to eliminate unwarranted assumptions. The analysis recovers Teleoceratini as more closely related to Aceratheriini than to Rhinocerotini, the first two tribes forming a monophyletic group within Rhinocerotidae. In contrast to previous analyses and traditional taxonomy, aceratheriines from North America do not form an exclusive clade, and *Mesaceratherium gaimersheimense* is placed within Teleoceratini. Another salient conclusion is the placement of *Turkanatherium* as a stem rhinocerotid falling outside Aceratheriinae. The relationships of the genera within Aceratheriinae are complex, and some of which remain debatable: *Alicornops simorrense* has a sister group relationship to *Aceratherium incisivum*, not to *Alicornops laogouensis*; *Aphelops mutilus* has a variable phylogenetic relationship with other late Neogene aceratheriines.

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 3:30 PM)

"KING KONG'S DEMISE": IMPLICATIONS FOR DIET AND EXTINCTION OF GIGANTOPITHECUS BLACKI FROM PLEISTOCENE CHINA BASED ON DENTAL MICROWEAR TEXTURE ANALYSIS

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Gigantopithecus blacki was the largest ape that ever lived. It was a key member of the *Stegodon-Ailuropoda* fauna and roamed the subtropical forests of China from ~2.0 Ma –300 ka. *G. blacki* is the only hominid genus to go extinct in the Pleistocene. The cause is unknown and may be related to climate change or ecological stress, due to habitat alteration and reduction in vegetation. Examining *G. blacki*'s diet may offer insights in the cause of its extinction. It is therefore the main aim of this specific diet study, as well as of the overall 'Giganto Project' that also includes research on stable isotopes, luminescence dating and palynology. Past, pioneering studies proposed different diets (of bamboo, C3 and C4 plants) for this prehistoric 'King Kong', based on phytoliths, stable isotopes, trace elements, and dental microwear by 2D scanning electron microscopy (SEM). More results, however, are desirable as its diet is still poorly understood. In recent years, more sophisticated dental microwear texture analysis (DMTA) has been increasingly applied. As it is a non-destructive, innovative and visual method to study vertebrate diets in 3D, based on the wear patterns on the occlusal surface of their dentition, it may offer potential solutions to our questions. We present the first application of this repeatable and quantitative technique on *G. blacki* (facets 3 and 9), correlated to known diets of extant Old World (sub)tropical frugivores (incl. hominids like *Pan troglodytes* and *Pongo pygmaeus*) and folivores (incl. *Gorilla beringei* and other taxa like Ailuropoda melanoleuca and Tapirus indicus). Extinct key taxa of Pongo and Ailuropoda were studied as well. The scans reveal microwear patterns that enable parameters like anisotropy, area-scale fractal complexity, scale of maximum complexity, and heterogeneity of complexity, to be assessed during dental areal surface texture analysis (DASTA) and scale-sensitive fractal analysis (SSFA). Preliminary results show a dominance of striae versus pits, indicating a preferred diet for year-round available but low nutritional foods (like leaves), with seasonal but high nutritional foods (like fruits) as potential fallback. The outcomes of this study are not only relevant for understanding regional megafaunal extinctions and reconstruction of past environmental conditions, but equally important for global conservation of current endangered megafauna like the giant panda in China and mountain gorilla in Africa.

Grant Information:
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Technical Session XVII (Saturday, October 12, 2019, 11:45 AM)

CHANGES IN DINOSAUR ECOSYSTEMS FROM THE HELL CREEK FORMATION LEADING UP TO THE CRETACEOUS-PALEOGENE BOUNDARY IN NORTH AMERICA

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The Cretaceous-Paleogene (K-Pg) boundary is associated with Earth's third largest mass extinction event. Despite being one of the best-studied intervals of time, there is considerable debate regarding the drivers and tempo of the extinction. The Deccan Traps flood basalt province and the Chicxulub bolide impact have both been suggested as drivers of the K-Pg mass extinction. With these drivers in mind, we provide a detailed and temporally constrained terrestrial fossil record that documents relative abundance of dinosaur skeletons from the latest Cretaceous of North America.

We use a high-resolution differential GPS survey and GIS to create a geostatistically interpolated model for the K-Pg boundary across a ~1200 square kilometer study area in the latest Cretaceous Hell Creek Formation of North America and plot the stratigraphic position and depositional environment for 143 dinosaur skeletons. Identification of three K-Pg boundaries with primary markers of the Chicxulub impact, 38 pollen-defined K-Pg boundaries, and six 30n/29r paleomagnetic chron boundaries throughout our study area allows us to evaluate the fossils in a high-resolution chronostratigraphic framework.

The Hell Creek skeletal dataset consists of ceratopsians (65%), *Edmontosaurus* (23%), *Thescelosaurus* (5%), tyrannosaurs (4%), pachycephalosaurs (2%), and other taxa (1%). The relative abundance of skeletons is not distributed evenly through time or depositional environment. The lower third has a relatively even distribution of ceratopsians (31%), *Edmontosaurus* (38%), and *Thescelosaurus* (31%), while the relative abundance of ceratopsian dinosaurs increases to 58% and 73% in the middle third and upper third, respectively. In addition, ceratopsians are preferentially found in mudstone overbank deposits by a 2:1 margin and *Edmontosaurus* and *Thescelosaurus*in sandstone riverine deposits by a 16:1 and 8:1 margin, respectively. The preferential occurrence of taxa with lithology, combined with a general lithologic change from a sandstone-dominated base to a mudstone-dominated top suggests depositional environment changes, likely a result of marine transgression, is a primary driver for observed changes in Hell Creek dinosaur ecosystems. The occurrence of all large, common dinosaurs within the uppermost Hell Creek, including two within the Fort Union Formation of Cretaceous age, suggests a rapid demise as a result of the bolide impact.

Technical Session XVII (Saturday, October 12, 2019, 10:30 AM)

THE CRANIAL ONTOGENETIC VARIATIONS OF *SINORNITHOMIMUS DONGI* (DINOSAURIA: ORNITHOMIMOSAURIA)

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Investigation of morphological changes that occur during ontogeny in dinosaurs is always hindered by the limited fossil material, and relatively continuous ontogenetic series is only documented within a few dinosaur species. The poor knowledge about ontogenetic variations in ornithomimosauria prevents a deep understanding of how this group of theropods evolved morphologically and taxonomically. *Sinornithomimus dongi* is an edentulous ornithomimid recovered from the Upper Cretaceous Wulansuhai Formation, Suhongtu, Inner Mongolia, China. To date, at least 27 individuals of *Sinornithomimus dongi* have been yielded and described. Previous studies of these specimens indicate an age range of 2-7 years, missing hatchlings and adult sized individuals. Therefore, the available specimens comprise the best-documented growth series of any ornithomimid species. Here we compare the cranial morphology of a juvenile specimen (IVPP V11797-11) and a subadult one (IVPP V11797-10) based on both naked-eye observation and CT scanning which reveals new information on previously poorly known anatomical regions such as the squamosal. Our comparisons indicate several ontogenetic changes in *Sinornithomimus dongi*, including the neurovascular foramina along the occlusal margin of the premaxilla that is more prominent in the subadults than in the juveniles, a prominent narial fossa in the anteroventral corner of the naris present in the subadult but absent in the juvenile, and the fossa on the maxillary process of the jugal larger and deeper in the subadult than in the juvenile.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

FINITE ELEMENT ANALYSIS OF OVIRAPTOROSAUR JAWS: IMPLICATIONS FOR DIETARY INFERENCE

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Oviraptorosaurs are a group of feathered dinosaurs that lived in Asia and North America during the Cretaceous. They are characterized by having distinct anatomical features in the skull that deviate from those of other theropods, which include the possession of a relatively deep, pneumatized skull and a beak. Basal oviraptorosaurs such as *Incisivosaurus* and *Caudipteryx* have undergone partial tooth reduction and retain a few teeth in their skulls. The mandibles of advanced oviraptorosaurs – caenagnathids and oviraptorids – are completely edentulous and developed diverse morphologies. Investigating the mandibular function and diet of oviraptorosaurs by qualitative comparison is challenging because their toothless jaws lack obvious adaptations to a certain kind of diet. Here, we conduct the first comprehensive investigation into the functional morphology of oviraptorosaur jaws using computer modelling and biomechanical techniques.

We use 2D and 3D finite element analysis (FEA) to model the biomechanics of oviraptorosaur jaws. Sixteen 2D FEA models were constructed based on first-hand photographs and published figures. 3D models of *Gigantoraptor* and *Nemegtomaia* were developed using photogrammetry. The 3D jaw models were digitally restored before being subjected to FEA. Comparison between 2D and 3D FEA models confirms 2D models are good representations of the biomechanics of the jaws. Two loading scenarios were set up to evaluate the functional performance of oviraptorosaur jaws: 1) dorsoventral bending tests and 2) muscle-driven bite force analyses using the reconstructed jaw muscles.

In general, the jaws of oviraptorids are more resistant to dorsoventral bending and have higher bite efficiency compared to those of caenagnathids. Substantial differences in jaw biomechanics are observed among basal oviraptorosaurs – the downturned dentary of *Caudipteryx* is structurally more stable than that of *Incisivosaurus* under bending and biting scenarios. Our results reveal a diverse functional capacity among oviraptorosaur jaws, which potentially indicates a wide dietary range.

Technical Session XIII (Friday, October 11, 2019, 3:15 PM)

CAUDAL AUTOTOMY IN MESOSAURID REPTILES AND ITS IMPLICATIONS FOR ANTI-PREDATORY BEHAVIOUR AND LOCOMOTION IN THE CLADE

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Mesosaurs are a distinctive clade of early reptiles that adopted a secondarily aquatic lifestyle in the Permian period. While their status as the first reptilian group to re-invade aquatic environments makes them unique, one of their most puzzling and controversial features is the potential for caudal autotomy. Several researchers have described fracture planes in mesosaur caudal vertebrae - unossified regions in the middle of caudal vertebral centra - that in many extant squamates allow the tail to separate and the animal to escape from a predator's grasp. However, the reports of fracture planes in mesosaurs have never been closely investigated beyond preliminary descriptions, which has prompted skepticism. Here, using numerous exceptionally well-preserved vertebral series, computed tomography scans, and histological sections, we provide a detailed account of fracture planes in the caudal vertebrae of several specimens from the three known mesosaur species. Fracture planes run through the middle of the centrum of all vertebrae, starting from the 8thcaudal and continuing posteriorly, but do not affect the neural arches. Caudal autotomy of this type is also present in other Paleozoic tetrapod clades, specifically captorhinid reptiles and 'microsaurs', revealing that this trait was more prevalent among early tetrapods than previously realized. Ancestral state reconstruction indicates that it is likely a plesiomorphic feature in reptiles. Furthermore, despite mesosaurs apparently having the ability to autotomize their tail, it is unclear if they actually made use of this behaviour, as they would have had few, if any, predators in the inland sea in which they lived. However, caudal autotomy would have been useful if they were spending time on land, as has recently been suggested. The identification of fracture planes in mesosaurs also challenges the idea of a principally tail-

driven propulsion in this clade, as opposed to many other aquatic sauropsids, and suggests the hindlimbs may have played a larger role in locomotion than previously assumed.

Technical Session VI (Thursday, October 10, 2019, 10:30 AM)

DIETARY NICHES OF EARLY MIOCENE FOSSIL HOMINOIDS FROM UGANDA

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The earliest fossil hominoids are found in East Africa at sites older than 20 million years, and are thought to have evolved in forested habitats. To characterize the dietary niches of fossil hominoids, we analyzed the stable carbon and oxygen isotopic signatures of five Miocene fossil catarrhine teeth from Napak and Moroto, Uganda, including those identified as *Morotopithecus*, *Proconsul* and *Rangwapithecus*. In addition, we analyzed the enamel of five modern hominoid genera including *Pan, Pongo, Gorilla, Hylobates, Syndactylus*; (n=85). Seven individuals from this extant sample were chimpanzees from a single population (Ngogo, Kibale, Uganda) with known diet. Based on the tissue-specific isotope values of these chimpanzees, the published isotopic contents of their food items, and the percent of time spent feeding on each food item, we derived a $\varepsilon^*_{enamel\text{-}diet}$ value for the Ngogo chimpanzees of 12.5‰. We used this value, rather than the commonly used 14‰ offset based on ruminant physiology, to calculate dietary input for the fossil specimens and other hominoids in this sample. The modern hominoid enamel samples had $\delta^{13}C_{enamel}$ values between ca. -18 to -14‰, more negative than the fossil hominoids, whose atmospheric-corrected values range from ca. -9 to -12‰. The fossil hominoid values are consistent with the $\delta^{13}C_{enamel}$ values of associated ungulate fauna in the fossil assemblages. Using the $\varepsilon^*_{enamel\text{-}diet}$ of 12.5‰ for physiological fractionation in fossil hominoids, the $\delta^{13}C$ dietary input for the fossil hominoids ranged from ca. -21 to -24‰. The data (assuming a predominantly C_3 environment) thus indicate that these early hominoids were foraging on more water stressed plant parts than any extant hominoid taxon, and suggest that the earliest hominoids evolved in more open environments than previously supposed, such as in woodlands or broken forests with significant seasonality, evapotranspiration, and/or irradiance.

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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

THE MAMMAL ASSEMBLAGE OF CRYSTAL CAVERNS AND A COMPARATIVE ANALYSIS OF CALIFORNIA CAVE DEPOSITS

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Caves are important geologic features that facilitate the preservation of terrestrial fossils, and thus provide valuable information about local taxa and ecology. Crystal Caverns in El Dorado County (California, U.S.A.), which was excavated in 1991, contains roughly 2,000 cataloged mammal specimens from the Pleistocene. The Pleistocene age is confirmed by the presence of the extinct shrub ox *Euceratherium*; however, many of the other taxa are extant. Over 90% of the mammalian assemblage is comprised of rodents, including *Aplodontia*, *Neotoma*, *Peromyscus*, and *Geomys*. Of these, more than half of the rodents in the Crystal Caverns deposit belong to the genus *Aplodontia*.
The abundance of *Aplodontia* in the Crystal Cavern deposit (~53% of rodent material) is striking, especially when compared to other cave deposits. In similarly aged Northern California cave deposits, aplodontiids make up less than 10% of the rodent material. This abundance may provide us with valuable ecological information on the ecosystem of the Crystal Caverns in the Pleistocene. *Aplodontia rufa*, commonly known as the Mountain Beaver, is the only remaining species in the genus Aplodontia. Mountain Beavers comprise an early diverging, morphologically primitive genus of fossorial rodents that prefer wet and densely forested areas. The high proportion of *A. rufa* at the Crystal Caverns site suggests that during the Pleistocene, the area had increased rainfall and was more heavily forested. Combining this interpretation with the modern distribution of other mammals found in the Crystal Caverns assemblage will provide further avenues for paleoenvironmental reconstruction and will help to characterize the fauna of this unique Pleistocene deposit.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

VERTEBRATE LAG DEPOSITS FROM A K/PG BOUNDARY SECTION NEAR MALVERN, ARKANSAS, U.S.A.: NON-CATASTROPHIC ACCUMULATIONS IN RESPONSE TO SEA LEVEL CYCLICITY

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A stratigraphic section exposing the Arkadelphia Formation and Midway Group (Maastrichtian–Paleocene) near Malvern, Arkansas, contains several vertebrate lag deposits that traverse the K/Pg mass extinction boundary. These lag deposits reside directly above erosional disconformities, with the largest occurring at the K/Pg boundary. An abundance of disarticulated vertebrate bones and teeth deriving from chondrichthyans, osteichthyans, plesiosaurians, and chelonians occur within these lag deposits and show evidence for multiple stages of exhumation and reburial. Comparison of these lag deposits to regional and global sea level curves indicates that they are the product of multiple exhumation and reburial events that occurred during as many as four, third order regressive-transgressive sea level cycles and accumulated over a duration of at least several million years. Preservation and taphonomic wear found in these vertebrate lag deposits that traverse the K/Pg mass extinction boundary also indicate that sea level cyclicity and habitat loss in the shallow marine environment are the primary driving forces for extinction and faunal turnover. Vertebrates within the Malvern, Arkansas, lag deposits represent non-catastrophic lag accumulations and parallel evolutionary trends seen in other K/Pg stratigraphic sections that are remote from the Chicxulub, Mexico, bolide impact site. Geochemical analysis ($^{87}Sr/^{86}Sr$, $^{44}Ca/^{40}Ca$, and $d^{15}N$) of these fossil assemblages across the K/Pg boundary, currently underway, will help to constrain the biostratigraphy, paleoecology, and paleoenvironmental conditions at the site.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

BRAINCASE ANATOMY AND DIGITAL ENDOCAST OF *CRYOLOPHOSAURUS ELLIOTI* (DINOSAURIA: NEOTHEROPODA).

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Cryolophosaurus ellioti from the Sinemurian lower Hanson Formation of the Central Transantarctic Mountains has variably been considered a large coelophysoid or a basal tetanuran theropod. It is known from a bonebed assemblage preserving parts of at least two individuals including two braincases. The complete holotype braincase was scanned at Ford Motor Co (Livonia MI) on an industrial computed tomography system allowing for virtual preparation of the skull, and extraction of a neurocranial endocast and basicranial pneumatic space volumes.

As in many theropods, the skull lacks ethmoidal and orbitosphenoid ossifications. The large, leaf-shaped parasphenoid rostrum is grooved along both dorsal and ventral edges and constricted at the level of the deep hypophyseal fossa. A single opening for the carotid arteries pierces the dorsum sellae between the openings for CN VI. The basisphenoid recess is conical and divided apically by a transverse lamina. The rostral opening is blind, while the posterior one leads into paired, asymmetric pneumatic spaces that invade the base of the occipital condyle. Paired pneumatic spaces also reach the condylar neck in *Sinosaurus* and *Murusraptor*, but are only known invade the condyle in carcharodontosaurids.

The digital endocast exhibits forebrain-midbrain and midbrain-hindbrain angles similar to other non-maniraptoran theropods like *Sinusaurus*, *Murusraptor,* and tyrannosaurids, but unlike the strongly angled endocasts of carcharodontosaurids. The midbrain is shorter than the medulla as is typical of both basal Tetanurae and Ceratosauria. The cerebral region is unexpanded as in *Murusaurus* and *Allosaurus*, but in contrast to Maniraptora. The estimated Reptilian Encephalization Quotient (100%) of 4.35 for the holotype specimen of *Cryolophosaurus* is comparable to that of *Tyrannosaurus* and some paravians, yet higher than in ceratosaurians, basal

tetanurans, and even *Archaeopteryx.* As in tyrannosaurids, however, much of the endocast volume was likely occupied by vascular sinuses. As one of the earliest-diverging theropods with an endocast model, *Cryolophosaurus* provides critical information for polarizing trends in theropod brain evolution.

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Technical Session II (Wednesday, October 9, 2019, 9:30 AM)

DWARFS AMONG GIANTS: RESOLVING THE SYSTEMATICS OF THE TITANOSAURIAN SAUROPOD DINOSAURS FROM THE LATEST CRETACEOUS OF ROMANIA

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Although most famous for their gigantic size, titanosaurs also comprise some of the smallest sauropod dinosaurs, including the dwarfed taxon *Magyarosaurus*, from the latest Cretaceous of Romania. The latter genus was one of the earliest titanosaurs to be discovered, but is yet to receive any modern treatment of its anatomy, taxonomy, or phylogenetic affinities. Although the latest Cretaceous of Romania has yielded a rich sauropod fossil record, skeletal associations are rare. The type species, *Magyarosaurus dacus*, is currently restricted to a caudal vertebra, whilst '*Magyarosaurus*' *hungaricus* is known only from a tibia and fibula. As such, *Magyarosaurus* has been largely excluded from analyses and discussion of titanosaurian evolutionary and biogeographic history. Detailed study of historical and undescribed remains enables us to build composite OTUs from a small number of overlapping, partial skeletons. We are able to refer multiple axial and appendicular remains to *Magyarosaurus dacus*. These include a tibia and fibula, which differ notably from the unusual morphology that characterizes '*M.*' *hungaricus*, otherwise known only in a small number of South American titanosaurs. Referrals of additional appendicular remains to the latter taxon enable us to further differentiate it from *M. dacus*. A poorly preserved partial skeleton with a distinct morphology demonstrates the presence of a large-bodied titanosaur, showing that this sauropod fauna was not solely composed of dwarfs. A fourth contemporaneous taxon, *Paludititan nalatzensis*, can be differentiated from *Magyarosaurus dacus*, but does not overlap with '*M.*' *hungaricus*. Unfortunately, many elements still cannot currently be referred to any taxon because of a lack of anatomical overlap. These include a well-preserved braincase. CT-scans of its internal anatomy, as well as study of its external morphology, reveal numerous differences with contemporaneous European titanosaurs. Phylogenetic analysis using TNT, based on a data matrix comprising 160 taxa scored for over 600 characters, indicates that *M. dacus*, '*M.*' *hungaricus*, and *Paludititan* are not closely related to one another. Our results support the presence of high sauropod diversity in the latest Cretaceous of Romania, and indicate a complex biogeographic assembly of this fauna. Alongside southwestern European taxa, our revision means that these Romanian sauropods can finally contribute to our understanding of the global distribution of titanosaurs, for which our biogeographic analyses indicate earlier events of geodispersal.

Grant Information:
Royal Society International Exchanges Award (IES\R1\180088)

Technical Session XVIII (Saturday, October 12, 2019, 1:45 PM)

3D-RECONSTRUCTION OF MULTIPLE SPECIMENS FROM THE LOWER CRETACEOUS OF CHINA REVEALS CHARACTER CO-EVOLUTION TOWARD THE BAUPLAN OF BASAL THERIANS

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Therians (marsupials, placentals, and their kin), multituberculates, and monotremes survived the K-Pg impact, but multituberculates went extinct in the Eocene. The survived monotremes are represented by only five species today, in sharp contrast to therians that account for nearly the entire diversity of extant mammals (*ca*. 6500 species), display a great disparity in size and shape, and successfully fill the vacant ecological niches left by non-avian dinosaurs. It was assumed that therians achieved this status owing to their unique body plan, but how such a body plan ancestral to therians evolved has remained little known because of poor preservation of fossils. Here we present a new species of basal therian based on multiple nearly complete skeletal specimens preserved in three dimensions. As revealed by μCT scan, many unequivocal and detailed features from these specimens show that during the evolution of mammals, the bauplan of therians must be accomplished through transformations of many key features in a mosaic fashion, such as transformation from the reversed-triangular molar to tribosphenic molar, detachment of the auditory bones from dentary to facilitate efficient hearing and chewing, elongation and coiling of the cochlear canals accompanied by development of various structures (e.g., the secondary bony lamina, reduced lagenar macula, and modified nervous and vascular systems), ossified and complicated nasal turbinals to cope with enhanced ventilation and endothermy, inflation of the olfactory bulbs, lateral expansion of cerebral hemispheres, dorsal expansion of braincase to differentiate of the midbrain, vermis and paraflocculi, and numerous changes in the postcranium to optimize the flexibility and agility of the animal body; all these took place in animals with miniaturized body mass and insectivorous diet. Under the working phylogenies of mammals, we would interpret that the new species shows a combination of morphologies, and inferred biology, representing the essential condition of therian bauplan that best fit the ecospace from the Cretaceous to the Cenozoic and led to the success of modern therians.

Grant Information:
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Technical Session VI (Thursday, October 10, 2019, 9:30 AM)

INTRINSIC CONSTRAINTS APPEAR TO UNDERLIE STRONG ALLOMETRIC PATTERNS IN AUSTRALIAN RODENT DIVERSITY

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Evolutionary biologists have studied allometry, or morphological variation as a function of size change, for almost a century and still debate whether intrinsic constraints or natural selection primarily drive strong allometric patterns in morphology. Theoretical research suggests it should be possible to distinguish between the constraint and selection-based hypotheses by observing patterns of static (within-species) and evolutionary (between-species) allometry. If evolutionary allometry is highly correlated with static allometry – even under intense diversifying selection such as those experienced during radiations – then this pattern supports the constraint hypothesis. As a model system, Australian rodents radiated into all major environments on the continent in under five million years, evolving diverse diets and locomotion. Despite this ecological variation, however, they have limited morphological variation, particularly in the cranium. Furthermore, Australian rodents span three orders of magnitude in size but most of their shape variation appears to be allometric. We performed 3D geometric morphometrics on 317 crania to test whether individual species and different genera had constant static and evolutionary allometric slopes, respectively. We used a time-calibrated, ultrametric tree to perform phylogenetically-corrected Procrustes ANOVAs. Among 38 species, 98.7% of pairwise comparisons of static allometric slopes were not significantly different. Among 14 genera, evolutionary allometries varied slightly, however, size and genus combined accounted for almost 67% of variation while their interaction term accounted for 6%. Recent research suggests that highly integrated animals – those with high covariation between modules within a structure – exhibit greater allometry and low allometric variation within a clade. Our results support the hypothesis that high integration in Australian rodent crania constrained their morphological evolution. Our results contrast with those from New World monkeys, which radiated under similar conditions to Australian rodents but have low cranial integration. These two mammalian clades could provide valuable systems for further untangling integration and allometry.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

SCIENTIFIC METHOD ON THE MOVE: GAMES AND INTERACTIVES CONVEY THE DYNAMIC, COLLABORATIVE NATURE OF SCIENCE

MARCY, Ariel E., University of Queensland, St. Lucia, Australia; WHITE, Lisa D., University of California Museum of Paleontology, Berkeley, CA, United States of America

Textbooks and lab reports often make science seem as straightforward as a recipe. Even peer-reviewed articles simplify the complex, iterative, and often unexpected combination of people, events, and scientific activities that produce a new finding. Communicating this reality engages students with a more dynamic and creative view of science's evidence-driven, problem-solving process. In 2008, the University of California Museum of Paleontology introduced their Understanding Science *How Science Works* flowchart, which organizes a variety of scientific activities into four interacting domains: Exploration & Discovery, Community Analysis & Feedback, Benefits & Outcomes, and centrally, Testing Ideas. As opposed to a recipe, the flowchart emphasizes the non-linear and never-ending cycle of scientific inquiry. The UCMP successfully supports classrooms worldwide with the *How Science Works* interactive flowchart, which encourages students to chart the paths of real scientific discoveries.
This year, we are collaborating on a new educational board game, Stunning Universe, which aims to introduce the *How Science Works* model into more informal education scenarios, such as museums, science camps, and family board game nights. Since games are systems that happen to be fun, the medium is ideal to engage players with a dynamic system of scientific inquiry. In Stunning Universe, players work together to investigate uncharted parallel universes teeming with aliens! Short "Science-ing Missions" gamify an activity from one of the four domains of scientific inquiry, such as, Community: Replicate a Finding. When one mission is completed, a player has some choice over which domain the next mission comes from. Their decision should take into account each player's special ability, the group's need to complete certain Main Objectives, and the ever-present challenge to use "Grant $$$" wisely (needed to move players' spaceships to experiment locations and to roll the Evidence Dice). Through the game, players model cooperative scientific decision-making as well as co-author a unique story of how specific people, chance events, and new evidence shaped their winding path to stunning scientific discoveries. With these interactive resources that emphasize the nature and process of science, our hope is that players are better able to value to essential elements of the scientific process.

Technical Session V (Wednesday, October 9, 2019, 2:45 PM)

THE SURROGATE ARM: FUNCTIONAL AND ECOLOGICAL DRIVERS OF NECK MORPHOLOGY IN EXTANT AVES

MAREK, Ryan D., University of Liverpool, Liverpool, United Kingdom

With the forelimbs primarily adapted for flight, the avian neck allows the head to perform a variety of tasks that would be carried out by the grasping hands of their dinosaur antecedents. This has created a strong additional selection pressure on the cervical column and has resulted in the evolution of a vast array of neck morphologies in extant birds. However, no quantitative assessment of this variation has been undertaken and as such there is little understanding of how the neck evolved to become such an important component of avian biology. Here I use a holistic approach to understand functional and ecological drivers in avian neck shape and length in a diverse selection (46 species) of modern birds by combining three-dimensional geometric morphometrics with multivariate statistics and quantitative dissection. I analysed the effects of ecology on the overall morphology of the avian cervical column by comparing cervical shape trajectories of a number of ecological groups (diet and locomotor mode) using Phenotypic Trajectory Analysis. Procrustes Distance phylogenetic Generalised Least-Squares models were used to assess the impact of ecological and functional factors (neck length, body mass and head mass) on the morphology of specific cervical regions. Results show that functional, not ecological, factors (particularly body mass and neck length) correlate with much of the variation in cervical morphology in different regions of the cervical column. Specialised species with ecologies that require radically different cervical motions (such as carnivores and piscivores) are the only ecological groups to show significant variation in cervical shape. Quantitative dissection reveals the muscles of these specialised groups have significantly different properties to other birds and these properties are linked to morphological variation in the vertebrae they attach to. Therefore, despite the appearance of abundant variability, the morphology of avian cervical column is actually highly generalised and only varies when specific cervical motions are required, such as for the tearing of flesh from prey in carnivorous taxa. The functional signal seen in both osteological and soft-tissue data instils confidence in future work that will investigate the evolution of the neck of dinosaurs and track the role of the cervical column as forelimbs adapt for flight in early birds.

Grant Information:
This project is funded by, and is part of, a NERC ACCE Doctoral Training Program.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

WHAT DO OSSIFICATION SEQUENCES TELL US ABOUT THE ORIGIN OF EXTANT AMPHIBIANS?

MARJANOVIĆ, David, Museum für Naturkunde, Berlin, Germany; LAURIN, Michel, CNRS/MNHN/Sorbonne Université, Paris, France; LAPAUZE, Océane, CNRS/MNHN/Sorbonne Université, Paris, France

The controversial origin of the extant amphibian clades has been studied using several sources of data and methods, including phylogenetic analyses of morphological data, molecular dating, stratigraphic data, and comparisons of ossification sequences. A consensus has failed to emerge, perhaps in part because the diversity of methods used hampers comparisons. We have compiled two datasets of ossification sequences of 101 extant and extinct terminal taxa and seven cranial bones, or 102 terminal taxa and six cranial bones. These data allow us to assess the relative support for six currently or recently competing hypotheses about the origin(s) of the most inclusive uncontroversial extant amphibian clades: a monophyletic origin among temnospondyls, a monophyletic origin among lepospondyls, a diphyletic origin among both temnospondyls and lepospondyls, a diphyletic origin among temnospondyls alone, and two variants of a triphyletic origin, in which anurans and urodeles come from different temnospondyl taxa while caecilians come from lepospondyls and are either closer to temnospondyls (including anurans and urodeles) or to amniotes. The data were analyzed through maximum likelihood, and the AICc (corrected Akaike Information Criterion) weights of the six hypotheses allow us to assess their relative support. By an unexpectedly large margin, our analyses of both datasets support a monophyletic origin among lepospondyls; a monophyletic origin among temnospondyls, the current near-consensus, is a distant second. All other hypotheses are exceedingly unlikely according to our data. Because we find a strong phylogenetic signal in the data, we are cautiously optimistic about future uses of ossification sequence data as characters in phylogenetic analyses.

Grant Information:
This work was supported by the Centre National de la Recherche Scientifique and the French Ministry of Research (unnumbered recurring grants to the CR2P, for ML).

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

A COMPARATIVE FUNCTIONAL ANALYSIS OF FORELIMB MORPHOLOGY IN AUSTRALIAN MARSUPIALS (MARSUPIALIA)

MARTIN, Meg L., Murdoch University, Murdoch, Australia; WARBURTON, Natalie M., Murdoch University, Murdoch, Australia; TRAVOUILLON, Kenny J., Western Australian Museum, Welshpool, WA, Australia; FLEMING, Trish A., Murdoch University, Murdoch, Australia

Digging is a common behaviour among Australian marsupials and monotremes from Australia, ranging from shallow diggings during foraging for subsurface food items to large scale burrow excavations for shelter and nesting. Functional adaptations for digging have been previously reported in both muscle anatomy and bone morphology for a range of species, however details of the covariation between these two integrated systems has not been comprehensively studied. Without a quantitative understanding of how muscle anatomy/architecture influences bone morphology, it is difficult to draw conclusions of the significance of many morphological traits of the skeleton. In this study, we investigated the relationships between muscle architecture and bone morphology in 12 Australian marsupial species, comprising both digging and non-digging representatives from three orders (Diprotodontia, Dasyuridae, and Peramelemorphia). Principal component analysis (PCA) was used to quantify the relationships between the forelimb musculature (muscle mass and physiological cross-sectional area) and bone shape (indices that reportedly represent digging behaviour, including index of fossorial ability (IFA) and epicondyle index (EI)). The PCA of both the muscle architecture and bone indices revealed that these quantitative measures successfully distinguish between non-digging and digging species, as well as between the three marsupial orders. The muscle architecture data and bone indices were correlated to varying degrees, indicating that the bone indices somewhat reflect observable differences in the muscle anatomy or development in response to adaptation for digging, though perhaps to a lesser

degree than might generally be inferred in the literature. Our study emphasises the importance of quantifying the relationships between these two integrated systems, and may assist in interpreting extant and extinct bony morphology to make more informed inferences of the potential musculature.

Grant Information:
Murdoch University

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

LATE JURASSIC SYNAPSIDS AND MAMMALS FROM THE LANGENBERG QUARRY (NORTHERN GERMANY)

MARTIN, Thomas, Universität Bonn, Bonn, Germany; AVERIANOV, Alexander, Zoological Institute of the Russian Academy of Sciences, St Petersburg, Russia; SCHULTZ, Julia A., Universität Bonn, Bonn, Germany; SCHWERMANN, Achim H., LWL-Museum für Naturkunde, Münster, Germany; WINGS, Oliver, Universität Halle-Wittenberg, Halle, Germany

The Langenberg Quarry near the town of Goslar yielded the first Jurassic mammal assemblage of Germany. The fossil bearing marls and limestones belong to the Süntel Formation that is well-dated as late Kimmeridgian by marine invertebrates. It was accumulated in a near shore area of the Lower Saxony Basin with influx of terrestrial sediments.
The diverse vertebrate assemblage of Langenberg Quarry includes chondrichthyan and osteichthyan fishes, marine turtles, a paramacellodid lizard, the small atoposaurid crocodylomorph *Knoetschkesuchus* and marine crocodyliforms, a pterosaur, the dwarfed sauropod *Europasaurus*, several theropod dinosaurs, two non-mammaliaform synapsids, mammaliaforms, and mammals.
The non-mammaliaform synapsids are represented by two postcanine teeth attributed to Trirachodontidae and Traversodontidae. The teeth represent the youngest record of non-mammaliaform eucynodonts worldwide, extending the range of Trirachodontidae and Traversodontidae by about 90 myr. For Trirachodontidae this is the first reliable record outside sub-Saharan Africa.
Morganucodontans are represented by a large upper molar of a new genus, being less than 10% smaller as the largest known morganucodontan specimen (lower molar of *Paceyodon davidi*). Docodontans are represented by upper and lower molar fragments and possibly one premolar. Multituberculates are most abundant and are represented by about two dozen isolated teeth. Three taxa occur, Paulchoffatiidae indet. (p4), the pinheirodontid *Teutonodon langenbergensis* (I3, M1, M2), and a new more derived paulchoffatiid (P3, ?4, P5, p3, and p4). The specimen formerly assigned to Eobaataridae indet. more likely belongs to the paulchoffatiid lineage. Cladotherians are represented by small dryolestid upper and lower molars resembling the teeth of *Amblotherium*.
Two phenomena of the Langenberg synapsid assemblage are recognizable caused by the paleogeographic situation of island isolation within the Late Jurassic European archipelago: (1) The late survival of trirachodontids and traversodontids (island relics) and (2) the large size of the new morganucodontan (island gigantism). Pinheirodontid and paulchoffatiid multituberculates represent endemic European clades that probably evolved on the Rhenish-Bohemian Massif and reached the Iberian Plate only in the Early Cretaceous.

Grant Information:
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Technical Session VII (Thursday, October 10, 2019, 11:30 AM)

A NEW, THREE-DIMENSIONALLY PRESERVED MONOFENESTRATAN PTEROSAUR FROM THE MIDDLE JURASSIC OF SCOTLAND AND THE COMPLEX EVOLUTIONARY HISTORY OF THE SCAPULO-VERTEBRAL ARTICULATION

MARTIN-SILVERSTONE, Elizabeth, University of Bristol, Bristol, United Kingdom; UNWIN, David M., University of Leicester, Leicester, United Kingdom; BARRETT, Paul M., The Natural History Museum, London, United Kingdom

The Middle Jurassic was a critical time in pterosaur evolution – a series of major morphological innovations underpinned radiations by, successively, rhamphorhynchids, basal monofenestratans, and pterodactyloids. Frustratingly, however, this interval is also one of the most sparsely sampled parts of the pterosaur fossil record, consisting almost exclusively of isolated fragmentary remains.
Here we report on the most complete individual found to date, a three-dimensionally preserved, partial pterosaur skeleton recovered in 2006 from the Bathonian-aged Kilmaluag Formation, near Elgol, Isle of Skye, Scotland. Micro-CT scanning, segmentation, and 3D-reconstruction using Avizo has revealed multiple elements of the axial column, fore-, and hind limbs, many of which were fully embedded within the matrix and inaccessible via traditional preparation and imaging techniques. Unique features of the coracoid distinguish the Skye pterosaur from all other species, indicating that it represents a new taxon. The new specimen was included in phylogenetic analysis that was conducted using maximum parsimony in PAUP on a data matrix consisting of 61 taxa scored for 136 morphological characters. This analysis generated 544,320 MPTs. The 50% majority rule tree places the Skye taxon as a basal monofenestratan in a clade with *Darwinopterus*, *Wukongopterus*, and, for the first time, *Allkaruen*, which was previously identified as non-monofenestratan. The Skye pterosaur, one of the earliest, most complete records for Monofenestrata, provides critical new insights into pterosaur evolution.
The distal end of the Skye pterosaur's scapula is expanded and articulated with the vertebral column, a feature shared with other basal mononfenestratans. Comparisons across Pterosauria show that this type of bracing was far more widespread than previously realized and seemingly present in many clades, with the exception of basal-most (Late Triassic) forms. The development of a notarium, providing additional stability and support, is confined to derived and often large and giant species and forms only part of the complex evolutionary history of the scapulo-vertebral contact.

Technical Session I (Wednesday, October 9, 2019, 10:45 AM)

MIOCENE BALEEN WHALES FROM THE PERUVIAN DESERT

MARX, Felix G., Monash University, Clayton, Australia; COLLARETA, Alberto, University of Pisa, Pisa, Italy; LAMBERT, Olivier, Royal Belgian Institute of Natural Sciences, Bruxelles, Belgium; DE MUIZON, Christian, Muséum national d'Histoire naturelle, Paris, France; URBINA, Mario, Museo de Historia Natural - Universidad Nacional Mayor de San Marcos, Lima, Peru; BIANUCCI, Giovanni, University of Pisa, Pisa, Italy

The Pisco Formation exposed in the Ica Desert of Peru is one the most fossiliferous Mid-Late Miocene lagerstaetten for marine mammals worldwide. A long-term field programme has produced a diverse and disparate assemblage of extinct toothed whales and dolphins (odontocetes), but only a relatively small number of baleen whales (mysticetes). Here, we provide an overview of the known baleen whale assemblage, and report several new forms representing at least three separate families.
Including our new material, the Pisco Formation has yielded at least 4 different rorquals, including *Balaenoptera siberi*, *Incakujira anillodefuego*, and two undescribed species; 5-6 cetotheriids, including *Piscobalaena nana*, *Tiucetus rosae*, *Cephalotropis* sp., one undescribed large-sized species, and the only named extinct neobalaenine, *Miocaperea pulchra*; and at least one stem balaenopterid, *Pelocetus* sp. Both rorquals and cetotheriids occasionally show signs of exceptional preservation, including phosphatised baleen and stomach contents. Despite the relatively young age of the Pisco deposits, right whales are curiously absent.
Together, the three allomembers of the Pisco Formation reveal considerable faunal turnover. Archaic cetotheriids and stem balaenopteroids dominate the lowest levels (P0 allomember), followed by large cetotheriids (lower P1 allomember) and finally a mix of small cetotheriids and abundant balaenopterids (upper P1 and P2 allomembers). Cetotheriids seem to decrease in size and relative abundance over time, and in concert with the rise of rorquals, mirroring similar patterns in the North Atlantic. Rorquals include a wide range of body sizes, including some latest Tortonian (7.55 Ma) and Messinian (6.93–6.71 Ma) specimens approaching 15–16 m in length. This size is comparable to that of most extant species, and suggests that modern gigantism arose gradually and relatively early, even though small species continue to dominate the overall assemblage.

Technical Session V (Wednesday, October 9, 2019, 3:15 PM)

A NEW LOOK AT THE LATE OLIGOCENE *PLATYDYPTES* PENGUINS OF ZEALANDIA

MATTS, Katie A., University of Otago, Dunedin, New Zealand; FORDYCE, Robert E., University of Otago, Dunedin, New Zealand

The dense bones of penguins are predisposed to fossilise, producing an excellent record of fossil penguins in ancient shelf sediments of Zealandia - proto-New Zealand. Of note is the endemic *Platydyptes*, one of the few described later Oligocene genera, which has been recovered mostly from the bioclastic Otekaike Limestone of Hakataramea, Waitaki region. Other studies have identified *Platydyptes* as one of the most crownward of the stem penguins, showing it as a precursor for the crown radiation of penguins. First named by Marples in 1952 the genus was last reviewed by Simpson in 1971. Since then new material including partially articulated skeletons, as well as

isolated bones, have been collected. Initially separated from each other by the size of the humerus of mature birds, the three named species appear to be distinct: *P. novaezealandiae* (humerus length = 104mm), *P. amiesi* (hl = 117mm), and *P. marplesi* (hl = 93mm). New material from Hakataramea, including OU22804, has shown an unnamed possible fourth species with a humerus (hl = 119mm) distinctly broader than the three named species.
Specimen OU22804 is a semi-articulated, partially-complete skeleton from the Otekaike Limestone (Waitakian, latest Oligocene), including several rarer elements; a partial mandible indicates a long spear-like bill, and a quadrate is comparable to *Kairuku.* OU22116 is also a partial skeleton which has both humeri and the taxonomically diagnostic tarsometatarsus. These partial skeletons alongside the holotypes of the genus have been key in redescription of the genus. Species of *Aptenodytes* (modern King and Emperor penguins), of similar size to *Platydyptes*, have helped with reconstruction of the body plan of *Platydyptes*, especially for interpolating incomplete vertebral columns, information valuable in revealing insight on structure, systematics and lifestyle of *Platydyptes*.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

UNEARTHING A GIANT: THE MAKING OF ZUUL

MAY, Peter, Research Casting International, Trenton, ON, Canada, K8V5C8; EVANS, David, Royal Ontario Museum, Toronto, ON, Canada; MADILL, Amelia, Research Casting International, Trenton, ON, Canada; FAIR, Matt, Research Casting International, Trenton, ON, Canada

In June of 2014 a huge sandstone block containing a large armoured dinosaur was excavated in Hill County, Montana U.S.A. Parts of the skeleton had been exposed while quarrying for a medium sized theropod that was lying on top of this skeleton.
A skull, tail club, articulated vertebrae and partial ribs were exposed in the field, small patches of skin impression, preserved armour plates and keratin indicated that there was something special to be uncovered.
In January of 2018 preparation of the Zuul body block got underway and exposed the skeleton from the hip to the base of the neck in articulation, a mold was taken, the block jacketed and a steel frame built. The block was then drilled through and cut in half with a diamond rope saw, lifted and flipped so the reverse side could be prepared, once prepped a fantastic representation of soft tissue in articulation with the skeleton was exposed.
The skeleton was then reconstructed using the information uncovered, this is the first time armour was placed in correct association and pattern on a mounted skeleton.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE FIRST PECTORAL AND FORELIMB MATERIAL ASSIGNED TO THE LAGERPETID *LAGERPETON CHANARENSIS*: COMPARING TO OTHER LAGERPETIDS AND OTHER AVEMETATARSALIANS

MCCABE, Mason B., Virginia Tech, Blacksburg, VA, United States of America; NESBITT, Sterling J., Virginia Tech, Seattle, WA, United States of America

The posture of the earliest dinosaurs is thought to be bipedal whereas their pseudosuchian relatives and stem archosaurs are thought to be typically quadrupedal. Therefore, the transition from quadrupedality to bipedality lies somewhere between the origin of Avemetatarsalia (bird-line archosaurs) and Dinosauria. However, studying this transition is hampered by the lack of forelimb fossils from many of the close relatives of dinosaurs and it is not clear if the morphology of the few dinosauromorphs that have forelimb material are unique or represent the plesiomorphic condition leading to dinosaurs. New forelimb fossils of dinosaur relatives and careful assessments of their osteology is sorely needed to help address this knowledge gap. Here we present the first pectoral (left scapulocoracoid) and forelimb (right humerus) bones of the important early dinosauromorph *Lagerpeton chanarensis*. The bones were prepared from a concretion that only consisted of *Lagerpeton* bones and from the cynodont *Massetognathus*. We identify the bones as belonging to *Lagerpeton* because the distal end of the femur possesses an inflated crista tibiofibularis – a lagerpetid character state – and the newly recognized pectoral and forelimb bones are generally similar to those of the lagerpetid *Dromomeron romeri* and *Ixalerpeton* with tall and constricted anteroposteriorly narrow scapular blade and a humerus with a highly asymmetrical proximal part of the humerus. The scapulocoracoid of *Lagerpeton* has a tall, but anteroposteriorly narrow scapular blade more like *Dromomeron romeri* than *Ixalerpeton*. The length of humerus and the proportions of the proximal and distal end in *Lagerpeton* are also more similar to that of *Dromomeron romeri*. Overall, the scapulocoracoids and humeri of lagerpetids are similar in proportion across taxa, but comparing the length of the forelimbs to the hindlimbs is hampered by the lack of articulated or unambiguously associated individuals of any member of the group. Currently, it is still not clear if the anatomy of the pectoral girdle and forelimb of lagerpetids, and thus posture, is unique for lagerpetids or represents the ancestral condition for dinosauromorphs.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 8:30 AM)

NEW EVIDENCE FOR THE AFFINITY OF THE MAZON CREEK PROBLEMATICUM *TULLIMONSTRUM GREGARIUM*

MCCOY, Victoria E., University of Wisconsin, Milwaukee, Milwaukee, WI, United States of America; WIEMANN, Jasmina, Yale University, New Haven, CT, United States of America; LAMSDELL, James C., West Virginia University, Morgantown, WV, United States of America; WHALEN, Christopher D., Yale University, New Haven, CT, United States of America; LIDGARD, Scott, Field Museum of Natural History, Chicago, IL, United States of America; MAYER, Paul, Field Museum of Natural History, Chicago, IL, United States of America; PETERMANN, Holger, Yale University, New Haven, CT, United States of America; BRIGGS, Derek E., Yale University, New Haven, CT, United States of America

The affinity of *Tullimonstrum gregarium*, the Tully Monster, from the Late Carboniferous Mazon Creek biota remains a matter of contention. Recent investigations placed it within vertebrates, but it has also been compared to annelids, arthropods and molluscs. These morphological analyses have yet to resolve the question of *Tullimonstrum* affinity; however, chordates, annelids, arthropods, and molluscs differ in the composition of their tissues – specifically teeth and mouthparts – suggesting that biomolecular analysis may provide relevant new information. The composition of the teeth of *Tullimonstrum* would particularly be useful for distinguishing between the two best supported morphological hypotheses: chordates have teeth composed of keratin, a protein, and molluscs have radula teeth composed of chitin. Here we investigate the composition of *Tullimonstrum* teeth using Raman microspectroscopy and compare them to those in other Mazon Creek animals: chordates and annelids (jaws) to represent proteinaceous tissues; and arthropods, annelids (setae) and a mollusc to represent chitinous tissues. The Raman bands were not interpreted directly, but rather the whole spectra were compared using principle components analysis (PCA) to determine if the teeth of *Tullimonstrum* are more similar to fossilized proteinaceous material, or fossilized chitinous material. PC 2 separates the definite fossilized proteinaceous tissues from the definite fossilized chitinous tissues into two non-overlapping groups; the *Tullimonstrum* samples overlap with the proteinaceous group but not the chitinous group. Therefore, *Tullimonstrum* teeth were similar in composition to the keratin/collagen tissues of chordates and annelid jaws and differ from the chitinous tissues in the mouthparts arthropods and molluscs and the setae of annelids. These results support a chordate identity for *Tullimonstrum.*

Grant Information:
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Technical Session IV (Wednesday, October 9, 2019, 2:00 PM)

THE REPEATED EVOLUTION OF APICOBASAL RIDGES IN AQUATIC-FEEDING AMNIOTES

MCCURRY, Matthew R., Australian Museum/UNSW, Sydney, Australia; EVANS, Alistair R., Monash University, Melbourne, Australia; FITZGERALD, Erich M., Museums Victoria, Melbourne, Australia; MCHENRY, Colin R., Monash University, Melbourne, Australia; BEVITT, Joseph, ANSTO, Sydney, Australia; PYENSON, Nicholas D., National Museum of Natural History, Washington, DC, United States of America

Over the last 250 million years, Earth's aquatic ecosystems have been ecologically dominated by numerous lineages of predatory amniotes. Many of these groups evolved elevated ridges of enamel that run down the apical-basal axis of their teeth, referred to here as apicobasal ridges, striations or dental ridges. While this trait is commonly used as a taxonomic tool to identify fossil species and higher groupings, the function of the ridges and their associated ecological significance is poorly understood. Here we aim to clarify the phylogenetic distribution of apicobasal ridges among amniotes and to examine how the morphology of apicobasal ridges varies across species. We undertook a survey of museum specimens to examine the occurrence of the trait, and micro CT scanned specimens to examine their external and internal morphology. We show that these ridges have evolved independently numerous times and are almost exclusively found in aquatic-feeding species. Ridge morphology varies, including tall pronounced ridges, low undulating ridges and interweaving ridges. Their internal structure also varies from tooth

crowns with locally thickened enamel to undulating enamel-dentine interface. Ridges are extremely uncommon in terrestrial feeding taxa, indicating that the function of these ridges is specific to some aspect of aquatic-feeding. We find that apicobasal ridges evolve on the surface of a wide variety of tooth morphologies including those that are not normally associated with high loading regimes. Furthermore, ridge height, ridge width or the number of ridges are not correlated with characteristics associated with durophagy (thickened enamel or robust teeth). Based on these findings we propose that the ridges do not primarily serve to strengthen the tooth but instead function to either improve grip, removal efficiency and/or puncture efficiency.

Grant Information:
We would like to acknowledge the support of a Peter Buck Predoctoral fellowship, the Remington Kellogg Fund and the Basis Foundation.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 10:30 AM)

THE PRE-EUROPEAN MAMMALS OF TASMANIA: WAS THE BASSIAN PLAIN A BRIDGE OR BARRIER?

MCDOWELL, Matthew, ARC Centre of Excellence for Australian Biodiversity and Heritage, University of Tasmania, Hobart, Australia

Tasmania, Australia's largest continental island, was connected to mainland Australia about 75,000 years ago when global cooling caused sea-level to fall. The resulting land-bridge, known as the Bassian Plain, connected Tasmania to mainland Australia for some 60,000 years, allowing mainland mammals to colonise Tasmania and vice versa. About 14,000 years ago terminal Pleistocene global warming resulted in rapid sea-level rise that flooding the Bassian Plain and isolated Tasmania from mainland Australia.
Several iconic species, including the Thylacine (*Thylacinus cynocephalus*) and Tasmanian devil (*Sarcophilus harrisii*) and 'endemic' species, the Tasmanian pademelon (*Thylogale billardierii*) and Long-tailed mouse (*Pseudomys higginsi*), persisted or continue to flourish in Tasmania long after their mainland populations were extirpated. However, despite an abundance of suitable habitat and thousands of years of access, 16 mammals that occupy southern Victoria today do not occur in Tasmania's Holocene or modern fauna. These consist of the Long-nosed Bandicoot (*Perameles nasuta*), Koala (*Phascolarctos cinereus*), Swamp wallaby (*Wallabia bicolor*), 5 carnivorous marsupials, 4 possums/gliders and 4 rodents, including the Bush rat (*Rattus fuscipes*), the best generalist murid in southern Australia. Were these species extirpated following the arrival of indigenous Australians, extinction of Australia's megafauna or during the Last Glacial Maximum?
Ongoing research on late Quaternary fossil assemblages from Tasmania, key Bass Strait Islands and Victoria suggest that the Bassian land-bridge may have allowed species to move north more easily than south suggesting that, at least for mainland species, the Bassian Plain may have acted more like a barrier than bridge.

Grant Information:
This research is supported by the Australian Research Council Centre of Excellence for Australian Biodiversity and Heritage

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

PEDAL CLAW MORPHOLOGY OF *CONFUCIUSORNIS SANCTUS* AND ITS IMPLICATIONS FOR DIET AND BEHAVIOR

MCINTOSH, Annie P., University of Alberta, Edmonton, AB, Canada

Confuciusornis sanctus is an Early Cretaceous bird from the Liaoning Province of northeastern China. Although much work has been published on this species, details of its diet and behavior remain unclear. Geometric morphometric analyses allow for the separation and comparison of specimens based on morphological variables. A geometric morphometric analysis was performed on the second pedal ungual of *C. sanctus* to determine how its morphology compares to that of extant birds and to elucidate details of its diet and behavior. A total of 128 specimens was examined, comprising 104 extant bird species and *C. sanctus*. Three fixed landmarks and 50 sliding semilandmarks were used to define shape. A principal component analysis yielded a principal component one that explained 56% of the variation among specimens and varies in the angle of claw curvature and sharpness of the claw tip. This, along with variation in centroid size, separates the extant taxa into three major behavioral groups: arboreal, terrestrial, and raptorial. The claw morphology of *C. sanctus* is dissimilar to extant raptorial birds, indicating that it was likely not using its claws to capture prey. *C. sanctus* falls within the claw morphology of extant birds displaying arboreal behavior, but is also similar to extant terrestrial birds. Additionally, the robust, toothless beak of *C. sanctus* is suited to a granivorous or piscivorous diet. Based on this, as well as reconstructions of the Jehol ecosystem as a heavily forested lacustrine environment, it is likely that *C. sanctus* spent most of its time foraging for seeds and invertebrates in densely wooded areas and fishes at the edges of shallow lakes. This indicates that *C. sanctus* may have been more of an omnivorous and opportunistic feeder, similar to modern crows.

Technical Session X (Friday, October 11, 2019, 12:00 PM)

QUANTITATIVE ANALYSIS OF ONTOGENETIC VARIATION IN THE DENTITION OF THE GREAT WHITE SHARK (*CARCHARODON CARCHARIAS*) WITH IMPLICATIONS FOR THE SHARK FOSSIL RECORD

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Isolated fossil shark teeth are often used to identify fossil specimens to the level of genus or species, but these identifications can be complicated due to the degree of morphological variation expressed by the teeth. Some Recent sharks have been shown to exhibit a considerable degree of ontogenetic variation, including the Great White Shark, *Carcharodon carcharias*. We qualitatively and quantitatively evaluated the level of morphologic variation present in a complete set of jaws from a neonate (152 cm total length) *C. carcharias*. From a qualitative descriptive perspective it is clear that there is a great deal of variation expressed in the neonate jaws – for example, lateral cusplets were inconsistently distributed across the teeth, and serrations varied considerably in size and number. We then employed landmark-based geometric morphometrics to more rigorously compare the morphologic variation present in the neonate jaws with respect to several jaw sets from adult *C. carcharias*. While there was some overlap in morphology, overall the neonate jaws expressed different shapes, and a greater variation of those shapes, than what we observed in the adult teeth. We also used landmark-based geometric morphometrics to compare the neonate teeth with isolated shark teeth from various other fossil and extant shark species. We found that some species, particularly Neogene lamnid and carcharhinid sharks, expressed a considerable degree of shape overlap with the neonate teeth. The qualitative similarity and quantitative overlap between the neonate shark teeth and certain specimens of the isolated fossil teeth from other lamnid and even non-lamnid species highlights that considerable caution must be exercised when identifying and drawing broader systematic conclusions from fossil sharks using only isolated teeth.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

A PLEISTOCENE VERTEBRATE FAUNA FROM A GROUND SLOTH SITE, GYPSUM CAVE, NEVADA, U.S.A.

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The 1930's excavation of Gypsum Cave, Nevada yielded both archaeological artifacts and paleontological fossils *in situ*, indicating the potential for contemporaneous existence and possible interaction of extinct megafauna and humans at this site. In addition to stratigraphic association, some of the fossils from varying depths exhibit coloration change due to burning, possibly from human activity. Due to the xeric environment the vertebrate fossils retain soft tissue remains such as muscles, tendons, skin, and claw sheaths. Hair and about 20 crates of fibrous dung originating from the Shasta ground sloth, *Nothrotheriops shastensis*, were also collected from the site. Since the original publications in the mid-1930s, surprisingly little research has been conducted on the Gypsum Cave collection.
Supported by a grant from the Bureau of Land Management, the Natural History Museum of Los Angeles County embarked on a project to finish the curation of the collection, making it more available to the scientific community. The predominant taxon of the cave is *N. shastensis* and the occurrence of juvenile or even possibly neonate specimens along with the copious dung indicates Gypsum Cave was a significant occupation site for this ground sloth. At least 27 taxa of amphibians, reptiles, birds, and mammals are represented in the cave fauna. Snakes are the most diverse group among the identified taxa with 4 species of colubrids and 3 species of rattlesnakes: western diamondback, *Crotalus atrox*; speckled rattlesnake, *C. mitchelli*; and Great Basin rattlesnake, *C. viridus*.
Using accelerator mass spectrometry, the ground sloth dung was dated to the Rancholabrean Pleistocene with an age of 19,875 ± 215 years before present. In addition to the age of the dung, burnt bone analysis does not support the contemporaneity of ground sloth and humans at Gypsum Cave. Plant DNA sequences gathered from the dung boluses illustrate the consumption of seven plant groups, some of which are currently found only at higher elevations than those of the cave today. The elevation change

indicates a cooler and possibly wetter more humid paleoclimate during the late Pleistocene in Southern Nevada.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

PRESERVATION AND PALEOBIOLOGICAL APPLICATIONS OF FOSSIL VERTEBRATE INTEGUMENT: INSIGHTS FROM TISSUE ULTRASTRUCTURE, CHEMISTRY AND TAPHONOMIC EXPERIMENTS

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The vertebrate integument underpins a spectrum of critical biological functions that include homeostasis, mechanical protection and coloration. Evidence of preserved integumentary structures in vertebrate fossils therefore has the potential to inform on the evolution of key anatomical innovations and associated ecological transitions. Fossilized integument typically preserves as mineralized replacements or carbonaceous residues; the latter often contain melanosomes, cellular organelles rich in the decay-resistant pigment melanin, but rarely preserve evidence of degraded keratinous tissue parts. Previous studies have focussed on the application of these tissue components to studies of original integumentary colour and the evolution of feathers, but major questions remain regarding the biology of melanosomes and the taphonomy of melanosomes and keratins. Here I will present recent and current work that sheds light on these major issues, with broad implications for interpretations of the soft tissue anatomy, physiology and behaviour of fossil vertebrates.

Grant Information:
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Technical Session III (Wednesday, October 9, 2019, 2:45 PM)

THE LATE QUATERNARY ECOLOGICAL EVOLUTION OF COYOTES AS EVIDENCED FROM RANCHO LA BREA

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Coyotes are the most common canid predator of small prey in North America. However, with their flexible social structure and labile prey preference, coyotes have not been confined to a single predatory niche for their evolutionary history. Previous morphological studies have found that Pleistocene coyotes were larger and more robust than they are today. Here, we use multiple lines of evidence from the coyotes at Rancho La Brea (RLB) to build the most comprehensive picture of coyote ecological change to date. These data comprise cranial and postcranial morphology and stable isotopes tied to a precise radiocarbon chronology. We obtained radiocarbon dates and stable isotopic values on bone collagen of 121 coyote mandibles from five pit deposits at RLB: Pits 10, 3, 13, 61/67, and 91. We collected morphological measurements on these mandibles as well as on 537 postcranial elements (stylopodials, zeugopodials, and metapodials) from unassociated coyote skeletons from these deposits. Dated specimens spanned 45,000 to 750 years before present. Cranial morphological data from these specimens confirm that coyotes were larger in the Pleistocene, however mandibular shape does not change in a way that would suggest major dietary differences. Postcranial morphological results do suggest ecological differences, confirming that Pleistocene coyotes were larger overall, as well as more robust and less cursorial than modern coyotes, mirroring trends observed in wolf evolution. Pleistocene coyotes have significantly higher $\delta^{15}N$ values than early Holocene coyotes from RLB ($p<0.001$), showing a precipitous decline in nitrogen values at approximately 10Ka. Bone collagen $\delta^{13}C$ values were significantly lower in Pleistocene coyotes than in early Holocene coyotes from RLB ($p<0.001$), suggesting a shift in prey to animals occupying more open environments. Declining $\delta^{15}N$ values are consistent with a shift to the consumption of smaller prey (which also have lower $\delta^{15}N$ values relative to vegetation consumed) and/or increased consumption of plants. The coyotes we observe today – highly opportunistic carnivorans known to consume small mammals, scavenge on carcasses, and eat a variety of plant resources (fruits and seeds) – are a post-Pleistocene phenomenon, and potentially a result of the extinction of numerous megafauna on the landscape.

Grant Information:
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Technical Session III (Wednesday, October 9, 2019, 3:45 PM)

ON THE FORM, MOVEMENT RANGE AND FUNCTION: CONSTRUCTING A MORPHOFUNCTIONAL SPACE FOR THE EXCAVATION MOTOR GESTURE FOR THE FORELIMB OF *CARAGUATYPOTHERIUM MUNOZI* (NOTOUNGULATA; MESOTHERIIDAE)

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How do animals move? The answer to this question in paleontology is problematic since similar morphologies may produce a variety of functions and the opposite might be true as well, hence there is no a single response. A way to tackle this problem is to determine the maximum and minimum movement boundaries within a Morpho Functional Space (MFS). *Caraguatyphotherium munozi* is an example of a midsize terrestrial mammal, with no modern relatives nor functional homologues. Therefore, we start exploring its motor capabililities for a forelimb digging capacity, which is aledged for other members of its Mesotheriidae family, and we compare it to a wide range of animals. Our aim was to construct an MFS considering the Effective Mechanical Advantage (EMA) of mainly wrist and elbow, as well as the Degree of Freedom joint (DFJ) in the wrist. To calculate the EMA, we obtained anatomical measurements related to the elbow extensor muscles moment arm (distance from the elbow to the tip of the olecranon) and the wrist flexor muscles (distance from the wrist to the insertion of the carpal flexors). To determine the moment arm of the ground reaction force, we obtained the distance from both, wrist and elbow joints, to the distal end of the third phalanx of digit III. This study includes 5 different Mesotheriidae specimens, including *C. munozi*'s Holotype, and 38 specimens from 21 families of modern mammals, classified by their known locomotor habit. The DFJ of maximum extension and flexion were obtained from the curvature of the conjoint surfaces and results compared to the recorded kinematics of *Vombatus ursinus* while scraping a soil surface. *C. munozi* shows that EMA is ≈8% lower than a conventional forelimb model developed with the extant data. On the other hand, EMA at the wrist is about 10% higher in all Mesotheriidae *versus* the modern ones, and *C. munozi* reaches up to 30% more. The wrist extension in *V. ursinus* is significantly superior to the one of *C. munozi* ($p=0.021$). We conclude that *C. munozi* shows a markedly different motor capacity to other mammals, with a lower extensory movement range and higher mechanical advantage for the wrist flexor muscles, conditioning it to a wrist powered excavation movement.

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Technical Session VIII (Thursday, October 10, 2019, 2:15 PM)

EVOLUTION OF THE MAMMALIAN JAW JOINT AND MIDDLE EAR AT THE STAGE OF BASAL THERIANS

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In non-mammalian cynodonts, a complex of jaw bones had functioned for jaw articulation, thus mastication, as well as for sound transmission to the innerear in hearing. During the evolution toward mammals, these jaw-joint bones reduced the size and were detached from the dentary. The latest stage of this evolutionary transition has been documented in fossils of eutriconodontans and symmetrodontans, which are taxa presumably basal to therians. This latest stage is characterized by the transitional mammalian middle ear (TMME) in which the malleus (articular and prearticular) and ectotympanic (angular) have detached from the dentary but still retained significant contact with the ossified Meckel's cartilage (OMC); the OMC was anteriorly lodged in the Meckelian groove on the rear medial surface of the dentary. Although it

considerably differs from the ancestral condition, such as that of *Morganucodon*, the configuration of TMME indicates that hearing and chewing in basal therians are still associated, contrasting to the condition in crown therians where these two functions and related structures are fully separated. Here we report a new Cretaceous species of basal therians that casts new light on the end stage of TMME or the beginning stage of the definitive mammalian middle ear (DMME). The new species shows that the animals died at rest, probably in sleeping. High-resolution micro-CT and painstakingly preparation of the specimens reveal structures critical for understanding jaw joint (chewing) and middle ear (hearing) evolution. The specimens show well-developed OMCs and their distinct residential groove on the dentary bone. More importantly, the well-preserved auditory ossicles (the stapes, incus, malleus, surangular, and ectotympanic) are nearly in situs and show many detailed morphologies unknown previously, such as the process for insertion of the stapedius muscle on the stapes and the ratio of the stapedial footplate to the tympanic membrane (as estimated from the frame well-formed by the auditory bones). In comparison with many Mesozoic forms that have the internal groove on their dentary, it is clear that some of the grooves are not the host for the OMC and that separation of the auditory bones from the dentary and/or the OMC must have evolved multiple times within mammals. It is also clear that the final separation of the hearing and chewing functions were affected by various factors, including body size, chewing pattern, insectivorous diet, and selective pressure for hearing of high frequency sounds.

Grant Information:
National Natural Science Foundation of China (41688103, 41404022) and the Kalbfleisch Fellowship, Richard Gilder Graduate School, AMNH.

Technical Session VIII (Thursday, October 10, 2019, 3:15 PM)

LARGE SCALE STUDY OF THE BONY LABYRINTH: A 3D GEOMETRIC MORPHOMETRICS ANALYSIS OF THE RUMINANT INNER EAR EVOLUTION

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The inner ear is the sensory receptor for balance and hearing. It has been shown in various placental mammals (e.g., humans, cetaceans, ruminants) that its bony capsule, the bony labyrinth, fully ossifies long before birth, at around mid-gestation. In placentals, after ossification is achieved, its shape and size will not change during life. Published analyses, based on 3D geometric morphometrics, revealed a low intraspecific variability, but a clear disparity at higher taxonomic levels. While numerous studies show ecomorphological interests for this structure, there is a growing consensus in many taxa that bony labyrinth morphology is also related to its phylogenetic history.
Here we present the first large scale bony labyrinth analysis (220 specimens of 140 species) of the ruminant bony labyrinth using 3D geometric morphometrics. This analysis encompasses 45 million years of ruminant history, and includes all extant families and tribes of ruminant (55 living species) as well as extinct families (85 extinct species). Morphological characters related to the insertion of the semi-circular canals or to the overall shape of the cochlea allow distinction between the different families of ruminant and help to understand the gradual evolution of this structure through time. The bony labyrinth of the Tragulidae, the only living non-Pecora, can be notably distinguished from the other living ruminants by a longer cochlea and an insertion of the lateral canal at the base of the common crus. Within the Pecora lineage, we observe a gradual modification of the insertion of the lateral semi-circular canal. From the anterior part of the posterior ampula in Stem Pecora, Antilocapridae, and giraffe-like Paleomerycidae, it inserts directly into this ampula within Cervidae, and posterior to it in Bovidae and Moschidae. It is interesting to note that the shape diversity observed in New world deer is higher than in the Old World ones reflecting their large diversity linked to a fast Plio-Pleistocene radiation. In addition, the shapes of the lateral semi-circular canal and of the fenestra vestibuli as well as the shape of the cochlea also seem to be correlated to environmental parameters.
The bony labyrinth is a high-potential tool to investigate both the phylogeny and the ecology of living and extinct animals.

Grant Information:
This study was founded by the Swiss National Science Foundation (project n° 200021_159854/1 and 200021_178853).

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 11:15 AM)

A PHYLOGENETIC SIGNAL RETAINED IN FOSSIL SOFT TISSUES PLACES (STEM) TURTLES IN THE REPTILE TREE OF LIFE

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Fossilization transforms vertebrate soft tissues via oxidative crosslinking into chemically stable and distinct fossilization products. The most abundant structural compounds in vertebrate bone are proteins which generate characteristic S-/N- and O-heterocyclic polymers during diagenesis. In living animals, proteins do not only constitute morphology, but also represent translation products of the genetic code – a prime resource for the understanding of organismic relationships. Do protein fossilization products (PFPs) record only detailed micromorphology, or also phylogeny? Here we explore potential phylogenetic signals preserved in a carefully selected set of fossil bones. Reptiles are well represented in the fossil record, and have a fairly well-known phylogeny with potentially interesting wild card taxa, such as turtles. Turtles supposedly diverged from their ancestors in the Permian, and while morphology of crown and stem turtles, and sequence analyses of crown turtles are contentious, “molecular” analyses of fossil stem turtles might offer a complementary, long-sought solution: we aim to use potential phylogenetic information in bone PFPs to elucidate phylogenetic affinities of stem turtles within reptiles.
Using *in situ* Raman Microspectroscopy (520 nm laser, 10s, 10 accumulations, 1800 grating), we analyzed compositional heterogeneities preserved in PFPs of bones across all major reptile clades. Fossil samples were selected for their brown-blackish color and oxidative depositional environments (deduced from the mineral composition of the host rocks). Raman spectroscopic data were obtained under identical conditions, and selected for PFP-diagnostic peaks which were transformed into a variance-covariance matrix. Based on this reptile PFP matrix we ran a Principal Components Analysis to identify trends in compositional heterogeneities, in a first run without any turtle samples, and in a second run including turtle samples. Within the first ChemoSpace a distinct grouping is observed separating archosaurs from lepidosaurs, suggesting preservation of a phylogenetic signal in our reptile PFP sample. In our second ChemoSpace, stem and crown turtles fall within the archosaur cluster. Lending support to the popular idea of an archosaurian affinity of turtles, as either sister to or nested within the group. Adding more stem turtles to the data set might help to further pinpoint the position of turtles within the reptile tree of life by exploiting the phylogenetic heterogeneities preserved in their fossil soft tissues.

Technical Session XIX (Saturday, October 12, 2019, 3:30 PM)

PLANT EVOLUTION AND DIVERSIFICATION SHAPED VERTEBRATE ECOSYSTEMS DURING THE LATE CRETACEOUS AND EARLY PALEOGENE IN WESTERN NORTH AMERICA

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The evolution and diversification of plants through the Late Cretaceous and into the Early Paleogene shapes the evolution and turnover in dinosaur- and placental mammal-dominated ecosystems. Fossil floras from this interval provide important insights into i) the evolutionary history of angiosperms, particularly as new food sources for vertebrates, ii) the compositional turnover of forest ecosystems, and iii) the extinction of plants at and following the Cretaceous-Paleogene (K-Pg) mass extinction.
During this critical time interval in Western North America, a nearly continuous stratigraphic record provides an excellent framework in which to study the short- and long-term changes in vegetation at a continental scale. Studies show an explosion of angiosperm species in the middle Cretaceous at low latitudes, the penecontemporaneous taxonomic demise of other major clades of plants, and then a steady northward migration of angiosperm diversity through the Late Cretaceous. By the Campanian, most fossil floras in channel or near-channel deposits are dominated by broad-leafed, woody dicot angiosperms. Some megafloras from ash falls show that while angiosperms diversified through the Late Cretaceous, they may have continued to occupy a relatively limited ecological niche. Ponds show a diverse aquatic flora and demonstrate that conifers were an important component of back swamp settings.
Mega- and palynofloras across the K-Pg event suggest that Cretaceous forests were diverse and heterogeneous and had few taxa in common with Paleocene

forests, which were depauperate and homogenous. This pattern is best-documented in the Williston and Denver Basins (North Dakota and Colorado, respectively), where ~50% of angiosperm leaf species and ~30% of palynomorph species disappear at the K-Pg boundary, demonstrating an instantaneous extinction with little evidence of preceding ecosystem stress. New floras from the Denver Basin that lived during the post-K-Pg extinction recovery phase indicate that pulsed climatic warming correlates with increased plant species richness and the immigration of energy-rich fruit types both of which may have supported the diversification of mammals in the Early Paleogene.

Preparators' Session (Thursday, October 10, 2019, 1:45 PM)

PITFALLS AND SUCCESSES: THE EVOLUTION OF THE NATIONAL MUSEUM OF NATURAL HISTORY (SMITHSONIAN INSTITUTION) PALEOBIOLOGY COLLECTIONS VOLUNTEER CATALOGING PROGRAM

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As 60-70% of the workforce, the volunteers at the Smithsonian National Museum of Natural History Department of Paleobiology have an enormous impact. Historically, volunteers worked with department research staff to assist with their projects, but with a renewed focus on creating accessible, high quality digital collections records to support research we determined that integration of a larger volunteer program was necessary. Establishing this program came with many challenges and lessons learned that ultimately led to a successful volunteer effort for collections digitization.

An early brachiopod cataloging project proceeded slowly due to numerous organizational problems with the collection and highly complex data that required constant supervisorial input to resolve transcription and data quality issues. These challenges resulted in an average of 6,000 new records per year. To help curb these issues, we created a four-hour volunteer evaluation which included an hour of training, a packet of relevant information, a detailed workflow, and a cataloging exam covering a suite of specimens that ranged in difficulty entering data. Prospective volunteers that used the workflow, asked questions, could work independently, and were detail driven became catalogers.

In addition to improving volunteer vetting, we revaluated the projects given to volunteers. The volunteers began a new project cataloging a subcollection of Wasatchian mammals. Since the data was more uniform and less complex, we could streamline data entry workflows and reduce the amount of data the volunteers collected. With the revisions, the volunteers recorded data for 17,000 mammals within the first six months of the project.

Since 2016, volunteers have created over 28,000 new digital records. Though collections staff manage most of the data processing, the focused efforts and number of volunteers results in a far greater rate of data creation than our staff could achieve. Volunteers can be an asset to any cataloging project if they are trained and vetted properly, and if projects are chosen carefully. Ultimately, this increases data accessibility to the benefit of the paleontological community.

Technical Session XV (Saturday, October 12, 2019, 12:00 PM)

ALLIGATORINE DIVERSITY DYNAMICS SUPPORT THE COMMON-CAUSE HYPOTHESIS OF MACROEVOLUTIONARY PATTERNS IN THE ROCK RECORD

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Alligatorines are used as paleothermometers. Previous analyses returned peaks over global thermal maxima in the early Paleogene and mid-Miocene. However, up-to-date taxonomies, phylogenetic hypotheses, and variation in rock exposure across time were not included, leaving potential for several sources of bias to heavily influence the results.

I compiled the most recent age estimates of all beds the oldest and youngest specimens identifiable to each currently valid alligatorine species have been found in, including a few undescribed new species, then plotted my phylogenetic hypothesis against time, resolving the single polytomy to minimize stratigraphic debt. I tabulated species richness, originations, and extinctions in four million year time bins both with and without ghost lineages and range extensions. I pulled outcrop area of fluviolacustrine and swamp rocks from North American regions and times alligatorines have been found in from Macrostrat. Data at this resolution was not available outside North America and most alligatorines have been found there. For climate, I pulled $\delta^{18}O$ values for mean annual temperature (MAT) from a NOAA dataset. Data failed tests for normality, so I compared diversity, rocks, and climate by calculating Spearman's rho correlation coefficients.

Alligatorine diversity tracks climate change well. Climate correlates with rock record to a lesser degree and variably—fluviolacustrine rocks decrease with increasing MAT, while swamp rocks show the opposite pattern, coinciding with the wettest part of the Cenozoic. Diversity has little correlation with rock exposure, with swamps vs. originations and presence incorporating phylogeny (but not presence without phylogenetic data) being exceptions. There is weak to no correlation when only taxonomic ranges preserved in the fossil record are compared. There was no correlation between rocks and extinction.

In contrast to analyses based on out-of-date taxonomic data, this pattern of correlations and lack thereof show that apparent alligatorine diversity is at least not entirely a reflection of rock record bias. Rather, any similar patterns are a secondary effect largely based on the co-occurrence of a warmer, wetter climate both with more swamps and higher alligatorine diversity. This supports the common-cause hypothesis—all three metrics are tied together rather than rock record bias creating apparent co-occurring changes of diversity and outcrop area. Future studies will include lithologic data outside North America.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 12:00 PM)

DIRE WOLVES WERE THE LAST OF AN ANCIENT NEW WORLD CANID LINEAGE

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The dire wolf is considered to be the most common and widespread large carnivore in Pleistocene America, yet relatively little is known about its evolution or extinction. To reconstruct the evolutionary history of dire wolves we sequenced genomes from five sub-fossil bones dating from 13,000 to over 50,000 years ago. Our results indicate that while morphologically very similar to extant gray wolf, dire wolves represent a highly divergent lineage that

separated over 4 million years ago. In contrast to numerous examples of hybridization across Canidae, there is no evidence for gene flow between dire wolves and either North American gray wolves or coyotes, suggesting the dire wolf evolved in isolation from the Pleistocene ancestors of these species. Our results support an early New World origin of the dire wolf, while the ancestors of the gray wolf, coyote, and dhole evolved in Eurasia and only colonized North America relatively recently.

Grant Information:
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Technical Session VIII (Thursday, October 10, 2019, 2:00 PM)

SENSING OR SUCKLING? THE EVOLUTION OF MAMMALIAN FACIAL MUSCLES

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Mammalian facial muscles are involved in a variety of functions, but their evolutionary origin has been popularly linked with the emergence of that quintessentially mammalian trait, suckling milk. Comparative morphological data on the neuroanatomy of stem-mammalian, mammalian, and outgroup taxa suggest an osteological correlate occurring in stem-mammals associated with the presence of a subset of facial muscles. We reason that the appearance of the infraorbital foramen and the orientation of this opening relative to the surface of the maxilla is associated with facial muscle-mobilized whisker pads, as this configuration is hypothesized to reduce mechanical stress on the infraorbital branch of cranial nerve V_2, which innervates the mystacial vibrissae, during active tactile exploration. In addition, we present ontogenetic data from extant marsupials and placental mammals. Facial muscles develop post-natally in the Short-Tailed Opossum (*Monodelphis domestica*), demonstrating that these muscles are not required for suckling in all taxa. But whether this represents an ancestral or derived condition is explored through comparing the sequence of facial muscle development across various taxa. We present these findings as support for the potentially greater role that innovations in active, direction-oriented gathering of sensory information played in the evolutionary origins and subsequent modifications of mammalian facial muscles.

Grant Information:
Yale University

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

REDESCRIPTION AND REASSIGNMENT OF "*LIODON*" *MOSASAUROIDES* TO THE GENUS *EREMIASAURUS* (SQUAMATA, MOSASAURIDAE)

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The genus *Prognathodon* is a diverse group of mosasaurine mosasaurs often typified in part by robust jaws and variable tooth shape and enamel structure. However, some analyses have found that members of the genus *Prognathodon* do not consistently form a monophyletic clade, requiring a reassessment of taxa to better resolve these unclear relationships. Recently, the genus *Liodon* was declared a *nomen dubium* and members of the group reassigned to *Prognathodon*, based on similarity between tooth crown ratios along the jaw. *Liodon* has been historically problematic as all species are poorly-preserved and comprise mainly of jaw fragments and teeth, although "*Liodon*" *mosasauroides* represents one of the best-preserved specimens, consisting of the premaxilla, partial maxillae and dentaries, and teeth *in situ*. Despite this, there has been no recent detailed comparison of both the jaw elements and dentition of "*Liodon*" *mosasauroides* to other taxa. An assessment of multiple genera finds several traits that distinguish the genus from *Prognathodon* and instead suggests "*Liodon*" *mosasauroides* and the mosasaurine *Eremiasaurus heterodontus* are congeneric. A medially-oriented anterodorsal process of the maxilla and raised ridges on the dorsal surface of the premaxilla found in "*Liodon*" *mosasauroides* and *Eremiasaurus heterodontus* are absent in multiple species of *Prognathodon*. Heterodont dentition is present to varying degrees in these taxa; however, strongly interdigitating teeth and interdental pits on the lateral surface of bone between tooth positions are absent in *Prognathodon*, but present in "*Liodon*" *mosasauroides* and *Eremiasaurus heterodontus*. Interdental pitting is present on the anterior portion of the jaw in some members of *Mosasaurus*, although those taxa lack distinct heterodont dentition. Conversely, the posterior teeth of "*Liodon*" *mosasauroides* interdigitate to a greater degree than in *Eremiasaurus heterodontus*, indicating the two taxa are not synonymous. As much of the holotype of *Liodon* is missing and therefore not comparable, the referral of "*Liodon*" *mosasauroides* to *Eremiasaurus mosasauroides* is proposed. This provides partial resolution for a historically problematic genus, underscoring the difficulties in interpreting poorly-preserved specimens.

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Technical Session XIX (Saturday, October 12, 2019, 4:00 PM)

VERTEBRATE TAPHONOMY IN DISTRIBUTIVE FLUVIAL SYSTEMS

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Approximately 87% of facies across all modern sedimentary basins are deposited as part of Distributive Fluvial Systems (DFS), a class of fan-shaped landforms including alluvial fans, fluvial fans, and megafans. There is evidence that DFS are also common in the rock record. The prevalence of DFS in the terrestrial rock record has implications for the vertebrate fossil record because as DFS deposit they prograde, producing an autochthonously generated secular series of environmental changes at any one location. According to the simplest DFS model, environments will shift from poorly-drained overbank deposits with many small channels lower in section to well-drained overbank deposits with few, larger, amalgamated channels higher in section. This environmental change will affect both the distribution of organisms on the DFS and a range of taphonomic factors (e.g., transport energy, rate of burial, surficial and subsurface degradation processes).
To investigate the taphonomic consequences of the DFS model a quantitative taphonomic model was written to describe the changes in vertebrate preservation associated with the sedimentological transitions across the surface of a DFS. Using initial conditions for intermediate to large DFS (10s-100s of km length), the mean overbank transport distance of vertebrate specimens is anticipated to increase upsection in DFS settings, leading to a shift from preservation of associated specimens near to the point of carcass deposition to broadly dispersed, unassociated fossils. Similarly, the proportion of specimens surviving to burial is projected to decrease upsection and the magnitude of size bias in the assemblage will increase upsection. What limited quantitative taphonomic data are available from known or hypothesised DFS settings show some agreement with the expectations of the quantitative model. If shown to be broadly present, these results suggest that secular changes in preservation should be anticipated in vertebrate sequences, and should be accounted for when developing paleoecological hypotheses.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

CRYSTALLOGRAPHY OF *LOURINHANOSAURUS* EGGSHELLS (DINOSAURIA, THEROPODA, ALLOSAUROIDEA)

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Upper Jurassic outcrops of the Lourinhã Formation (late Kimmeridgian−Tithonian; Lusitanian Basin; Lourinhã, Portugal) are renowned by their diverse vertebrate fauna, including mammals, amphibians, squamates, testudines, crocodylomorphs and dinosaurs. Among the fossils recovered in thisfFormation, the record of eggs and clutches of dinosaurs and crocodylomorphs, sometimes containing embryos, is of special relevance. This record includes two of the oldest records of theropod embryos known so far, and the oldest crocodylomorph eggs.
The "Paimogo clutch" is a group of over a hundred partial eggs, some of them containing embryos, collected in the outcrops close to the Paimogo fort. Most of the eggs in the group can be attributed to the theropod *Lourinhanosaurus*. In addition, four crocodylomorph eggs were collected in close relation with the rest, including the holotype of the ootaxon *Krokolithes dinophilus*. Here we present the first detailed report of the crystallographic architecture of the *Lourinhanosaurus* eggshell using electron backscattered diffraction (EBSD). *Lourinhanosaurus* eggshells are composed of calcite and are thin –800 um. The eggshells show obliquiprismatic morphotype, with a mammillary to continuous layer ratio of 1:2. The shell units are wider than in most theropod eggshells –width to height ratio of 1:3. Pore canals are wide and oblique. They

can be classified as the ootaxon *Preprismatoolithus coloradoensis*, described in the contemporary Morrison Formation, U.S.A. .
Electron backscatter analysis shows that *Lourinhanosaurus* eggshells have a crystallographic architecture homologous to most theropod eggshells, with small crystalline domains radiating in all directions at the bases of the mammillae that transform into large columnar domains in the continuous layer. Inverse pole figure maps based on the orientation of the c-axis of the calcite crystals show a progressive reorientation of the c-axis towards the outer surface of the eggshell. At the transition point between the mammillary and continuous layers, these axes are perfectly parallel to the eggshell growth direction. Grain boundary maps show a reduced number of low angle (<5º) boundaries, with clean crystal domains separated one from the other of over 20º boundaries. The boundaries are not roughed, thus supporting the observed absence of squamatic ultrastructure. The presence of the typical theropod architecture in an allosauroid dinosaur suggests that the eggshell growth mechanism of derived theropods was achieved early in theropod evolution.

Grant Information:
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Technical Session I (Wednesday, October 9, 2019, 11:30 AM)

THE OLDEST KNOWN PACIFIC SIRENIAN FROM THE EARLIEST OLIGOCENE, SAIKAI, NAGASAKI PREFECTURE, WESTERN JAPAN

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A new fossil sirenian from Japan was collected from shallow marine strata of the Kakinoura Formation, Nishisonogi Group, Saikai, Nagasaki, western Kyushu Island. The recovered fossil remains consist of a mid-anterior vertebra, a posterior thoracic vertebra, an isolated thoracic neural spine, an anterior caudal vertebra, and a number of ribs, all from a single individual. The geologic age of the Kakinoura Formation is earliest Oligocene (Rupelian), based on calcareous nannofossils (CP 16b and 16c subzones). The vertebrae preserve characteristic sirenian features, which in the case of the thoracic vertebrae include triangular-shaped centra, short transverse processes, and relatively large neural canals. The posterior thoracic vertebra also has a well-developed ventral keel. The single caudal vertebra has a hexagonal-shaped centrum and dorsoventrally thick transverse processes that project horizontally. The ribs have a dense bone histology without spongy tissue, and are pointed at their distal ends. The ribs vary in shape, with some being very thick and banana-shaped (features typical of sirenians), while others are rather narrow. The dimensions of the largest thoracic vertebral centrum (42.6 mm in width and 24.1 mm in height) and the largest rib (33.3 mm in diameter), ; suggest that the Saikai sirenian is one of the smallest known sirenians. It cannot be established, however, whether this individual was a juvenile or small adult.
Sirenians first evolved in the Atlantic (or western Tethys Ocean) in early Eocene time, and their sparse Paleogene record in the Pacific suggests a much later dispersed into the Pacific Ocean presumably via a seaway through Southeastern Asia. Previously, the oldest sirenian record from the western Pacific was a dugongid vertebra from late Oligocene strata in northern Kyushu. However, with identification of the Saikai sirenian, the Pacific record for this group can be extended back into the early Oligocene, suggesting a much earlier dispersal of sirenians into the Pacific. The Saikai sirenian was originally discovered in 1980, but it was only recently prepared with support from the Educational Board of Saikai City.

Grant Information:
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Technical Session XV (Saturday, October 12, 2019, 10:30 AM)

THE FIRST NON-MAMMALIAN CYNODONTS FROMAUSTRALIA AND THE UNUSUAL NATURE OF AUSTRALIAN CRETACEOUS CONTINENTAL TETRAPOD FAUNAS

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Cynodont therapsids appeared by the late Permian and gave rise to mammals in the Late Triassic. Several non-mammalian cynodont clades were diverse until the Early Jurassic, but most were extinct by the mid-Cretaceous. Although these globally distributed synapsids have an abundant fossil record in Gondwana, no representatives of this key group have yet been reported from Australia. Here we present non-mammalian cynodont remains from the early Late Cretaceous of New South Wales (NSW) and Queensland (QLD), describing or reinterpreting specimens that are here provisionally included within Haramiyida and non-mammaliaform Probainognathia, respectively. *Kollikodon ritchiei* from the Cenomanian Griman Creek Formation of NSW was first interpreted as monotreme and subsequently as a basal australosphenidan. However, distinctive characters linking *Kollikodon* to haramiyidans challenge these views, including: (1) postcanines with multicusped rows; (2) orthal jaw movement (although *Kollikodon* lacked the palinal action of haramiyidans); and (3) mediolateral divergence of upper postcanines, a possible haramiyidan synapomorphy. Furthermore, both *Kollikodon* and the haramiyidan *Haramiyavia* have a plesiomorphic lower jaw that may have retained substantive postdentary bones. Other Australian non-mammalian cynodont fossils include a fragmentary femur and an incipiently divided molar tooth root from Cenomanian–Turonian strata of the Winton Formation in QLD. The anteroposteriorly compressed femur has an unusually long lesser trochanter like that of non-mammaliaform probainognathians (such as chiniquodontids and basal prozostrodontians) from the Late Triassic of South America and Africa. Identification of the tooth root is equivocal but it likely possesses a non-mammalian cynodont feature: incipient bifurcation of postcanine roots precedes the fully divided roots of mammals and was independently acquired in several cynodont lineages. These fossils are all substantially stratigraphically younger than those of their closest known relatives, adding to the unique and unprecedented faunal mix of archaic (e.g., temnospondyls, tuataras), endemic, and relictual Gondwanan species (e.g., monotremes) found in the Mesozoic of Australasia. Australia's late-surviving non-mammalian cynodonts fill the last void in the global distribution of these animals. The blend of typically 'Triassic,' 'Jurassic,' and 'Cretaceous' taxa that coexisted in the mid-Cretaceous high-latitude environs of Australasia had no parallel elsewhere.

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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

A NEW SPECIES OF EOGRUIDAE (AVES, GRUIFORMES) FROM THE MIOCENE OF THE LINXIA BASIN, GANSU, CHINA: EVOLUTIONARY AND CLIMATIC IMPLICATIONS.

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Despite having one of the most robust fossil records within core-gruiform birds (rails, cranes and allies), the biogeographic history of Gruidae (cranes) and key drivers of diversification within this group remains largely unknown. The Eogruidae of Eurasia represent some of the earliest known crane-like fossils. Here, we present description of a new species represented by a well-preserved specimen of a foot from the late Miocene (7-6.5Ma) Liushu Formation of Linxia Basin, Gansu, China. It is the only eogruid fossil that has been found in this Formation and is the first eogruid known from northwest China. Linxia Basin is located along the margin of the northeastern Tibetan Plateau, which allows for new insight into Miocene dispersal of the Eogruidae and potential climatological and geological connections. It is also the first specimen with an associated tarsometatarsus and nearly complete phalanges, including a claw, which provides further morphological information on this taxon. Referral of the new specimen to Eogruidae is based on extreme reduction of the metatarsal II trochlea, which is most similar to the condition present in the eogruid subclade traditionally termed Ergilornithidae.

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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

MINERALIZED NOTOCHORD-ASSOCIATED TISSUES PRESERVED IN FOSSIL CENTRA SUGGESTS A UNIQUE DEVELOPMENTAL PATTERN IN THE AXIAL SKELETON OF CHORISTODERA

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The notochord is a cord of soft tissue that forms in every chordate embryo and persists throughout life as the core of the vertebral column in the deeply amphicoelous centra of most fishes, most amphibians, and some amniotes. In other amniotes, the notochord may disappear during development or, as in mammals, may be transformed into the nucleus pulposus at the center of the intervertebral disc. In this study, we focussed on the acoelous vertebrae of Choristodera, a group of semiaquatic to aquatic diapsid reptiles known from the Jurassic to the Paleogene. We examined microanatomical features of centra using X-ray CT scans and found a mineralized notochord or notochordal sheath in choristoderan genera including a basal form, *Cteniogenys* from the Middle Jurassic, and a derived form, *Champsosaurus* from the Late Cretaceous. Histological analysis revealed that a continuous filamentous microstructure is preserved in the core of the centrum in juvenile to sub-adult *Champsosaurus* and adult *Cteniogenys*. In adult *Champsosaurus*, the filamentous structure was not observed in the endochondral domain, and instead, we found small masses of mineralized tissue without any visible cell structure and optical anisotropy along the longitudinal axis. A small boss or fossa at the point where the longitudinal axis meets the intervertebral surface in subadult-adult *Champsosaurus* indicates the persistence of a notochordal remnant at these growth stages. At the center of the centrum, we found a tiny elongated cavity that may be divided into two parts by a thin, foam-like septum in well-preserved specimens. This septum corresponds to condensed notochordal cell membranes, as observed in geckoes and tuataras, suggesting that the similar tissue in choristoderes was preferentially mineralized and preserved in the fossil vertebrae. Such a biomineralized notochord or its associated tissue has not been reported from the amniote axial skeleton and demonstrates a higher level of variation in centrum development than previously known. Furthermore, we investigated fossilized vertebrae of the enigmatic aquatic reptile *Pachystropheus* from the uppermost Triassic of Europe, which sometimes is considered as the oldest choristodere. The vertebrae also show small, optically isotropic masses in the endochondral spongiosa, suggesting that the previously unknown vertebral structure was already present in the common ancestor of *Pachystropheus* and other choristoderes before the beginning of the Jurassic.

Grant Information:
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Technical Session XVII (Saturday, October 12, 2019, 10:15 AM)

THE ORIGIN OF DROMAEOSAURID HYPERCARNIVORY: INSIGHTS FROM MICRO-CT SCANNING OF *SHANAG ASHILE*

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Microraptorine dromaeosaurids are predominantly known from two-dimensional remains that obscure many details of internal anatomy. The holotype of *Shanag ashile*, however, consists of an isolated but exquisite, three-dimensional maxilla and partial mandible. The specimen was so delicate that it could not be freed from matrix; however, modern high-resolution micro-CT scanning allows us to visualize its medial surface and internal anatomy. Incorporation of these observations into a phylogenetic dataset consistently recovers *Shanag* as a microraptorine dromaeosaurid. The CT data also yields substantial insight into microraptorine predatory ecology. *Shanag* possesses three deeply-rooted maxillary teeth in the middle of the toothrow, with the largest abutting the ventral margin of the maxillary fenestra. These teeth are reminiscent of those found in extant arboreal predatory squamates that heavily incorporate birds as a dietary component. We constructed a morphometric dataset comprising 26 extinct theropods and 11 extant squamates to assess the predatory ecology of *Shanag ashile* and other microraptorine dromaeosaurids, which we analyzed using principal components analysis and ancestral state reconstruction in a phylogenetic framework. Microraptorines show the same pattern of morphological divergence from more basal dromaeosaurids as arboreal, bird-eating squamates do from their terrestrial relatives – they have fewer, longer, and generally straighter and more vertically inclined teeth in the maxilla and dentary. This dental morphology stands in marked contrast to the many peg-like teeth found in basal paravians. The deep rooting of the largest teeth in *Shanag* likely represents an adaptation to resist struggling prey of a large size relative to its own. We propose that *Shanag* and other microraptorines were habitual bird-eaters, preying on avialans and possibly small troodontids and dromaeosaurids. Our findings suggest that dromaeosaurids began preying upon animals close to their own body size early in their evolution, and that microraptorines represent a radiation specialized for arboreal hunting of their closest relatives.

Grant Information:
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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ENDOCRANIAL SHAPE VARIATION IN FOSSIL AND MODERN XENARTHRANS USING 3D GEOMETRIC MORPHOMETRICS

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Xenarthrans (anteaters, armadillos, sloths and their fossil relatives) are one of the earliest diverging clades of placental mammals, with all members originating and diversifying in South America. The earliest xenarthran fossils, belonging to the armadillo clade, are recovered from early Eocene (~53 MA) deposits in Southeast Brazil. Sloths are first known in the fossil record from late Eocene (~36 MA) deposits and anteaters are not recovered until the early Miocene (~20 mya). Xenarthrans reach an impressive taxonomic diversity of over hundreds of species in 180 genera and 15 families; today their diversity spans 31 species, 14 genera, and 5 families. Through time this order has ranged in body mass from 100 g (the pink fairy armadillo, *Chlamyphorus*) to ~4,500 kg (the giant ground sloth, *Megatherium*), in locomotor strategy from fully subterranean to aquatic, graviportal and suspensory, and in dietary preference from myrmecophagy to more general insectivory, carnivory, omnivory and folivory.

To better understand variation in xenarthran brain morphology through time and as it changes with respect to these diverse ecological variables, we use three-dimensional geometric morphometrics (GM) to quantify shape in digital cranial endocasts derived from high-resolution X-ray computed tomography scans of representative skulls. Cranial endocasts included in the study belong to 5 species of fossil armadillo relatives, ranging in age from 23 million to 11,000 years ago, 12 species of modern armadillos, 8 species of fossil sloths, including ground and aquatic, 2 species of modern sloths, 4 species of modern anteaters, and the pangolin, *Manis javanica*, as an outgroup representative. In total, 30 landmarks were placed on the left side of each sampled cranial endocast. Results from a Principal Component Analysis on Procrustes shape variables show similar patterns to those found in recent morphometric studies on mammalian digital cranial endocasts in that endocranial shape variation correlates with morphological phylogenies, with a secondary ecological signal. In particular, the location of xenarthran taxa in morphospace is influenced by both phylogeny and locomotor mode, with endocranial shape separation along the 1st Principal Component axis presenting a clear divide between fossorial and terrestrial/arboreal taxa. These results highlight the potential for use of GM studies on digitally derived cranial endocasts to add to our understanding of fundamental aspects of the biology of fossil xenarthrans.

Grant Information:
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Technical Session IV (Wednesday, October 9, 2019, 3:45 PM)

TOOTH COMPLEXITY BLUEPRINT AND THE EVOLUTION OF THE ANTEROCONID IN RODENTS

NASRULLAH, Qamariya, Monash Univ, Monash University, Australia; EVANS, Alistair R., Monash Univ, Monash University, Australia

The anteroconid of the first molar in the muroid rodents is a new anterior cusp that appeared in the fossil record around 50 Ma. It is considered to be phylogenetically informative for evolutionary studies on living and extinct taxa. Seemingly, at the same time as the appearance of the anteroconid, the premolar that was found in the basal pre-muroid *Tribosphenomys* was lost in evolving muroids. It has been suggested that the premolar was lost due to fusion with the developing m1, providing developing tissue to produce the anteroconid. However, studies suggest that during development, teeth inhibit one another, influencing tooth size and complexity via the inhibitory cascade mechanism. This mechanism provides an alternative hypothesis for the appearance of the anteroconid. This hypothesis further implies that there is a disparity between the potential and final shape of a tooth. Our aim was to experiment with inhibition and interactions between tooth germs in cultured tooth samples to unlock the potential of tooth shape. Using laboratory mice *Mus musculus* we employed a developmental approach of culturing transplanted molars of differing developmental stages together to pinpoint key timepoints of shape determination, to see how easily the anteroconid could be induced in the second molar. Importantly, we found that tooth complexity increased when inhibition was reduced, such that the second molar can express an anteroconid. As well as providing a clear mechanistic basis for the anteroconid in fossil murids, these findings have significant implications for tooth shape diversification and evolution in all vertebrates.

Grant Information:
Australian Research Council Future Fellowship FT130100968

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 9:15 AM)

LIMESTONE CHICKEN WINGS: SOFT TISSUES FROM A STEM-BIRD FROM LAS HOYAS (CENTRAL SPAIN) AND THE EARLY EVOLUTION OF FLIGHT IN BIRDS

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Exceptionally preserved fossil remains represent rare opportunities to access anatomical information often not available for extinct species. The limestone deposits of Las Hoyas (Cuenca, Spain) is one of the most celebrated cases of exceptional preservation of soft and hard tissues. The microbial mat-driven taphonomy of this paleo-wetland environment allowed pristine preservation of fine anatomical details from the soft tissues of many vertebrates, including unique cases in the whole fossil record. Here, we show the structural and ultrastructural details of preserved connective and feather tissues in an isolated but articulated wing belonging to a stem-bird. The fossil documents one of the first occurrences in the fossil record of modern avian patagia, including propatagium, postpatagium and, remarkably, alular patagium. Within the postpatagium and in close association with the calami of flight feathers we found a series of complex striations that ultrastructurally resemble the connective system that controls flight feather movements in modern birds and guarantees aerodynamic proficiency during flight. This information reinforces the views that some lineages of stem-birds, in particular the speciose enantiornithines, were already proficient fliers capable of developing complex flight styles. Furthermore, our analysis of the organized layers of melanine-bearing melanosomes preserved within the covert and flight feathers of this specimen suggests the wing of this bird might have been iridescent black in life, perhaps hinting diurnal habits. Our study represents a good case on how studying in detail fossil soft tissues can help unravel ecological traits in extinct species and how integrating this information in a phylogenetic context can deepen our understanding of large macroevolutionary transitions such as the origin and early evolution of flight in birds.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

NEW PERSPECTIVES ON THE EVOLUTION OF THE AVIAN SKULL

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The wide array of cranial morphologies displayed by modern birds is often believed to have evolved mainly in response to tight adaptation to feeding ecology. Recent research, however, suggests that the connection between cranial morphologies and feeding ecologies in birds is not as simple and strong as often perceived. Instead, a more complex picture of the drivers affecting craniofacial diversification in birds is emerging. Here, we review some of our latest research on this topic using shape analysis, phylogenetic comparative methods and experimental development, and how our results have influenced current knowledge of the evolution of the avian skull. For instance, the concomitant evolution of shape and size (allometry) has proven to be an important factor driving skull evolution in raptors and parrots. Similarly, the coevolution of different areas of the avian skull (integration) is associated with the pattern and tempo of cranial evolution. These associations are central to understanding the classic examples of adaptive radiations of passerines, suggesting that intrinsic factors, not just ecological ones, may have played a major role in shaping feeding adaptation in birds. Regardless of the specific nature of these evolutionary associations, all of them manifest over craniofacial development. On a broad macroevolutionary scale, we find that the developing brain is a major driver of avian skull evolution, constraining craniofacial development via pleiotropic associations and via physical interactions, and showing the developmental non-independence among the different systems in the head. For instance, development of the beak phenotype depends on the cooperation of morphogenetic genes and their timing and area of their expression. Other alterations of development, such as heterochrony, are important drivers in the origin of the modern avian architecture and in the subsequent diversification of some lineages among the modern radiation of birds, such as strisorans. Integrating this novel information with ever-increasing amounts of ecological and morphological data, new fossil findings that fill temporal and morphological gaps in avian evolution, and new experimental data in craniofacial development, will be critical in the next years to deepen our understanding of the diversification of birds.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 11:45 AM)

DECAY CHANGES THE DISTRIBUTION AND SHAPE OF MELANOSOMES IN AQUATIC VERTEBRATES: IMPLICATIONS FOR THE INTERPRETATION OF COLOUR PATTERNS IN FOSSIL TAXA

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Pigmented integument in aquatic vertebrates may serve several functions such as camouflage, intra-species communication and display. Much of the pigmentation comprises melanosomes (melanin-producing organelles) which are found throughout many organs and tissue types where they play other biological roles including as protection from microbial infection, regulating nerve impulses and chelating harmful metals. Owing to their geological stability, recognition of melanosomes has been used to make a wide variety of exciting inferences about fossil taxa. In particular, their distribution has been suggested to indicate countershading in an Ornithischian dinosaur, and colour banding in a fossil feather. Furthermore, their size and shape is utilised to determine the type of colour preserved: prolate forms corresponding to black colouration, and oblate forms responsible for more rufous colours. However, there is a preponderance of studies on terrestrial tetrapods and feathers, with little focus on basal aquatic vertebrates. Moreover, little is known about how decay can influence the shape and distribution of melanosomes throughout integument prior to fossilisation. We tested the hypothesis that the distribution and shape of fossil melanosomes from the integument of basal vertebrates is a faithful representation of *in vivo* pigmentation in extant analogues. We used a series of taphonomic experiments, coupled with a morphometric analysis to track the changes in melanosome shape and distribution in lamprey (cyclostomata) and several

species of patterned teleost fish during decay. Our results show that decay reduced the definition of some skin colour patterning in all species of fish whilst also creating new, distinct patterns that were not present in life. Furthermore, statistical tests on shape analysis data demonstrate that the skin integument melanosomes of lamprey retain their morphology throughout decay. This demonstrates that taphonomic processes can affect the distribution of seemingly robust pigmented structures throughout external integument. Our results further highlight the importance of understanding how the degree to which a carcass is subject to decay, coupled with the timing and onset of fossilisation, can affect subsequent anatomical and ecological interpretations. We anticipate that further research into the taphonomic influences on pigmented integument will allow paleontologists to better answer questions surrounding the appearance, ecology and evolution of extinct organisms.

Technical Session XVII (Saturday, October 12, 2019, 9:45 AM)

CONVERGENT SENSORY ECOLOGIES BETWEEN ALVAREZSAUROIDEA AND EXTANT TYTONID OWLS

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Alvarezsauroidea were a widespread clade of small-bodied theropods characterized, in part, by highly derived manus morphologies that are generally considered to be specializations for digging into and feeding upon termite colonies. However, it remains unknown how alverezsauroid sensory systems were adapted to this unusual feeding ecology, particularly with regards to hearing and visual ability. With the use of sliding semilandmarks, we applied geometric morphometrics to examine vestibular (i.e., inner ear) and sclerotic ring morphologies in 126 avian and 14 non-avian theropod taxa that represent a broad phylogenetic and ecological sample. We show that the alvarezsaur, *Shuvuuia deserti*, has a greatly elongated endosseous cochlear duct (or ECD), which contains the basilar papilla – the region of the inner ear responsible for hearing. The ECD of *S. deserti* is by far the longest recorded for any non-avian theropod, and curves ventromedially to sit below the brain cavity. This condition is remarkably similar to that seen in the extant *Tyto alba* (barn owl), which is well-known for its highly-sensitive directional hearing that allows it to hunt with precision in complete darkness, and for its extended high-frequency hearing range. The similarity also extends to the presence of prominent bony external ear apertures in both owls and *S. deserti*, which funnel sound into the external auditory meatus. Principle component analysis shows that *S. deserti* not only clusters with owls in morphospace, but specifically with *T. alba*. In addition, the early branching alvarezsauroid *Haplocheirus sollers* shares with owls a deep, highly-concave sclerotic ring, indicating similar nocturnal visual acuity between the two groups, and deep origins of derived behaviours in alvarezsaurians.
Our results suggest that Alvarezsauria and owls, specifically Tytonidae, convergently evolved similar, highly-specialized sensory ecologies. *S. deserti* had sensitive directional hearing and could have located concealed prey in complete darkness, and may have also shared a similar ability to hear extended high frequencies.

Grant Information:
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Technical Session I (Wednesday, October 9, 2019, 11:15 AM)

FIRST KNOWN MYSTICETE FROM THE FAIRHAVEN MEMBER OF THE CALVERT FORMATION

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The early to middle Miocene Calvert Formation has greatly informed the cetacean fossil record of eastern North America. The Plum Point Member, in particular, is renowned for fossils of both odontocetes and mysticetes, as well as other marine mammals. However, the lower member of the Calvert Formation, the Fairhaven Member, is depauperate in marine mammal fossils. There is one sirenian, *Metaxytherium*, and no pinnipeds. The Fairhaven Member has a small assemblage of odontocetes, namely *Squalodon whitmorei*, *Phocageneus venustus*, and *Schizodelphis sulcatus*, but mysticetes are completely unknown from the Fairhaven Member. The Burdigalian-age Fairhaven Member is thought to have accumulated in a restricted basin with deep water, as opposed to the younger Plum Point Member, which is an open shelf deposit. Here we present the first known mysticete from the Fairhaven Member of the Calvert Formation; this specimen consists of the partial cranium, including the supraoccipital, parietals, squamosals, exoccipitals, basioccipital, and possibly the frontal; the incomplete right periotic; and distal right dentary, with the coronoid, condyloid, and angular processes well preserved. This specimen, housed at the National Park Service's Museum Resource Center in Landover, Maryland, was found just outside the District of Columbia from Suitland Parkway. Preliminary morphological comparisons based on size, morphology of the occiput and apex, as well as the morphology of the periotic between the Suitland Parkway mysticete and other mysticetes known from the Plum Point Member suggest affinities with *Parietobalaena*, a basal chaeomysticete.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A NEW DINOSAUR FROM THE *COELOPHYSIS* QUARRY (?END NORIAN) INDICATES THAT LOW LATITUDE DINOSAURIAN ASSEMBLAGES REMAINED SIMILAR IN CLADE COMPOSITION THROUGHOUT THE TRIASSIC PERIOD

NESBITT, Sterling J., Virginia Tech, Blacksburg, VA, United States of America

The origin and early evolution of dinosaurs in the Late Triassic has been documented across much of Pangea and recently refined temporal control has demonstrated that dinosaur assemblages in the low and high latitudes were distinct during much of the Norian (~228-208 mya). However, the dinosaur record at the end of the Triassic Period in the low latitudes is poor, and it is unclear whether those dinosaurian assemblages reflect more cosmopolitan or biogeographically separated taxa. The *Coelophysis* Quarry in western North America fills this temporal gap, yet to date, the quarry has only produced remains of the small neotheropod *Coelophysis* and a single individual of the ?theropod *Daemonosaurus*. Here, I recognize a third dinosaur from the *Coelophysis* Quarry (from *Coelophysis* block C-3-82), represented by much of a partially articulated skull (CM 31368) only missing the premaxilla, parts of the maxilla, and parts of the dentary. The skull (estimated length = 25 cm) is assigned to Dinosauria based on the combination of the following character states: anterior portion of the quadratojugal inserts into the jugal, supratemporal fossa present, and a clear gap between the exocciptials on the basioccipital. Reconstructed skull proportions demonstrate a short facial region relative to the orbit and temporal region. The jugal of this new form is dorsoventrally tall and lacks an anteroposteriorly oriented ridge, features that clearly differentiate this form from the contemporaneous dinosaurs *Coelophysis bauri* and *Daemonosaurus*. The relative size of the jugal as well as the postorbital morphology and proportions of the skull are most similar to those of *Tawa hallae*. Similar to *Tawa*, *Daemonosaurus*, and the early diverging sauropodomorph *Buriolestes*, the recurved teeth of CM 31368 bear pointed and bear 4-5 minute serrations per mm. A close relationship between CM 31368 and *Tawa* indicates that a clade of *Tawa*-like dinosaurs were present from the onset of Chinle Formation deposition in the early Norian until nearly the end of the Triassic. Moreover, the early diverging position of the clade composed of CM 31368 + *Tawa* indicates that early-diverging dinosaurs in the low latitudes persisted to near the end of the Triassic. This supports a separate biogeographic province for dinosaurs in low versus high latitudes and adds that this division was established early in dinosaur evolution and was only lost after the end of the Triassic.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

HALF A DECADE OF LARGE-SCALE SCIENCE OUTREACH: USING THE INTERNET FORUM ASKSCIENCE TO CONNECT WITH THE PUBLIC

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For the past five years, members of the Society of Vertebrate Paleontology have participated in live question-and-answer events via AskScience, a forum

on the social networking site Reddit. These events, known as "Ask Me Anything" sessions (AMAs), take place during the annual meeting with prior approval from the Society. Participants representing different disciplines volunteer time to answer questions from the public, responding to hundreds of questions and comments each year. Reddit has grown in popularity since our first AMA in 2014. As of April 2019, AskScience has over 17.4 million subscribers, up from 3.8 million in 2014. The first AMA received 17,500 unique views, while the most recent AMA (2018) received 37,300 unique views from users who actively clicked through to the AMA. Additionally, over 1.2 million users landed on a page where our 2018 AMA title was linked. This reflects the popularity of our post across Reddit's entire site, and leads to additional visibility for the Society. Over the course of several hours during the meeting, our AMA participants field questions pertaining to our stated disciplines. We also receive questions about evolution, climate change, recent discoveries, and reconstructing extinct organisms' locomotion, behavior, and color. Furthermore, we frequently receive requests for educational or career advice, or scientists' opinions of pop cultural references to paleontology. In selecting panelists, we aim to maximize both the disciplines represented and a diversity of backgrounds. Given the breadth of interest, we find large, collaborative teams are particularly effective at responding to the volume and variability of questions. Recent surveys have shown that most members of the public are unable to name a single living scientist. This lack of familiarity speaks to the challenges facing the scientific community when communicating with the public, conveying the importance of their science, and justifying research funding and educational programs. Active online engagement provides scientists with a platform for directly interacting with large numbers of the public in ways that require minimal effort for all participants. In addition to communicating specifics of the science, these events also humanize the discipline, making scientists more accessible to people outside of academia.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 8:30 AM)

A FLOCK OF FOSSILS: NEW FOSSIL EVIDENCE ON THE EVOLUTION OF AUSTRALIAN SONGBIRDS (PASSERIFORMES)

NGUYEN, Jacqueline M., Australian Museum, Sydney, Australia

Birds are excellent environmental indicators because they are sensitive to habitat change and their ecological requirements are well studied. The Australian fossil record of birds can help us to understand how the progressive aridification of the continent, beginning in the Miocene, shaped the diversity and distribution of the modern avifauna. In this talk I will focus on songbirds (order Passeriformes), which are a major component of bird faunas in Australia and globally, and are believed to have originated in the Australian region before spreading to the rest of the world. I will present an overview of the latest fossil evidence of songbirds from the Riversleigh World Heritage Area, northwestern Queensland, Australia. These fossils come from several sites at Riversleigh that span the late Oligocene to the early Pleistocene, offering a unique window into regional songbird diversity over the last 25 million years. To date, the Riversleigh fossils include the oldest known records for 14 extant songbird families, and two extinct genera and six species. This fossil evidence indicates a shift in taxa characteristic of rainforests and other densely vegetated habitats, such as lyrebirds, logrunners, and bristlebirds, to taxa associated with more open, drier environments, similar to the avifauna of the Riversleigh region today.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

AN EXAMINATION OF MIOCENE EUROPEAN CROCODYLIAN SPECIES DIVERSITY: THE PHYLOGENETIC RELATIONSHIPS OF ITALIAN AND MALTESE TOMISTOMINES

NICHOLL, Cecily, University College London, London, England; RIO, Jonathan P., Imperial College London, London, United Kingdom; MANNION, Philip, University College London, London, England

Once a much more globally widespread crocodylian clade, Tomistominae is today represented by just one longirostrine species, *Tomistoma schlegelii* (the false gharial), which is restricted to the fresh waters of southeast Asia. Although tomistomine fossil occurrences are recognised from the early Eocene (~55 Ma) onwards, their remains can often be relatively incomplete, making appropriate taxonomic classification within the group particularly problematic. This is especially pertinent to several taxa from the Miocene (23.03–5.33 Ma) of Europe, which were historically erected from fragmentary remains, potentially distorting our knowledge of crocodylian species diversity. Here we re-examine and describe four contemporaneous taxa from Malta and Italy: *Melitosaurus champsoides*, *Tomistoma calaritanum*, *Tomistoma gaudense*, and *Tomistoma lyciensis*. We place them for the first time into a phylogenetic analysis, comprising 68 taxa and 245 characters, several of which are revised or novel. A unique combination of features confirms *Melitosaurus champsoides* to be a valid taxon, and *Tomistoma calaritanum* is tentatively considered to be its junior synonym. *Tomistoma gaudense* is deemed to be a distinct species, but given its fragmentary (and possibly juvenile) nature, a new genus name is not erected. These taxa are recovered as derived tomistomines, with characters such as a thin posterior wall of the supratemporal fenestrae, and a narrow interfenestral bar, suggesting a close relationship with the approximately contemporaneous European taxa, *Tomistoma lusitanica* and *Gavialosuchus eggenburgensis*. *Tomistoma lyciensis* is regarded as an indeterminate tomistomine due to its especially incomplete nature. Our taxonomic and phylogenetic revision helps to elucidate past tomistomine diversity. This is an important first step in resolving tomistomine interrelationships that will also have a bearing on constraining the routes and timings of tomistomine dispersal both throughout Europe and globally.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

IMPACT OF EOCENE-OLIGOCENE GLOBAL COOLING ON THE SIZE OF LAMNIFORM SHARKS.

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Body size is a key trait in all animals, reflecting interactions between life history, development, physiology and ecology. It is also affected by environmental factors such as temperature. Global warming is predicted to result in reduced body size in aquatic ectotherms such as fish, with size increase expected during episodes of global cooling. This hypothesis can be tested by analysing size change in fossil organisms during past episodes of climate change, and for large marine animals that cannot be studied *in vivo*, the fossil record may provide the only empirical dataset to test such predictions.
The Eocene-Oligocene transition marks a major episode of global cooling. Lamniform sharks, a clade which still occupies the highest trophic-level in extant marine ecosystems, lived through that transition, and this study tested whether Eocene-Oligocene cooling drove an increase in the size of lamniform sharks, using tooth size as a proxy for body size.
To quantify changes in tooth morphology, twelve morphometric variables from 690 individual teeth spanning fourteen genera were measured. Overall, tooth size increased significantly across the Eocene/Oligocene (E/O) boundary in the entire assemblage, consistent with the hypothesis that global cooling leads to an increase in the size of marine animals. However, assemblage-level differences in size could simply be due to biotic turnover at the E/O boundary and changes in taxonomic composition. Three genera in our dataset ('*Carcharias'*, *Araloselachus and Otodus*) span the E/O boundary in sufficient numbers for individual analysis. All three genera record larger mean tooth sizes in the Oligocene, with significant increases in mean cusp height recorded by *Otodus* and '*Carcharias'*, and in both mean cusp height and width recorded by *Araloselachus*.
This supports the size-temperature hypothesis and the prediction that cooling results in an increase in the size of lamniform sharks. Tooth size and shape are closely linked to diet and feeding ecology. Within each genus, tooth morphospace is distinctly different in each time bin, and also differs from the morphospace occupied by extant representatives, suggesting significant changes in feeding ecology through time. Techniques used in this study can be applied to other episodes of past climate change, to better understand how lamniform ecology changed through time in response to fluctuations in global temperature.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 9:30 AM)

THE FIRST DINOSAUR EGG WAS SOFT

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The calcified eggshell protects a developing embryo against environmental stress and thereby contributes to the parent's reproductive success. Since modern crocodilians and birds lay hard-shelled eggs, this eggshell type has also been inferred for nonavian dinosaurs. Known dinosaur eggshell is characterized by an innermost shell membrane, an overlying protein matrix that contains calcite, and an outermost waxy cuticle. The egg calcite may occur in a single or multilayered ultrastructure which, alongside respiratory pore configurations, differs drastically across the three major clades of dinosaurs. While only hadrosaurid, derived sauropod, and tetanuran theropod eggshells have been definitely identified to date, missing intermediate shell types challenge efforts to homologize eggshell across these highly derived taxa. Here we present mineralogical, organochemical, and ultrastructural evidence for a soft-shelled nature of exceptionally preserved eggs of the ornithischian *Protoceratops* and basal sauropodomorph *Mussaurus*. Statistical evaluation (UPGMA, rho, unconstrained, one-way) of *in situ* organic phase Raman spectra obtained for a representative set (n=40) of hard and soft eggshells from fossil and extant diapsids clusters the organic, but phosphatized *Protoceratops* and the fully carbonaceous *Mussaurus* eggshells with soft-shelled eggs. Histology corroborates the organic composition of these two soft-shelled dinosaur eggs, and reveals a stratified arrangement resembling soft turtle eggshell. An ancestral state reconstruction of eggshell composition and ultrastructure compared eggshells from *Protoceratops* and *Mussaurus* to those of other archosaurs, and revealed that the first dinosaur egg was soft. The calcified dinosaur egg evolved at least three times independently throughout the Mesozoic, explaining the bias towards eggshells of highly derived dinosaurs in the fossil record.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

***SCELIDOSAURUS*, A POORLY KNOWN AND MISUNDERSTOOD ORNITHISCHIAN DINOSAUR**

NORMAN, David B., University of Cambridge, Cambridge, United Kingdom

Scelidosaurus harrisonii is the first known, near-complete, ornithischian dinosaur; it is also Sinemurian (193 Ma) and therefore among the earliest members of the clade. It was described (confusingly) by Richard Owen and is, paradoxically, one of the least well-understood ornithischians. *Scelidosaurus* has now been described in detail. Contrary to previous understanding, the skull has a complete supraorbital series, two prominent occipital 'horns' and a large exostosis (but no osteoderm) on the mandible. The skull was also encased by keratinous scales. The interior of the skull reveals bones unique among ornithischians.
The postcranial skeleton is known in totality (including clavicles and the complete forelimb). The body surface was covered by a morphological variety of osteoderms. In the cervical region large osteoderms are underlain by base-plates that grew in the dermis and during ontogeny, fused to form 'tricorns' and partial cervical collars. The torso bore three principal rows of ridged osteoderms and, between these, many subsidiary osteoderms. The osteoderms of the tail have a different arrangement to those seen on the rest of the body.
Most analyses position *Scelidosaurus* as the sister-taxon to Eurypoda (=Ankylosauria + Stegosauria). Correcting character scores and re-running systematic analyses prompts a revision of this topology.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

TRACKING CLIMATE SEASONALITY IN EQUID TEETH THROUGH SERIAL SAMPLING OF ENAMEL ISOTOPES

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The isotopic composition of tooth enamel provides an archive of dietary and environmental conditions ranging from daily/weekly increments to months or years, as enamel grows incrementally over long periods of time. Seasonality represents an elusive but critical climatic parameter that can be captured in this archive that records subannual differences in an animal's diet and environment. However, to date no sampling procedures has been standardized to systematically assess climatic/resource variability utilizing detailed histological sections to inform isotopic sampling strategies. Tooth histology and enamel growth patterns and rates must be linked to the location of isotopic samples so that the time of enamel mineralization is well constrained relative to other samples from the tooth and within the life history of the individual. Developing a procedure for collecting time-constrained isotopic samples from the enamel of extant zebra molars with high-resolution climatic context (including seasonality patterns) provides proof of method for application to the fossil record.
This study aims to create an integrative method for interpreting intra-tooth isotopic variability in fossil equid teeth as a proxy of seasonality in the past. This approach was established by analyzing modern assemblage of zebra (*Equus grevyi*) from Ol Pejeta Conservancy in Kenya, where long term climate data has been collected. Consecutive molars from all *Equus greyvi* individuals (n = 12) included in the study were serial sampled and the carbon and oxygen isotope ratios were analyzed with respect to known climatic conditions and seasonality at Ol Pejeta Conservancy. These results have important ramifications for paleoenvironmental studies where tracking seasonal variation of equid diet is of interest by providing a new basis for linking isotopic variability within teeth to climate change. These data provide novel insights into how isotopes from paleontological fauna can be interpreted as indicators of broader environmental change, particularly changing seasonality.

Grant Information:
Rackham Graduate Student Research Grant (University of Michigan)
Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 11:00 AM)

INVESTIGATING PROBABLE REPRODUCTIVE TISSUES IN STEM BIRDS USING ADVANCED MICROSCOPIC ANALYTICAL METHODS

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Two types of reproductive tissues have been identified in stem birds from the Early Cretaceous Jehol Biota: maturing ovarian follicles and medullary bone. Identification of both tissues has previously relied primarily on superficial observations such as anatomical location and gross morphology. For both purported tissues there exists alternative interpretations; ovarian follicles may potentially represent misidentified stomach contents and some bone pathologies superficially resemble medullary bone. This necessitates further investigation into these preserved traces to confirm (or dispute) original interpretations, better understand the exact types of tissues that are preserved, and to clarify the taphonomic processes responsible for their fossilization. Here we investigate these two reproductive tissues at the microscopic level using standard paleohistological analyses combined with a slew of more advanced analytical techniques including histochemical staining, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), computed tomographic (CT) and laminographic (CL) scanning, and synchrotron radiation based Fourier-transform infrared (SR-FTIR) spectroscopy. Despite the diverse range of applied methods, conclusions regarding the purported ovarian follicles are evasive. However, new data does not refute the original hypothesis.

Grant Information:
National Natural Science Foundation of China (41688103)

Technical Session XVII (Saturday, October 12, 2019, 11:00 AM)

NEW AVIALAN FOSSIL FROM THE MAEVARANO FORMATION, MAHAJANAGA BASIN, NW MADAGASCAR EXPANDS CRANIAL SHAPE DISPARITY AMONG MESOZOIC BIRDS VIA AN EXPANDED MAXILLA CONTRIBUTING TO ENHANCED ROSTRALIZATION

O'CONNOR, Patrick M., Ohio Univ, Athens, OH, United States of America; TURNER, Alan H., Stony Brook University, Stony Brook, NY, United States of America; GROENKE, Joseph R., Ohio University, Athens, OH, United States of America; FELICE, Ryan N., University College London, London, United Kingdom; ROGERS, Raymond R., Macalester College, St Paul, MN, United States of America

Latest Cretaceous vertebrates from the Maevarano Formation have significantly increased the realized morphology in a number of vertebrate groups including a growing diversity of avialans. Among avialans are representatives of multiple non-neornithine groups, including early-branching pygostylians, enantiornithines, and ornithuromorphs. Ongoing preparation of fossils collected between 2010 and 2015 continue to yield an amazing assemblage of avialan material that includes isolated bones, partial skulls, and articulated partial skeletons. Most specimens retain near-3D quality.

Among the most significant is a recently identified partial cranium that represents a new avialan. The specimen preserves a long, tall rostrum, palate, and periorbital region that includes scleral ossicles. The specimen is small (skull size = ~70 mm long, ~25 mm high) and extremely lightly built. Notable features include an elongate rostrum consisting of a small, tooth-bearing premaxilla and an enlarged, yet thin (<1 mm), toothless maxilla that forms ~85% of the pre-orbital face. An extended caudoventral process of the maxilla, along with the unique caudally-projected ventral process of the lacrimal, mark the ventral contour of an enlarged orbit. The external nares are rostrally positioned, with broad, vaulted nasals that delimit the high arched contour of the rostrum.

Significantly, the long, high facial skeleton is dominated by the maxilla, contrasting sharply with the condition expressed in virtually all avialans. Among Mesozoic birds, the relative contribution of the maxilla to total rostrum length in the new form exceeds that of longipteryigid enantiornithines and the ornithuromorph *Dingavis*. Moreover, the height of the rostrum in the Malagasy avialan exceeds that of all known Mesozoic forms, and is similar to the condition in a number of neornithine groups. Alternative patterning and size differentiation of craniofacial bones in non-neornithine avialans such as the new Malagasy form indicate a degree of developmental lability not yet appreciated in Mesozoic birds, and precede consolidation of the premaxilla-dominated rostrum expressed throughout neornithine diversification.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

THE RANGE OF ATLANTO-OCCIPITAL JOINT MOTION AS A NEW INDICATOR FOR THE FEEDING BEHAVIORS OF CETACEANS

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The feeding behaviors of cetaceans are greatly diversified—the ways they aim at and capture the prey. However, the evolutionary process is yet to be fully understood, because it remains difficult to reconstruct the feeding behaviors of extinct taxa. We focused on the cranium mobility to the trunk of cetaceans which largely depends on the range of atlanto-occipital joint motion (ROM) due to the inter-cervical inflexibility. We compared the ROMs among 56 extant cetacean skeletal specimens representing 30 species, 25 genera, and nine families. According to the analysis, we identified that the ROM depends on where they approach the prey (e.g., demersal/benthic or pelagic), and the technique the cetaceans use to capture prey into the oral cavity (e.g., engulfment, suction, raptorial-swallow, and raptorial-tear). The cetaceans that rely more on benthic/demersal prey had a relatively large ROM compared with those that rely more on pelagic prey. The ROM was relatively large in raptorial feeders, followed by suction- and engulfment feeders, in ascending order. Among raptorial feeders, the ROM tended to be larger in taxa that facultatively tear off the prey's flesh than the ROM of taxa that swallow the prey without processing. Therefore, the ROM could be a powerful tool to reliably reconstruct the feeding behaviors of extinct cetacean taxa.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

SPACE-INDEPENDENT MEASURES OF MODULARITY IN GEOMETRIC MORPHOMETRICS, WITH AN EXAMPLE FROM *SMILODON* AND *CANIS DIRUS*

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Modularity is the notion that subsets of features in a biological population show enhanced patterns of covariance relative to other subsets. In geometric morphometrics, modularity is generally evaluated by inspection of a covariance matrix extracted from the landmarks after Procrustes superimposition. Patterns of covariance are then explored by application of a model and calculation of an appropriate statistic, such as RV. While powerful, this approach is limited by space dependence, because the sets of landmarks defining each taxon space differ. For instance, a recent study of *Smilodon*jaws at Rancho La Brea utilized 14 landmarks, while another study on *Canis dirus*jaws used 16. Only ten landmarks are common across the studies, and while the jaws can be analyzed in their subspace of intersection, important aspects of intrataxic variation will be lost. Here we develop a metric that overcomes this space dependence. The approach is to characterize the topology of the hyperellipsoid occupied by each group through analysis of the vector of eigenvalues from the correlation matrix of the landmark data. The eigenvalue vector contains information on principal component magnitude but not eigenvector direction; properties of this vector are therefore comparable across shape spaces of equivalent dimensionality. Here we model the vector of eigenvalues as a continuous exponential function parameterized by a scale height S and growth rate R, with confidence intervals calculated via bootstrapping. Essentially we are treating the jaw as a single module, and measuring differences in oblateness of the hyperellipsoids defined by the principal axes of each group.

We investigated modularity in the dentaries of*Smilodon*and *C. dirus* using the metric described above. The data were two dimensional landmark data gathered from photographs of dentaries in labial view; we used the 14 landmarks published in previous work on *Smilodon*jaws, and 14 of the 16 landmarks from *C. dirus*. The three pits investigated were pit 77 (35 kya), pit 13 (18 kya), and pit 61/67 (12 kya). Our clearest result is that *Smilodon*jaws are significantly more integrated than those of *C. dirus*in all pits, a sensible result when comparing a dedicated hypercarnivore to a generalized dog. The dentary of *Smilodon*also shows a large increase in integration over time. We hypothesize that this increase in jaw integration is an adaptation to increased hypercarnivory. Use of the continuous modularity measure described here shows promise for the analysis of modularity within and among taxa.

Grant Information:
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Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 9:00 AM)

HOW 'OLD' IS THE AUSTRALIAN ARID ZONE: A HERP'S EYE VIEW ACROSS MOLECULES AND MORPH.

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Australia is a predominately arid continent, but paloeclimatic data strongly indicate this was not always the case. How, when and where, has Australia's environmental transition from relatively mesic to largely arid occurred? Coming at this question from the perspective of reptiles, based on review of molecular and fossil data, we suggest three broad patterns that may warrant further cross-disciplinary investigation: 1) many exclusively arid and semi-arid-zone radiations (including some with specialisations associated with aeolian landforms) date back at least to late Miocene (and potentially earlier); 2) the arid-zone may have functioned as a source area for surrounding biomes (especially for the savannahs of northern Australia); and 3) varying definitions, oversimplification and especially a focus on biomes at opposite ends of the climatic extremes, may have clouded our understanding of environmental history in Australia.

Technical Session IV (Wednesday, October 9, 2019, 2:15 PM)

TOOTH MIGRATION, REPLACEMENT, AND THE EVOLUTION OF MULTIPLE TOOTH ROWS IN ENDOTHIODONT DICYNODONTS (THERAPSIDA: ANOMODONTIA)

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Multiple tooth rows (MTRs) evolved several times in Amniota as a way to efficiently process plant matter. In reptiles, MTRs develop via growth of the jawbone, which carries functional teeth labially before their roots can be resorbed by the development of replacement teeth. However, nearly all of our understanding of MTR evolution is restricted to reptiles, despite the occurrence of this complex structure in a therapsid: the multiple-tooth-rowed dicynodont *Endothiodon*. In order to assess the applicability of the "reptilian" model of MTR evolution to *Endothiodon*, we examined tooth replacement patterns in µ-CT scans of *Endothiodon* specimens with MTRs. Additionally, we scanned an *Endothiodon* with single tooth rows and several close relatives of *Endothiodon*, allowing us to track changes in tooth development throughout Endothiodontia that may have contributed to the evolution of MTRs in this therapsid.

Unlike the condition in MTR-bearing reptiles, none of the dicynodonts examined here fuse their teeth to the jaws, instead retaining a permanent gomphosis (soft tissue attachment of tooth to bone). The replacement mode is

generally lingual in most specimens, but it is sometimes antero- or posterolingual in the endothiodonts. Most specimens exhibit a trail of alveolar bone lingual to each functional tooth, indicating that unlike MTR development in reptiles, the teeth migrated labially from their initial sites of development and were not carried by asymmetric jaw growth. An *Endothiodon* mandible with few MTRs exhibits slight erosion of labial teeth by adjacent lingual teeth, but a specimen with many MTRs shows no evidence for erosion. In specimens with MTRs, the labial teeth are smaller than the lingual ones, suggesting that they erupted early in the animal's life and that the addition of tooth rows took place over an extended period.
Based on the above data, we propose the following mechanism for the evolution of MTRs in *Endothiodon.* In all of the endothiodonts, each tooth migrates via labial erosion of tooth and bone and lingual deposition of alveolar bone, maintaining the ligamentous attachment of the tooth to the jaw in the process. In *Endothiodon* with MTRs, the functional teeth migrate fast enough to avoid erosion by replacement teeth, allowing *Endothiodon* to retain multiple tooth generations. We therefore present a new model for MTR development outside of Reptilia, highlighting the importance of a gomphosis and tooth drift to the development of a complex dentition in endothiodonts.

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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

PRELIMINARY REASSESSMENT OF THE TAXONOMY AND SYSTEMATICS OF THE GENUS *BOAVUS* MARSH, 1871 (SERPENTES, BOOIDEA)

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The genus *Boavus* comprises some important fossil forms of booids that date back to the early to middle Eocene of California and Wyoming, US. Three species were first described by Marsh (1871): *B. occidentalis*, *B. brevis* and *B. agilis*. Later, Gilmore (1938) synonymized *B. agilis* with *B. occidentalis* (senior synonym), and described a new species, *B. idelmani*, from a fairly complete and articulated skeleton, which so far constitutes the most informative specimen in the genus. Unfortunately, the type specimen of *B. idelmani* is currently in a private collection, and only its cast is available for study in the collections of the American Museum of Natural History, NY. One more species of *Boavus* was later described by Brattstorm (1955), *B. affinis,* but the type specimen was not figured. Here we present a preliminary re-assessment of all the *Boavus* material, including: (a) an anatomical comparison of all the type specimens; (b) an evaluation of the taxonomic validity of the four putative species based on the inter- and intraspecific (e.g., intracolumnar variation) variability observed in modern booids; and (c) a preliminary proposal for the systematic placement of this important fossil material. We find that the justification of a distinct species for *B. affinis* is contentious, because purported diagnostic features like the triangular shape of the neural canal, the oval shape of the cotyle, and the presence of paracotylar foramina, may actually be the result of intracolumnar variation and none of them represents a reliable diagnostic/autapomorphic trait. In this sense, the lack of distinct autapomorphies combined with the same stratigraphical age of *B. affinis* and the genotype *B. occidentalis*, leads us to suggest that the former should be considered a junior synonym of the latter. With regard to the systematic placement of *Boavus* within Booidea, the genus shares some anatomical features with basal booids (i.e., chariniids, calabarids and erycids), such as the absence of prezygapophyseal processes, the absence of a median lobe or the crenate condition on the zygosphene, and the absence of parasagittal ridges; however it cannot be unequivocally assigned to any of the extant families due to the following distinctive vertebral features: (1) well lateralized confluent paradiapophyses and (2) low dorsoventrally neural spine which arises directly from the zygosphene roof. The phylogenetic position of *Boavus* within a genus-level phylogeny of extant booids will eventually be tested upon completion of the collection of osteological data from modern forms.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

HIGH-PRECISION TEMPORAL, PALEOCLIMATIC AND PALEOENVIRONMENTAL ANALYSIS OF OLIGOCENE VERTEBRATE-BEARING SEQUENCES IN THE RUKWA RIFT BASIN, TANZANIA

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The Oligocene (~25.5-24.5 Ma) Songwe Member of the Nsungwe Formation represents one of the only continental vertebrate fossil records of this age in sub-equatorial Africa, making accurate paleoclimatic and paleoenvironmental interpretation crucial for understanding the context of these fossils. The succession has yielded a diverse fossil assemblage of trace fossils, including the earliest evidence of fungus-farming termite nests, and both invertebrate and vertebrate fossils, highlighted by examples of the earliest apes and Old World monkeys. Many of the fossils are preserved within paleosols formed on volcanic ash-laden paleo-landscapes permitting the reconstruction of the climatic and environmental history using macromorphology and geochemistry in a highly resolved temporal framework. Results of six newly dated volcanic carbonatite tuffs (conducted via U-Pb CA-ID-TIMS zircon geochronology) now permit the precise correlation of isolated fossil localities across the field area, and demonstrate remarkably rapid sediment accumulation rates (~30cm/ka) of the Songwe Member within a period of <1 Ma.The paleosols represent soils that formed in a dynamic floodplain landscape that oscillated between periods of aggradation by fluviolacustrine processes, and tectonic quiescence that permitted periods of exposure and pedogenesis. Vertisols formed on lacustrine deposits, characterised by homogenous brown mudstones, whereas Argillisols and Calcisols formed on fluvial deposits, defined by normally graded, red muddy sandstones. The depth-to-calcic horizon function suggests a mean annual precipitation of ~270mm through the stratigraphy, however a well-developed Vertisol sequence recorded a peak of ~1000mm mid-way through the Songwe Member at ~25 Ma. Carbonate soil thicknesses calculated precipitation seasonality ranged between 67-76mm for the argillic and calcic paleosols. The carbonate soil thickness method cannot be applied to Vertisols, however vertic morphologies and illuvial clay accumulations indicate pronounced wet and dry periods. This is broadly consistent with modern Vertisols, which are observed in ustic soil moisture regimes. Stable isotope derived temperatures from pedogenic carbonates indicate mean annual temperatures ranged from 29.8 to 35.8°C, across the time period. Based on these findings the paleosols of the Songwe Member suggest that late Oligocene vertebrate faunas in the Rukwa Rift Basin existed in a tectonically and volcanically active ecosystem with a dominantly warm, semi-arid climate.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

NEW DIVERSITY IN EARLY TETRAPOD HINDLIMBS

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Recent studies of early tetrapod crania have challenged previous phylogenetic hypotheses. Comparable work on postcrania has lagged behind, reflected in low character counts in phylogenetic datasets and the greater age of prevailing evolutionary scenarios. Here we present new morphological data that add to early hindlimb disparity and propose a distal-first pattern of morphological divergence.
New data on *Whatcheeria* reveal femoral synapomorphies with *Pederpes*, adding to a list of characters diagnosing a monophyletic Whatcheeriidae. However, the distal hindlimb of *Whatcheeria* differs strongly from *Pederpes* and contains at least two autapomorphies- broad, flattened epipodials with a small, circular interepipodial space and flattened phalanges that are broader than long. The result is morphological conservation in the proximal hindlimb but divergence distally. Unexpectedly, this pattern is reinforced by the hindlimb of *Eugyrinus*, the second-oldest temnospondyl. The femur

resembles those of other early temnospondyls, but the short epipodials and large foot are more like those of early amniotes. Extraordinarily, the unguals are elongate and distally curved: a unique feature among early lissamphibians. These data support an emerging pattern of distal disparity versus proximal conservatism. Comparative consideration of femoral characters reveals different patterns on different portions of the tetrapod stem and conserved lineage-specific patterns in total-group amniotes and lissamphibians.
The distal-first pattern builds on previous observations documenting hindlimb disparity in the earliest limbed tetrapods, particularly in digit morphology and number. In conjunction with new hypotheses of tetrapod relationships, the emerging picture is consistent with previous early-burst hypotheses of evolutionary rate and mode. *Eugyrinus* and *Whatcheeria* expand both character space and morphospace in each of their respective lineages and raise new questions about clade-specific patterns of ecomorphological diversification in early tetrapods.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

AUSTRALIA'S OLDEST AND HIGHEST PALEOLATITUDE CROCODYLOMORPHS FROM THE LOWER CRETACEOUS EUMERALLA FORMATION (UPPER APTIAN–LOWER ALBIAN) OF DINOSAUR COVE, VICTORIA

PARAGNANI, Cassia P., Swinburne University of Technology, Hawthorn, Australia; POROPAT, Stephen F., Swinburne University of Technology, Hawthorn, Australia; VICKERS-RICH, Patricia, Swinburne University of Technology, Hawthorn, Australia; RICH, Thomas H., Museum Victoria, Melbourne, Australia

The Australian Mesozoic crocodylomorph fossil record is restricted to the upper Albian–Cenomanian Griman Creek Formation of Lightning Ridge, New South Wales, and the approximately coeval Winton Formation of Isisford, Queensland. Crocodylomorphs have also been reported from the upper Aptian–lower Albian Eumeralla Formation of Dinosaur Cove, Victoria, but no specimens have been described. The Dinosaur Cove crocodylomorph material includes a quadratojugal, 28 teeth, a dorsal vertebra, a humerus and five osteoderms, and is the oldest (~113 Ma) and highest paleolatitude (~70°S) evidence of crocodylomorphs known from Australia. Most of the specimens show affinities with semi-aquatic freshwater mesoeucrocodylians. All of the shed teeth are conical, with vertical longitudinal grooves and ridges, and weakly defined mesial and distal carinae. However, one tooth shows a 'false-ziphodont' morphology, a rare condition in which denticles are formed by curving ridges over the carinae. The morphology of the quadratojugal suggests that it was part of a dorsoventrally flattened skull, similar to those of extant crocodylomorphs. The dorsal vertebra has a short neural arch, an elongate centrum and broad transverse processes, whereas the humerus is gracile; these are all hallmarks of crocodylomorphs with strong swimming capabilities. The dorsal osteoderms are rectangular, bisected by a weak midline keel, and did not interlock with, or overlap or underlap, adjacent osteoderms, whereas the nuchal osteoderms are circular, strongly keeled and did interlock. Such osteoderm features are rare in Mesozoic crocodylomorphs, but more common in Cenozoic taxa. The stark morphological differences between the known taxa indicate that Australian Mesozoic crocodylomorph diversity was higher than previously appreciated; however, the fragmentary nature of the Dinosaur Cove material precludes classification beyond Mesoeucrocodylia. The presence of crocodylomorphs and absence of temnospondyls in the Eumeralla Formation (upper Aptian–lower Albian), and the inverse situation in the Upper Strzelecki Group (upper Barremian–lower Aptian), supports previous hypotheses of a prominent paleoclimatic shift, from cooler to warmer annual average temperatures, during the late Early Cretaceous in southeast Australia. If the Victorian semi-aquatic freshwater crocodylomorphs were ectothermic, and subject to similar thermal constraints as extant species, then southeast Australia might have experienced mean annual average temperatures of >14.5°C at ~113 Ma.

Technical Session XI (Friday, October 11, 2019, 12:00 PM)

CLARIFYING CLIMATE'S ROLE IN MEGAFAUNAL EXTINCTION THROUGH NICHE MODELING

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Competing hypotheses regarding Pleistocene megafaunal extinction typically pit climate based causes against human based causes, particularly in North America. However, few climate-based arguments specify how climate change would have directly, or indirectly, impacted megafauna in a negative manner. Correlative species distribution models are increasingly used to inform our understanding of climate's impact on species. Using occurrences from the Neotoma Paleoecological Database and simulations of late Quaternary climates from the PaleoClim dataset, we test the hypothesis that North American climate became unsuitable for megafauna at the end of the Pleistocene. In total, we analyze seven time bins: the Last Glacial Maximum ("LGM", ca. 21 ka), Heinrich Stadial 1 (17.0-14.7 ka), the Bølling-Allerød (14.7-12.9 ka), Younger Dryas Stadial (12.9-11.7 ka), the early-Holocene (11.7-8.326 ka), mid-Holocene (8.326-4.2 ka), and late-Holocene (4.2-0.3 ka). We define the climate space that was available vs. occupied by eleven megafaunal species from the LGM to the early Holocene. We include extinct (*Mammuthus columbi*, *Mammut americanum*, *Hemiauchenia macrocephala*, *Camelops hesternus*, *Platygonus compressus*, *Tapirus veroensis*, *Bison antiquus*) and extant herbivores (*Antilocapra americana*, *B. bison*, *Odocoileus virginianus*) with varied diets and ecologies. We use maximum entropy species distribution modeling to estimate the total climatically suitable area in North America throughout each time bin, and calculate the percent change in area across time, for each species. If climate change was the primary driver of megafaunal extinction, we would expect suitability to decline through the extinction window and for habitable areas to contract. The extinct megafauna in our analyses fall well within the climatic designation of modern biomes, alongside extant species, during the late Pleistocene. With few exceptions, species within the same biome are similarly constrained by mean annual temperature, temperature seasonality, annual precipitation, and precipitation variability. We found that early and middle Holocene climates were suitable for the eleven species we analyzed, seven of which are extinct, and find little evidence for a direct climatic cause of the megafaunal extinction under the assumption of niche conservatism. Collectively, these models have broad relevance and implications for megafaunal extinctions in North America, potentially pointing to other drivers of megafaunal species decline.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

THREE NEW SKULLS OF THE LATE CRETACEOUS ARMORED DINOSAUR *TALARURUS PLICATOSPINEUS* MALEEV, 1952

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Talarurus plicatospineus is an ankylosaurid dinosaur from the Upper Cretaceous Baynshiree Formation (Cenomanian-Santonian) of Mongolia. Since its first discovery from the Bayan Shiree type locality in the eastern Gobi Desert, various specimens have been recovered including partial postcranial skeletons of six individuals and many other fragmentary bones. However, cranial elements of *Talarurus* have been rare and only two partial specimens including the holotype were described in the scientific literature. Here we present three additional skulls of *Talarurus*, which are much better preserved than the previously described ones. The skulls feature unique characters such as an anteriorly protruding single large internarial caputegulum, a vertically oriented elongate loreal caputegulum with a pitted surface, an elongate lacrimal caputegulum positioned above the posterodorsal border of the maxilla, two longitudinally arranged large frontal caputegulae surrounded by smaller rhomboid caputegulae, small but elongate medial supraorbital caputegulae, a posterior supraorbital caputegulum that is four times larger than the anterior one, up to three transverse parallel grooves on the dorsal surface of the posterior supraorbital caputegulum, postocular caputegulae situated along the ventral to posterior rim of the orbit and that almost extend to the anteroventral margin of the squamosal horn, a longitudinal furrow tapering towards apex of the squamosal horn, and a middle nuchal caputegulum four to five times larger than other nuchal caputegulae. The phylogenetic position of *Talarurus* was assessed with an updated data matrix by using TNT. *Talarurus* was recovered as a sister taxon to *Akainacephalus*, which together are the sister clade to *Nodocephalosaurus*. Both *Akainacephalus* and *Nodocephalosaurus* are North American taxa, and the placement of *Talarurus* within this clade supports a faunal exchange between North America and Asia. Other North American ankylosaurids (e.g., *Ankylosaurus*, *Euoplocephalus*, *Scolosaurus*) formed another clade, which was recovered as a sister group to the derived Asian taxa (e.g., *Saichania*, *Tarchia*, *Zaraapelta*). Our study shows that there were two distinct clades of North American ankylosaurids during the Late Cretaceous.

Grant Information:
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Technical Session I (Wednesday, October 9, 2019, 9:00 AM)

EXAMINING THE EVOLUTION OF ECHOLOCATION IN ODONTOCETES (MAMMALIA: CETACEA) VIA MORPHOLOGICAL DISPARITY OF THE COCHLEA

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Odontocetes (toothed whales) are the most successful lineage of marine mammal, highly specialised apex predators and a key component of modern ocean ecosystems. The catalyst for their evolutionary success is their ability to use echolocation - a form of biological sonar - that allows them to sense their environment using high-frequency sound, which is produced in the forehead and detected by the cochlea. Recent studies have indicated that the morphology of the cochlea is an excellent proxy to distinguish hearing ability in extant and extinct taxa, allowing changes in echolocation abilities to be tracked over time. Using high-dimensional 3D geometric morphometrics (371 landmarks), we quantify shape variation in toothed whale cochleae (n = 90) and use the resulting principal component scores to calculate disparity-through-time in the clade. We found that cochlear disparity is relatively low in the Oligocene, then increases throughout the duration of the Miocene, peaking around the Miocene - Pliocene boundary, before beginning to decrease again until the present. We hypothesise that the increase in disparity coincides with the diversification of delphinoids (delphinids, phocoenids and monodontids), with several modern lineages originating contemporaneously with peak cochlear disparity. Additionally, there are statistically significant differences between platanistoid and delphinoid cochlear morphologies. Taken together these results indicate that the refinement and specialisation of echolocation abilities in delphinoids (e.g., narrow-band high frequency hearing in phocoenids) as they spread into new ecological niches, played a role in their successful replacement of platanistoids as the dominant odontocete group during the Miocene. The apparently low cochlear disparity of stem odontocetes may influenced by small sample size.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

TAPHONOMY AND PALEOCOMMUNITY STRUCTURE OF LD94 SITE, A MIDDLE MIOCENE FOSSIL DEPOSIT IN THE RIVERSLEIGH WORLD HERITAGE AREA, NORTHWESTERN QUEENSLAND

PARKER, Antonia H., University of New South Wales, Paddington, Australia; ARCHER, Michael, University of New South Wales, Maroubra, Australia; HAND, Suzanne J., University of New South Wales, Sydney, Australia; MYERS, Troy, University of New South Wales, Bowral, Australia

Australia has a diverse and unique modern fauna, and the Riversleigh World Heritage Area provides much of our knowledge about its evolutionary history. However, there has been less study of how specific taphonomic agents have shaped fossil preservation at Riversleigh. Focusing on Riversleigh's relatively unstudied LD94 Site, this study describes the LD94 Local Fauna (LF), confirms the presence of new species, determines LD94's biostratigraphic placement and possible membership within recognised paleocommunities, and identifies potential taphonomic agents involved in fossilisation of the LD94 assemblage. This adds to the deep-time history of Australian fauna through enhanced understanding of the taphonomic processes operating at one of Riversleigh's richest fossil sites, describes a new, highly-diverse local fauna, possibly a new paleocommunity and two putative new species with future research potential.

Grant Information:
Australian Research Council DP170101420

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

NARACOORTE CAVES: INTERPRETING THE WORLD HERITAGE OF SOUTH-EASTERN SOUTH AUSTRALIA

PARKER, Evan A., The University of Adelaide, Adelaide, Australia; REED, Liz A., The University of Adelaide, Adelaide, Australia

The caves of Naracoorte in the South-East of South Australia have long been known for their extensive deposits of Quaternary vertebrate fossils. In 1858 bone material was first reported from Blanche cave by the Reverend Julian Tenison-Woods. This was followed by relatively sporadic collection of material from various caves in the region, until a major discovery was made in the Victoria Fossil Cave in 1969. Discovered by cave explorers, the Fossil Chamber yielded a vast deposit of vertebrate fossils and became the site of intensive research for several decades. In 1994 the Naracoorte Caves received UNESCO World Heritage listing as the Australian Fossil Mammal Sites (Riversleigh/Naracoorte) for their contribution in telling the story of Australia's unique prehistoric mammal faunas.
The Fossil Chamber has yielded almost 100 vertebrate species, including extinct megafauna. Geochronology of the site indicates a middle Pleistocene age for the deposits. Since the discovery of the chamber, visitors to the park have been able to view the deposits and see paleontologists at work on the site. This has provided an outstanding opportunity to interpret the paleontological record of the site to visitors, leaving a lasting impact on the general public. This is one of the key functions of the Naracoorte Caves World Heritage Area.
The current study titled 'The paleoecology of Fossil Chamber small vertebrates' will report on the understudied small vertebrate fossils from Victoria Fossil Cave. Identification of vertebrate fossil (>5kg) will be undertaken on previously excavated material and dating of the site completed with faunal species being assigned to depositional layers. A detailed paleoecological reconstruction will then be reported on.
The secondary output of the research is the concurrent development of interpretive and educational material for the Victoria Fossil Cave relevant to, and stemming from, the study. Effective interpretation is relevant, engaging and factual, thus a review of the current interpretative offerings from Victoria Fossil Cave is undertaken and reported on with special consideration given to the smaller vertebrate fauna (<5kg). The methodology of the interpretation is discussed and visitor engagement recorded.
It is hypothesised that the development of new interpretive materials to the Victoria Fossil Cave site with result in an increase in the engagement of the general public t the Naracoorte Caves National Park.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

REVEALING THE PALEOBIOLOGY OF AUSTRALIA'S EXTINCT MEGAFAUNA USING SYNCHROTRON X-RAY FLUORESCENCE MICROSCOPY: A CASE STUDY OF MACROPODIFORMES

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Throughout the life of a mammal, growth and development are accompanied by changes in diet and environment. Important life history events are often associated with transitions in the trace element composition of mammalian teeth. In extinct species that are disparate in ecology or body size to their modern relatives, analysis of trace element composition within teeth can be a powerful method to assess life history. Such disparity is typified by the marsupial radiations of Australia where the overwhelming majority of large-bodied species went extinct in the late Quaternary. Trace element analysis provides an avenue to understand how these giant megafaunal species underwent the altricial developmental pattern unique to marsupials.
As an animal's teeth develop, incremental lines in enamel and dentine track growth at a daily resolution. These lines may be used to determine an exact age in days at which an individual was depositing a specific region of mineralised dental tissue. Through correlating incremental growth lines in marsupial enamel with trace element concentrations it is possible to determine the age at which developmental and environmental transitions occurred in extinct marsupials. Our initial data collection at the XFM beamline of the Australian Synchrotron comprised sectioned teeth from three key macropodiform species. The Tammar Wallaby (*Notamacropus* (formerly *Macropus*) *eugenii*) is a model species for the study of extant marsupials and has a well-documented developmental timeline. The Eastern Grey Kangaroo (*Macropus giganteus giganteus*, ~60 kg) is a dwarfed subspecies of extinct giant Pleistocene kangaroo (*Macropus giganteus titan,* ~150 kg). In analysing these closely allied subspecies, direct comparisons may be made between trace elemental indicators of development and environment for living and extinct marsupials while simultaneously allowing us to detect any impact of diagenesis. Our data demonstrates that strontium is a key trace element in this type of analysis. Initial weaning and subsequent seasonal fluctuations appear to be reflected in the high-resolution strontium distribution mapped onto sequential teeth along the tooth row. Expanding this combined analysis of trace elements and incremental growth lines will allow us to understand marsupial development on a megafaunal scale.

Grant Information:
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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

A NEW REPTILE FROM THE ?MIDDLE TRIASSIC OF MADAGASCAR MAY REPRESENT THE EARLIEST-DIVERGING AVEMETATARSALIAN (ARCHOSAURIA)

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Understanding of the evolution of the earliest avemetatarsalian (bird-line) archosaurs and the morphology of the hypothetical common ancestor of Archosauria is hampered by a poor fossil record. The earliest-diverging avemetatarsalians known, such as *Teleocrater*, are separated from the earliest-diverging pseudosuchian (crocodylian-line) archosaurs, and the closest outgroups of Archosauria
by a clear morphological gap. Here we describe a potential early-diverging avemetatarsalian from the Middle Triassic (~ 230 Ma) "Basal Isalo II" beds of Madagascar, which appears to bridge these gaps. This new taxon is represented by a well-preserved partial skeleton including articulated cervical vertebrae with articulated osteoderms; a scapulocoracoid; a partial femur; isolated trunk, sacral, and caudal vertebrae; and an ilium. Noteworthy features of the neck region include: anteroposteriorly elongated vertebrae with laterally expanded dorsal ends of the neural spines, and an articulated set of osteoderms dorsal to the vertebrae. The cervical osteoderms, three pairs per vertebra, arranged in paramedian row, and bear tapering anterior processes. Potential synapomorphies of this specimen with avemetatarsalians include: femur with an incipient anterior trochanter, 1st sacral vertebra with a dorsoventrally expanded sacral rib, and ilium possessing a notch on the articulation surface with the ischium. This combination of features places the new taxon represented by this specimen at the base of Avemetatarsalia, outside aphanosaurs + dinosaurs, but this position is poorly supported. More broadly, this new specimen indicates that cervical osteoderms were present in the earliest avemetatarsalians and were soon lost in the lineage. The generally plesiomorphic morphology of the new taxon also underscores the difficulty of identifying early avemetatarsalians from incomplete skeletons. Presence of an early diverging avemetatarsalian together with a lagerpetid and silesaurid in the "Basal Isalo II" beds of Madagascar documents the co-occurrence of multiple avemetatarsalian subgroups in Gondwana during the Triassic.

Grant Information:
National Geographic Society
Field Museum of Natural History
American Museum of Natural History

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

PALEONEUROANATOMY OF A NEW RIOJASAURID (DINOSAURIA, SAUROPODOMORPHA) FROM THE LATE TRIASSIC OF ARGENTINA

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Here, we present the first paleoneurological study based on CT scans of the skull of a new riojasaurid sauropodomorph (PVSJ 849) from the Los Colorados Formation (Late Triassic) of Argentina. The CT scan allowed the rendering of the braincase and endocranial cavities, resulting in the most complete anatomical data for a South American representative of the clade. The cranial endocast of PVSJ 849 characterizes by a low dorsal expansion, cerebral hemispheres poorly expanded laterally, elongated olfactory tract and bulbs, a relatively well developed flocculus of the cerebellum, and bulbous and short pituitary. The cranial endocast has a marked sigmoidal shape in lateral view, with the olfactory bulbs aligned with the forebrain, the midbrain posteroventrally inclined and the hindbrain parallel and ventral to the forebrain. The flocculus is similar in size to that in the basal form *Saturnalia tupiniquim* and basal Neotheropoda, but contrasting with the small flocculus in the sauropodomorph *Plateosaurus* sp (a state of character that is considered a derived condition within Sauropodomorpha). The inner ear has slender semicircular canals, and the relative size of anterior, posterior and lateral semicircular canals are similar to *S. tupiniquim*. In dorsal view, the angle formed between anterior and posterior semicircular canals is about 80 degrees. The brain, cranial nerves and inner ear of few Triassic sauropodomorph dinosaurs have been studied, and within South American taxa these include only *S. tupiniquim* from Brazil. The preliminary comparisons of the neuroanatomy suggest a primitive condition within Riojasauridae, represented by PVSJ 849 with a neuroanatomy that is more similar to *S. tupiniquim* than to the more derived (and more closely related) *Plateosaurus sp*.

Grant Information:
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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

TEMPORAL LOBE VARIATION IN EXTANT AND FOSSIL OLD WORLD MONKEYS (CERCOPITHECOIDEA, CATARRHINI)

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Paleoneurologists have previously described changes in the relative proportions of cerebral regions during the evolution of Old World Monkeys (Cercopithecoidea). Compared to fossil catarrhines, extant cercopithecines have an absolute increase in total brain volume with relatively larger frontal lobes but reduced olfactory bulbs. There is no consensus whether extant cercopithecine temporal lobes show a relative increase or decrease from fossil catarrhines. The temporal lobe of the brain occupies the middle cranial fossa of the basicranium with close spatial proximity associated with cranial change and indirectly impacting brain form. We aimed to clarify the correspondence between the temporal lobe and fossa through regression analysis, predicting temporal lobe volume from fossa size, before determining the variation of temporal lobe size in extant and fossil catarrhines. Our sample included two African early Oligocene catarrhines, *Parapithecus grangeri* and *Aegyptopoithecus zeuxis* and two species of extant cercopithecines, *Macaca mulatta* and *Cercocebus atys*. *Ex vivo* Computed Tomography (CT) and Micro-Computed Tomography (µCT) cranial scans produced 3D digital crania before 6 digital measurements were recorded on the endocranial surface of the fossa, approximating temporal lobe location. *In vivo* Magnetic Resonance Imaging (MRI) of the primate brain provided direct calculation of temporal lobe volume. Phylogenetic Least-Squares (PGLS) regression tested the correlation between temporal lobe volume and fossa size. A statistically significant correlation ($r \leq 0.80$; $k \leq 0.90$) between extant anthropoid temporal lobe volume and fossa size determined fossil predictions were reasonable. The average predicted temporal lobe volumes in extant cercopithecines were larger, absolutely, than fossil catarrhines, however, proportion of the brain occupied by the temporal lobes was relatively smaller in extant cercopithecines than *Aegypotopithecus zeuxis* and *Parapithecus grangeri*. Despite sample size limitations, we confirm the fossa provides a suitable estimate for predicting temporal lobe volume and corroborate other findings that fossil catarrhines possessed relatively larger temporal lobes compared to extant species. We note; however, that relatively smaller temporal lobes in extant species does not necessarily indicate a reduction in temporal lobe size over time but could reflect other findings on relative increase in other cerebral regions.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

FRESHWATER FISH FAUNAS FROM TWO PERMIAN RIFT VALLEYS OF ZAMBIA, WITH BIOGEOGRAPHIC IMPLICATIONS FOR SOUTHERN PANGEA

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Toward the end of the Paleozoic, Earth's landmasses formed the supercontinent Pangea. Despite the relative lack of large-scale physical dispersal barriers, patterns of endemism and regionalization existed, likely driven by climatic conditions. Given the increasingly arid and landlocked conditions of the interior of Pangea, as well as patterns of endemism in modern aquatic rift valley faunas, the study of freshwater vertebrate

communities can help discern biogeographic patterns across the supercontinent.
Here we report two Permian fish assemblages from the Madumabisa Mudstone Formation of Zambia consisting of actinopterygians and large-bodied sharks, each of which is found in the immediate proximity of terrestrial tetrapod fossils. The middle Permian material is from the Mid-Zambezi Basin and consists of associated peg-and-socket scales and bony fragments belonging to an actinopterygian. The upper Permian material is from the Luangwa Basin and was collected in the 1970s, but has not been reported in detail until now. It consists of several actinopterygian fossils, including semi-articulated skeletons with dermal bones, teeth, fin rays, scales, and partial body outlines, as well as several types of ornamented dorsal fin spines belonging to euselachian sharks, the largest of which is approximately 14 cm long.
These assemblages compare well with middle and late Permian freshwater ichthyofaunas from Australia (Rangal Coal Measures, Bowen Basin), Brazil (Rio do Rasto Formation, Paraná Basin), and South Africa (Beaufort Group, Karoo Basin). However, no Permian elasmobranchs have been reported from the well sampled Karoo Basin. Our finding of comparable ichthyofaunas agrees with previous analyses of Permian ecosystem structure across southern mid to high paleolatitudes, which found high similarity between basins dominated by glossopterid floras and their attendant dicynodont therapsid consumers.

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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

MAMMALIAN MORPHOLOGICAL DISPARITY IN THE CONTEXT OF LANDSCAPE EVOLUTION AND TECTONISM IN THE MIOCENE OF NORTH AMERICA

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The Miocene Epoch (ca. 23.03-5.33 Ma) represents a period of great climatic and tectonic change in western North America. The Great Basin during this time is characterized by ongoing volcanic and tectonic activity, punctuated periodically by events of significant magnitude (e. g., the eruption of the Columbia River flood basalts, uplift of the Colorado Plateau and Sierra Nevada Mountains, and peak volcanism in the Great Basin) which contributed to substantial topographic changes in this region. This occurred in synchrony with long-term cooling, which was interrupted by a considerable warm interval (i.e., the Miocene Climatic Optimum, ca. 17-14.7 Ma; MCO) and followed by major cooling during the Miocene Climatic Transition (MCT, beginning around 14.8 Ma). These changes resulted in a landscape typified by relative climatic and topographic complexity which, in turn, is thought to generate biotic diversity.

While taxonomic diversity changes through this interval have been well-studied, work to date has not addressed whether patterns of morphological diversity align with known taxonomic change. We investigate the diversity in morphological form through lower m1 length disparity in rodents. Lower m1 length has been shown to correlate closely with overall body mass. We use rodents for this analysis given their abundance on the landscape, short generation time, and susceptibility to topographic gradients. We consider the North American continent in two broad regions: the tectonically active region stretching from the Rocky Mountains to the Pacific coast, characterized by significant tectonic activity and ensuing increases in landscape complexity; and the tectonically passive region ranging from east of the Rocky Mountains to the Mississippi River, characterized by comparatively homogenous topography.
We analyze disparity through a suite of measures, including mean pairwise distance and the mean distance from the centroid. Our statistical comparisons across both time and tectonic regime find that the Hemingfordian and Arikareean North American Land Mammal Ages (NALMAs; approximately aligning with the Early Miocene) display the highest average pairwise distances, indicating a more morphologically disparate population. We find that disparity generally decreases following the MCO and MCT in the Middle and Late Miocene. We also observe that morphological disparity varies by tectonic regime. However, similar long-term averages exist for both the active and passive regions during the entire Miocene.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

NEW POSTCRANIA OF SCIURAVIDAE (RODENTIA): IMPLICATIONS FOR LOCOMOTION AND PHYLOGENY

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Sciuravids are an early clade of lophodont rodents endemic to the early and middle Eocene of North America, where they are an abundant component of many faunas. While some assessments of sciuravid affinities view the group as an early experiment in lophodonty independent of any living group, relationships to extant rodents, particularly myodonts, have also been proposed. As with many other early rodent groups, the postcranium of sciuravids remains poorly known, limiting our understanding of the habitat preferences, locomotor habits, and phylogenetic relationships of the family. In fact, the only postcranial element described to date for any sciuravid is an isolated distal tibia referred to early Eocene *Knightomys*.
We report here additional postcrania referable to three sciuravid genera. Material referable to *Sciuravus* from the late Uintan of southern California includes astragali, calcanei, a navicular, and a distal humerus and tibia, while new postcrania of Wasatchian *Knightomys* and Uintan *Pauromys* are restricted to the proximal tarsus. Astragali of *Sciuravus* and *Knightomys* are very similar sharing a comparatively narrow, symmetric trochlea, the presence of a shelf on the astragalar body medial to the trochlea, an oblique astragalar head, and a smooth medial transition between head and neck. Calcanei of *Sciuravus* and *Knightomys* share substantial overlap between ectal and sustentacular facets, a distally extended peroneal tubercle, and a relatively proximal plantar tubercle. The proximal tarsus of *Pauromys* lacks many of these features, consistent with recent suggestions that the genus represents a basal myodont, not a sciuravid.
In comparison with a diversity of other early rodents, most of the features present in the tarsus of *Sciuravus* and *Knightomys* suggest relatively terrestrial habits. This impression is strengthened by the distal humerus of *Sciuravus*, which has a less projecting medial epicondyle and narrower trochlea than is present in ischyromyids. This contrasts with the much more arboreal morphology present in *Microparamys*, casting doubt on the hypothesis that sciuravids have a microparamyine ancestry.

Technical Session VII (Thursday, October 10, 2019, 10:45 AM)

A NEW ORNITHOCHEIRID PTEROSAUR FROM THE WINTON FORMATION (CENOMANIAN–LOWER TURONIAN) OF NORTHEAST AUSTRALIA: PALEOBIOGEOGRAPHIC AND PALEOECOLOGICAL IMPLICATIONS

PENTLAND, Adele H., Swinburne University of Technology, Hawthorn, Australia; POROPAT, Stephen F., Swinburne University of Technology, Hawthorn, Australia; SLOAN, Trish, Australian Age of Dinosaurs Natural History Museum, Winton, Australia; ELLIOTT, Robert A., Australian Age of Dinosaurs Natural History Museum, Winton, Australia; ELLIOTT, Harry A., Australian Age of Dinosaurs Natural History Museum, Winton, Australia; ELLIOTT, Judy A., Australian Age of Dinosaurs Natural History Museum, Winton, Australia; ELLIOTT, David A., Australian Age of Dinosaurs Natural History Museum, Winton, Australia

The Australian pterosaur fossil record is poor by world standards, with fewer than 20 specimens — each comprising one or two isolated bones — reported from the entire continent. Only two taxa have been named (*Mythunga camara* and *Aussiedraco molnari*), each based on fragmentary cranial remains from the Toolebuc Formation (upper Albian) of Queensland. In April 2017, a new pterosaur specimen was discovered on a property northeast of Winton, Queensland. This specimen, which comprises a partial skull with premaxillary and dentary crests, forty teeth, five cervical vertebrae, the majority of the left wing and fragments of the right wing, is the most complete pterosaur known from Australia, and the first reported from the Winton Formation (Cenomanian–lower Turonian) of the Eromanga Basin. All of the elements are three-dimensionally preserved, with their internal spaces infilled by ironstone. Although the Winton pterosaur was discovered in a fragmented state in the bank of a normally dry ephemeral creek, it is likely that the skeleton was articulated prior to erosion: the upper and lower jaws were found articulated, and several wing elements key into matrix adhering to anatomically adjacent elements.
The inclusion of the Winton pterosaur in a phylogenetic analysis of Pterosauria resolved it within Anhangueria, specifically as the sister taxon to *Mythunga camara* (Australia). The new specimen differs from *Mythunga* in that the latter possesses more robust teeth. In contrast, the new pterosaur possesses a mandibular crest, and the mandible is distally expanded when compared with *Aussiedraco*. This Australian clade occupies the most derived position within Ornithocheiridae, with *Ornithocheirus simus* (United

Kingdom), *Coloborhynchus clavirostris* (United Kingdom) and *Tropeognathus mesembrinus* (Brazil) as successive sister taxa. This implies mid-Cretaceous ornithocheirid cosmopolitanism, rather than Laurasian/Gondwanan provincialism.
Most anhanguerians derive from coastal or lagoonal paleoenvironments, and the apparent absence of anhanguerians in post-Cenomanian strata supports the notion that they went extinct at the Cenomanian–Turonian boundary. Thus, the discovery of the Winton pterosaur in a Cenomanian–lower Turonian-aged, non-marine unit is doubly unusual. The Winton pterosaur might represent the latest-surviving anhanguerian, as well as one of few specialised for a floodplain setting.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

CHONDRICHTHYAN DIVERSITY OF FLORIDA IN RESPONSE TO CENOZOIC CLIMATE CHANGE

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Chondrichthyan taxa are poorly documented from Florida, despite their popularity, abundance, and utility for interpreting paleoecology. The Florida Museum of Natural History (FLMNH) has a curated collection of 103,364 chondrichthyan specimens spanning from the Eocene through the Pleistocene, and yet less than 1% of these have been published in peer-reviewed literature. Arguably, the two most profound climate events over this time span were the Eocene Oligocene Transition (EOT) and the Middle Miocene Climatic Optimum (MMCO). The EOT marks abrupt global cooling, with estimates of ~2.5 °C drop in tropical sea surface temperatures. The MMCO represents a more prolonged global warming event, in which sea surface temperatures increased ~3–5 °C and atmospheric CO_2 concentrations were comparable to today (~350–400 ppm). In the Eocene, lamniform sharks are the most diverse and abundant chondrichthyans; however, five genera of lamniform sharks go extinct at the Eocene–Oligocene boundary. In the Oligocene, carcharhiniform sharks become the most diverse and abundant chondrichthyans. This change in the dominant taxonomic group reflects a prominent transition in dental functional type from grasping-dominant Eocene taxa to cutting-dominant Oligocene taxa. Within the Miocene, there is a marked increase in chondrichthyan diversity and abundance (25% of FLMNH collection); which is well represented by a major radiation within the genus *Carcharhinus*, with first appearances of at least nine species. During the MMCO, there is little change in dental functional diversity; however, there is notably high chondrichthyan abundance. While this is in part a product of sampling bias, high abundance of chondrichthyan fossils during the MMCO is also reflected in other deposits (e.g., Shark Tooth Hill in Bakersfield, CA and Calvert Cliffs in Calvert County, MD), which has been attributed to increased primary productivity. Peak abundance of chondrichthyan taxa in Florida occurs during the Pliocene (70.1% of FLMNH collection), which is predominantly associated with phosphate-rich, high nutrient environments. Transitioning into the Pleistocene, as global climate continues to cool, chondrichthyan abundance decreases dramatically (3.6% of FLMNH collection); however, this may reflect a sampling bias related to the fewer number of marine sites. This study documents local chondrichthyan diversity trends and sampling limitations, which are imperative for improving our comprehension of global diversity and projecting for future climate change.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

ON THE PRESENCE OF A PUTATIVE ORNITHURAE (AVES) IN THE LATE MAASTRICHTIAN VERTEBRATE FAUNAS FROM SOUTHERN PYRENEES (SPAIN)

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Remains of Late Cretaceous birds are scarce, especially in the Maastrichtian of Europe. Up to now, just some Enantiornithes (e.g., *Martinavis cruzyensis*) and Ornithurae remains have been recovered. In this context, one of the most remarkably remains corresponds to the giant bird *Gargantuavis philoinos* from the early Maastrichtian of France, unfortunately its phylogenetic position within Aves remains unknown.
Here we present a cervical vertebra (MPZ 2019/264) belonging to a large-sized bird recovered from the upper Maastrichtian fossil locality 'Dolor 3' (Tremp Fm), near the village of Serraduy within the Tremp Basin in the Pyrenean range (Huesca, Spain). The Tremp Fm deposits from this area have been dated by magnetostratigraphy and biostratigraphy as belonging to the Chron C29r. Therefore MPZ 2019/264 is one of the youngest Mesozoic Aves of Europe, very close to the Cretaceous/Paleogene boundary (K/Pg), and the first report of this clade in the Tremp Basin.
MPZ 2019/264 is an almost complete cervical vertebra just lacking the posterior articular face. The morphology of the anterior section of the vertebral centrum, which is concave transversely and convex dorsoventrally, confirms an advanced heterocoelous condition. In addition, a micro-CT analysis showed a very strong vertebral pneumatization with camellate internal structure. MPZ 2019/264 also bears two lateral pneumatic foramina in the neural arch and another one in the centrum. These foramina, along with a low and anteroposteriorly elongated neural spine and the arrow-shaped section of the centrum, differentiate MPZ 2019/264 from the cervical vertebra of *Gargantuavis* from Montplo-Nord (France). A cladistic analysis using a dataset comprising 23 ornithuromorphs, 29 enantiornithes and 8 basal avians, recovers both *Gargantuavis* and MPZ 2019/264 as Ornithuromorpha. When *Gargantuavis* is not included in the analysis, MPZ 2019/264 is recovered as member of Ornithurae. Nevertheless, these results have to be considered with caution, as the fragmentary condition of both *Gargantuavis* and MPZ 2019/264, and the lack of preserved unambiguous synapomorphies in the later hinders further taxonomic attribution.
In conclusion, the vertebra MPZ 2019/264 represents the second and youngest taxon of a Maastrichtian giant bird in the Ibero Armorican Island, adding new data to the scarce Aves fossil record of Europe during the last few hundred thousand years before the K/Pg extinction event.

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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

ANALYSIS OF ECOLOGICAL DIVERSIFICATION IN MARSUPIAL MAMMAL EVOLUTION BY MULTIVARIATE ANALYSES OF THEIR LIMB SKELETON IN BOTH EXTANT AND FOSSIL MARSUPIALS

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Ecological diversification is an important aspect of the evolution of mammals. There have been many recent advances showing a broader ecological diversity for mammaliaform predecessors to mammals in the Mesozoic than had been previously thought. There have also been many recent studies on placental ecological diversity. However, the origin and ecological diversification of marsupials has not seen as much attention. This study took a quantitative approach to explain the origin of marsupial ecological diversification. This was done by compiling the largest dataset to date on skeletal measurements of extant marsupial species with known locomotor modes, with a small subset of this dataset corroborated by CT scans. These measurements were used to calculate locomotor functional indices. Statistical significance of these indices was determined via ANOVA analyses. The statistically significant functional indices were then analyzed using a Principal Components Analysis and Linear Discriminant Analysis to associate the indices with locomotor modes. Both of these multivariate analyses show clear discrimination between locomotor modes, demonstrating that skeletal measurements can be informative about locomotor mode. When a fossil marsupial was placed into these analyses, it placed closely to the scansorial group, indicating that early marsupials were scansorial. While this does not contradict previous qualitative analyses that early fossil marsupials had arboreal skeletal adaptations, it does suggest that the evolution of locomotion in marsupials may not be a simple story of descending from or climbing up to trees. Rather, it may be indicative of a non-linear trend of generalists diversifying to occupy specific ecological niches.

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Technical Session IX (Thursday, October 10, 2019, 2:00 PM)

FOSSIL AND EXTANT MORPHOLOGIES REVEAL REPEATED DEVELOPMENT OF DISTAL HINDLIMBS IN THE EVOLUTION OF SNAKES

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Competing hypotheses of the interrelationships of Cretaceous snakes with well-developed hindlimbs require homoplasy in either the evolution of derived cranial characters or in the pattern of hindlimb reduction and loss in snake phylogeny. Specifically, a derived position of limbed snakes requires either multiple histories of limb loss in extant snake clades, or the 're-evolution' of hindlimbs that include zeugopodial and autopodial elements in Cretaceous taxa. Retention of limb-patterning mechanisms during embryogenesis in extant *Python* indicates a potential mechanism for evolutionary reacquisition of hindlimb elements; however, the extreme reduction of limb elements in extant taxa has not previously provided support for the evolutionary polarity of hindlimbs in fossils nor the role of developmental modification in potentially re-establishing limbs. Here we combined high-resolution Micro C-T comparative anatomy of the pelvic region in extant snakes with Ancestral State Reconstruction (ASR) methods to model the evolution of distal limb elements in the evolution of snakes.

Based on C-T data from 50 snake species, we discover the first unambiguous evidence for zeugopodial ossifications in extant taxa and map their distributions across competing molecular, morphological, and combined phylogenetic hypotheses for Serpentes. ASR analyses reveal multiple histories of redevelopment of an ossified zeugopod for all topologies, regardless of the interrelationships of limbed fossil taxa, and demonstrate the persistence of late-stage limb patterning throughout snake phylogeny. These results support concepts of complex anatomical system reacquisition through deep time and are permissive of hypotheses of derived interrelationships of limbed fossil snakes.

Grant Information:
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Technical Session XIX (Saturday, October 12, 2019, 3:00 PM)

EXPLAINING WHY MOLECULAR CLOCK ANALYSES MISSED THE POST KPG DIVERSIFICATIONS OF MAMMALS AND BIRDS OBSERVED IN THE FOSSIL RECORD

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Molecular dating estimates for placental mammals and birds echo fossil inferences for an explosive interordinal diversification, but typically place this event some 10–20 million years earlier than the Paleocene fossils, among apparently more "primitive" faunas. Efforts to resolve this discrepancy have focused on fossil sampling biases or hidden molecular rate accelerations inferred under controversial fossil calibration schemes. However, the sampling bias explanation fails when considered across multiple orders and the rate acceleration explanation lacks a sound theoretical foundation and we show is also contradicted by patterns of selection on DNA sequences.

Here we present simulations and empirical analyses that explain overestimation of mammalian and avian molecular divergence estimates. Firstly, we show that current models of molecular evolution underestimate parallel rate decelerations across lineages of large, long-lived mammals and birds, such as whales, hominids, and Anseriformes. Calibrating among these taxa shifts the rate model errors deeper in the tree, inflating interordinal divergence estimates. Molecular dating accuracy is substantially improved in the simulations by focusing on calibrations for taxa that retain plesiomorphic life-history characteristics. Applying this strategy to the empirical data favours the soft explosive model, in line with traditional paleontological interpretations – a few Cretaceous lineages give rise to rapid interordinal diversifications following the 66 Ma Cretaceous-Paleogene boundary mass extinction.

Our soft explosive model for the diversification of placental mammals and birds provides consilience of evidence from previously incongruous molecular, fossil, and life history data sources. More generally, we suggest that the evolutionary properties of adaptive radiations may leave current molecular dating methods susceptible to overestimating the timing of major diversification events.

Grant Information:
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DP170103227 awarded to M.J.P.

Preparators' Session (Thursday, October 10, 2019, 2:30 PM)

COMPACTED FIBERGLASS ARMATURE FOR SUPPORTING SMALL FOSSIL SPECIMENS

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Armatures to support fossil specimens are commonly constructed with metals such as steel or brass. Metallic armatures can present risks for small and delicate fossil specimens, as repeated fit tests, abrasion, and metal corrosion can damage the fossil. An alternate armature material is here presented, made using stacked layers of fiberglass cloth which are saturated with Butvar B-76 adhesive liquefied in acetone, and compressed between sheets of Tyvek polyethylene cloth until set. The result is a stiff sheet of archival material which can be cut to size, adjusted in shape with the use of a liquid solvent, and adhered directly to the specimen if desired. The reversible properties of the adhesive used ensure that the armature can be removed in the future. This method is an adaptation of preexisting related techniques: using string temporarily adhered to segments of easily-fractured fossil, and using paper or fiberglass adhered to thin specimens as a supporting backing material. A drawback of this technique is the reduced function of the fiberglass support when spanning large weights or across large surface areas. This method can be used not only in exhibit environments, but also in creating storage supports which can be CT scanned along with the specimen, and for the reinforcement of select fragile specimen features.

A case study is presented using this method and materials to alter a historical display mount of the small mammal *Leptomeryx evansi* (USNM V16754) to provide support for fragile freestanding articulated limbs. The use of this method reduced time needed in working with the specimen, avoided the use of equipment and hazards associated with welding or brazing, and avoided risk to the specimen associated with altering the original mount structure to properly anchor metal armature. Results of work include the greatly reduced likelihood of fracture and loss of limb elements, preserving the integrity of the specimen as both a display and research object.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

PALEOECOLOGY AND OCEAN VIEWS: DECLINE OF MAMMAL SPECIES RICHNESS DURING LATE QUATERNARY ISLAND FORMATION IN THE MONTEBELLO ISLANDS, NORTH-WESTERN AUSTRALIA

PIPER, Cassia J., Western Australian Museum, Welshpool, Australia; VETH, Peter, University of Western Australia, Crawley, Australia

During the Last Glacial maximum, 26 to 19ka, sea levels fell to approximately 120 m below present level, exposing much of the north-west shelf of Australia as lowlands and elevated plateaus. As sea levels rose, low-lying areas were swamped and elevated areas became islands. Changes in sea level and island formation can impact the distributions and abundances of local fauna, and these paleonenvironmental investigations can give long-term context to biological conservation and wildlife management. Paleoenvironmental knowledge of the north-west during the late Quaternary is sparse, particularly the impact of island formation on the local fauna, as all cave faunas until now have been excavated from the mainland.

Peter Veth and his teams conducted archaeological surveys of the Montebello Island group between 1991 and 1993. These islands lie 70 – 90 km off the present-day coastline of north-western Australia, and 20 km NNW of nearby Barrow Island, a Class A Nature Reserve. During surveys, Veth found a group of three caves on the eastern side of Campbell Island, which were named Noala, Hayne's and Morgan's Caves. Noala and Hayne's Caves were excavated and analysed in the early 90s; Morgan's Cave remained unanalysed due to little cultural material being recovered. However, this latter site offers an opportunity to refine paleoenvironmental interpretations by providing further information on the original, pre-European fauna of the north-west shelf, the process of island formation due to sea level rise, and the resulting impact on the local fauna.

Bone material from the cave was sorted, identified and counted to create relative abundance data for the fossil mammal species in the deposit. The assemblage from Morgan's Cave is similar to those recovered from Noala and Hayne's Caves.

There are strong patterns of reduction and changing relative abundances in certain species within the deposit through time, indicating faunal evidence of multi-staged island formation due to sea level rise. The most notable of these trends is the declining relative abundance of the sandy-substrate species, *Notomys alexis*, (Spinifex Hopping-mouse). Conversely, *Pseudomys nanus* (Western Chestnut Mouse) shows an increase in relative abundance towards the top of the deposit, as do several other species that are extant on Barrow Island today. Unique knowledge derived from this paleoecological reconstruction can be used to inform conservation actions today on Barrow Island's unique island ecosystem, and in the management of mammal faunas on other islands and conservation reserves.

Technical Session XIV (Friday, October 11, 2019, 2:00 PM)

INTERNAL AND EXTERNAL FLIGHT-RELATED ANATOMY OF EARLY THEROPOD FLIERS REVEALED BY LASER-STIMULATED FLUORESCENCE FILLS KNOWLEDGE GAPS IN FUNCTIONAL MORPHOLOGY AND FLIGHT CAPABILITY

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Exceptional coelurosaurian theropod dinosaur fossils provide astonishing insight into the evolution of theropod flight. Comparative morphology and different modelling approaches (such as physical models and aerodynamic equations) have documented a range of early flying strategies (including thermal soaring) as well as the functional abilities of coelurosaurs that appeared just short of entering the aerial realm. Laser-Stimulated Fluorescence (LSF) is a rapid, non-destructive geochemical imaging technique that has important applications in early theropod flight studies because it can visualise otherwise hidden flight-related anatomies exposed as fine geochemical differences in these fossils. LSF has so far revealed near complete soft tissue body outlines including of the wings and legs as well as propatagial feather follicle patterns in a small sample of select early theropod flyers and near-flyers. Here we present LSF data from ~600 specimens of the short-tailed early bird *Confuciusornis* (Pygostylia: Confuciusornithidae) that for the first time reveals the soft tissue outline of the pectoral girdle and tail as well as subsurface details of the original propatagial muscle complex. We detect the form of the ancestral propatagial ligament, extensively muscled shoulders anchored to the well-known, unusually expanded deltopectoral crest of the humerus as well as reduced breast muscles associated with its sternum-less ventrum. Our results directly record a novel avian flight architecture that pre-existed the ventrally-placed flight muscles of the modern avian flight apparatus and that was also relatively long-lived among Confuciusornithidae. Our results underscore the youth of the modern condition and the antiquity of the role of dorsally-positioned muscles in the avian flight stroke.

Grant Information:
Dr Stephen S.F. Hui Trust Fund (201403173007), the Research Grant Council of Hong Kong's General Research Fund (17103315), The Faculty of Science of the University of Hong Kong

Technical Session VII (Thursday, October 10, 2019, 8:15 AM)

NEW JURASSIC AND CRETACEOUS NEOSUCHIANS FROM THE SAHARA ADD TO AFRICA'S REMARKABLE CROCODYLIFORM DIVERSITY AND ITS PALEOGEOGRAPHIC CONNECTIONS WITH NORTHERN LANDMASSES

POL, Diego, Museo Paleontológico Egidio Feruglio, Trelew, Argentina; SERENO, Paul C., University of Chicago, Chicago, IL, United States of America

New fossils discovered in Upper Jurassic and Cretaceous rocks in Niger and Morocco add significant diversity to the neosuchian record for Africa and additional complexity to its paleogeographic history. Jurassic forms include the first African goniopholidids, two new genera from the Tiouraren Formation (? Middle Jurassic) of Niger. One is known from a complete skull that exhibits the classic external maxillary fossa and other cranial features highly reminiscent of Laurasian *Goniopholis*. The second goniopholidid has a narrow cranium and elongate snout, subdued surface texture and spaced maxillary teeth of similar size. The goniopholidids present another intriguing connection between Africa and Laurasia. There are three new Late Cretaceous (Cenomanian) genera in addition to new material of the bizarre flat-skulled neosuchian *Laganosuchus*. The new forms include a large species similar to the Moroccan genus "*Hammadasuchus*," a large-bodied peirosaurid rivaling *Sarcosuchus* in size with a transversely compressed snout and diminutive postcranium, and an agile smooth-skulled, long-limbed notosuchian lacking body armor. Together these new African genera, along with those described previously from Niger and Morocco, document an extremely diverse crocodyliform assemblage in the latter half of the Mesozoic, comparable to that in South America. The new neosuchians add further complexity to African biogeographic associations, linking to southern Europe in the Middle Jurassic and to Madagascar in the Late Cretaceous.

Technical Session XI (Friday, October 11, 2019, 11:45 AM)

THE ASSEMBLY OF CAT COMMUNITIES IN THE NEW WORLD: ECOMETRICS AND NEOGENE FAUNAL TURNOVER

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Cats possess some of the highest ankle gear ratios of any extant carnivorans, a feature that facilitates leaping and sprinting involved in ambush predation and scansorial lifestyles. This paper addresses questions about the phylogenetic origin of their high ankle gear ratios and the history of their occupation of high gear ratio niches in the late Cenozoic of North America. Across all carnivoramorpha it was found that gear ratios range from 1.08 (with extant ursids and viverrids and extinct miacids and barbourofelids having the lowest values) to 1.46 (with extant felids, herpestids, and canids having the highest values). Using phylogenetic ancestor reconstruction it is shown that the ancestral carnivoran and ancestral felid had gear ratios about halfway between these extremes, consistent with a digitigrade or semidigitigrade stance that was not overly specialized for either cursoriality or saltation. Barbourofelids and some machairodontines evolved very low gear ratios, emphasizing mechanical efficiency over advantage. The Miocene felids of North America did not occupy high gear ratio niches and, in fact, occupied some of the lowest gear ratio niches during the Barstovian, Clarendonian, and Hemphillian. A major restructuring of gear ratio distributions in North American carnivoran communities occurred during the Blancan that appears to have resulted from clade sorting processes involving the selective loss of low gear ratio groups.

Grant Information:
This research was supported by National Science Foundation Grant EAR-133829 and by Indiana University's Robert R. Shrock Fund.

Technical Session II (Wednesday, October 9, 2019, 9:15 AM)

NEW SAUROPOD DINOSAUR DISCOVERIES IN THE LOWER UPPER CRETACEOUS WINTON FORMATION (CENOMANIAN–LOWER TURONIAN) OF QUEENSLAND, AUSTRALIA: IMPLICATIONS FOR TITANOSAURIAN EVOLUTION

POROPAT, Stephen F., Swinburne University of Technology, Hawthorn, Australia; MANNION, Philip D., University College London, London, England; UPCHURCH, Paul, University College London, London, United Kingdom; ELLIOTT, David A., Australian Age of Dinosaurs Museum of Natural History, Winton, Australia

The lower Upper Cretaceous Winton Formation (Cenomanian–lower Turonian), exposed near Winton, central Queensland, has produced a plethora of sauropod dinosaur specimens in the past decade. Three taxa have been established to date—*Wintonotitan wattsi*, *Diamantinasaurus matildae* and *Savannasaurus elliottorum*—and several recent discoveries promise to enhance our understanding of these taxa and of titanosauriform sauropods generally.

The first sauropod footprints from the Winton Formation (discovered in 2016) demonstrate that at least one taxon was capable of adopting both relatively narrow- and wide-gauge stances, while also retaining a prominent pollex ungual (previously hypothesised for *Diamantinasaurus*). This suggests that both gauge and presence/absence of a pollex ungual are problematic criteria for identifying titanosaurs from trackways. The hip height of one track-maker exceeded 2.6 metres, implying that body fossils of larger sauropods from the Winton Formation await discovery.

The most complete sauropod ever found in Australia—comprising four teeth and much of the postcranial skeleton—was unearthed in 2017. Preliminary analysis has enabled its referral to *Diamantinasaurus*; thus, the postcranial skeletal anatomy of this taxon is now almost completely known, improving our understanding of its phylogenetic position and paleobiogeographic implications. Notably, this specimen also preserves gut contents and possible skin impressions. Synchrotron scanning of the gut contents has revealed abundant plant fossils within, thereby providing the first direct evidence of sauropod feeding habits in the fossil record.

Lastly, a partial sauropod skull, associated with a hind limb, was discovered in 2018. Although it is still under preparation, it includes a braincase, quadrates, quadratojugals, a left squamosal, postorbitals, and several unprepared elements. Relatively few titanosauriforms are represented by cranial material, making this a critically important specimen that bridges the spatiotemporal gap between pre-Cenomanian titanosauriforms (e.g., *Giraffatitan*, *Euhelopus*, *Abydosaurus*, *Tapuiasaurus*), the Cenomanian–Turonian titanosaur *Sarmientosaurus*, and post-Turonian titanosaurs (e.g., *Nemegtosaurus*, *Rapetosaurus*), known from nearly complete skulls.

These new discoveries demonstrate the huge potential of the Winton Formation as a paleontological resource. Moreover, they greatly enhance our

understanding of the evolution and ecology of Late Cretaceous Australian titanosauriform sauropods.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

CRANIAL SUTURES AND MECHANICAL PERFORMANCE IN TETRAPOD SKULLS DURING THE WATER-LAND TRANSITION

PORRO, Laura B., University College London, London, United Kingdom; MAY, Julia R., University of York, York, United Kingdom; DUTEL, Hugo, University of Bristol, Bristol, United Kingdom; MARTIN-SILVERSTONE, Elizabeth G., University of Bristol, Bristol, United Kingdom; RAYFIELD, Emily J., University of Bristol, Bristol, United Kingdom

The emergence of tetrapods from the water and their conquest of the land was a key moment in the history of life marked by dramatic skeletal evolution. Changes in overall skull shape, a reduction in the number of bones, shifts in the size and distribution of the teeth, and presumed modifications in jaw muscle architecture are assumed to reflect new feeding mechanisms and diets, and/or differing environmental constraints. Experiments on living animals have demonstrated that sutures – fibrous joints between skull bones – impact the mechanical response of the skull to feeding forces, and different suture shapes are associated with tension, compression, or other load regimes. High-resolution micro-computed tomography was used to capture skull shape in fossil tetrapod skulls spanning the transition – from the Late Devonian to the Early Triassic – as well as in extant relatives. Suture shapes throughout the skull were documented and used to predict load regime. The predominance of overlapping contacts suggests highly variable load regimes in the skulls of *Polypterus* and tetrapodomorph fish such as *Eusthenopteron*. This may be related to a combined use of suction feeding and biting to capture and ingest prey, and/or hydrodynamic constraints imposed by an aquatic lifestyle. In contrast, the skulls of later stem tetrapods such as *Acanthostega* and *Crassigyrinus* exhibit interdigitated sutures associated with compression. Their distribution suggests forces being channelled from the teeth to the skull roof, consistent with load regimes generated by biting. After correcting for taphonomic damage and distortion, 3D reconstructions from CT data served as the basis for finite element models of the skulls of early tetrapods and their extant relatives. We compare skull mechanical response under simple feeding loads in finite element models to load regimes predicted by suture shape, including validation of model results using experimental data from living taxa.

Grant Information:
This research was funded by NERC Standard Grant NE/P013090/1 (”Skull evolution and the terrestrialization and radiation of tetrapods”).

Technical Session I (Wednesday, October 9, 2019, 12:00 PM)

NEW WALRUSES FROM THE PURISIMA FORMATION REVEAL PATTERN OF HIGH LOCAL PINNIPED DIVERSITY IN THE MIO-PLIOCENE EASTERN PACIFIC

POUST, Ashley W., University of California, Berkeley, Berkeley, CA, United States of America; BOESSENECKER, Robert W., College of Charleston, Charleston, SC, United States of America; CHURCHILL, Morgan, University of Wisconsin Oshkosh, Oshkosh, WI, United States of America; BOESSENECKER, Sarah, College of Charleston, Charleston, SC, United States of America

The monotypic living walrus is only one highly-aberrant descendent of a much more diverse lineage, extending from at least the early Miocene (Burdigalian). Recent attention to vertebrate assemblages in the eastern North Pacific (ENP) has revealed a number with three or more odobenid taxa, including the Wilson Grove, Capistrano, and San Diego formations. We report two new taxa from the well-known Purisima Formation of north-central California, already one of the most diverse fossil odobenid assemblages. Both species are represented by relatively complete skulls. A new species of *Valenictus* is differentiated from *V. chulavistensis* by rostral and basicranial features, in addition to its large size. This specimen clarifies previous reports of *Valenictus* sp. in the formation and further distinguishes the fauna from later and more southern assemblages characterized by other members of the genus. The second new walrus belongs to the genus *Gomphotaria*, showing differences in tooth number and tooth-row orientation among other features. The description of this large dusignathine confirms the presence of at least five walrus taxa, with two currently unique to the Purisima Fm. Inclusion of these new taxa within a phylogenetic analysis yields several important results including the recognition of a monophyletic Dusignathinae (including the new species) and the recovery of *Pliopedia* as sister to *Valenictus*. The combination of these walruses, *Callorhinus* and an indeterminant otariid is distinct from the extant, walrus-free pinniped fauna of several otariids and 2 phocids. The diversity of the Purisima Fm. walruses suggests that these multi-taxon communities may represent the rule during the Mio-Pliocene. A greater degree of faunal endemism in the ENP is indicated by the recognition of these new distinct species, an effect that would likely be magnified by comparison with other regions, such as the western North Pacific or northern Atlantic. This increased inter-basin provinciality provides support for theories linking the Late Miocene peak in odobenid diversity with the effects of marine regression on reproductive isolation of previously connected populations. As more assemblages with multiple fossil walrus taxa are recognized we should move from seeking the “most diverse” towards exploring the patterning of pinniped communities across the basins of the Eastern Pacific preceding the Plio-Pleistocene boundary and subsequent loss of odobenid diversity.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

DISCRETE VARIATION IN MAXILLAE OF EUDROMAEOSAUR DINOSAURS AND ITS RELATION TO TRENDS IN SNOUT MORPHOLOGY

POWERS, Mark J., University of Alberta, Edmonton, AB, Canada; CURRIE, Philip J., University of Alberta, Edmonton, AB, Canada

During the Late Cretaceous, dromaeosaurids filled the small to medium-sized predator niche with a nearly global distribution. The most iconic of these ‘raptor’ dinosaurs are the Eudromaeosauria, a clade of dromaeosaurids that excludes microraptorines and unenlagiines. This group is largely represented by taxa from Asia and North America, predominantly *Velociraptor* and *Deinonychus* respectively. Other eudromaeosaur taxa are known from partial material, some as few as single elements. Among these elements the maxilla has been given a lot of taxonomic weight. In the description of several North American species, represented by maxillae and some associated material, researchers have noted two potential morphotypes. Asian taxa tend to be long-snouted whereas North American taxa are usually short-snouted. Some authors have proposed taxonomic relationships relating to the elongation of the snout. Whether these variations are valid homologous characters, or convergent similarities due to ecological pressures is untested. Proportional characters have the problem of often being ambiguous and difficult to code, therefore careful, critical examination of the data is essential for determining the significance of these characters and their states.
Up to 14 measurements were taken from 15 maxillae across 10 recognized species to look for distinct groupings within the range of data. Both bivariate and multivariate analyses were used to identify these distinct groups with a focus on proportions relating to elongation of the maxilla and its various features. In comparison with complete skull and femoral lengths, the Asian taxa have longer, lower snouts, whereas the snouts of most North American taxa are shorter and deeper. Distinct groupings also exist between Asian and North American taxa based on the length/height ratios of the maxillae. The length/height ratio of the lateral lamina of the maxilla shows a similar dichotomy, however, the North American taxon, *Acheroraptor*, has lateral lamina proportions like the Asian taxa. However, the proportions of the maxilla in this taxon is closer to its North American relatives, which suggests that the elongation of the lateral lamina can occur separately from the elongation of the snout. North American taxa appear to have had stronger bite forces than their Asian relatives, although the latter could close their jaws more rapidly. This implies some fundamental ecological differences between eudromaeosaurs on the different continents during the Late Cretaceous.

Grant Information:
Natural Sciences and Engineering Research Council of Canada
Dinosaur Research Institute Student Project Grant

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

TAPHONOMIC CHANGES OF EARLY MIDDLE PLEISTOCENE *STEGODON* BONE ASSEMBLAGES FROM FLORES, INDONESIA.

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A fossil *Stegodon* bone assemblage from an early Middle Pleistocene fluvial sandstone layer in the So’a Basin on the Indonesian island of Flores, were analyzed in order to identify and differentiate fresh post mortem fractures from other fractures. The layer of interest has yielded stone artefacts as well as hominin remains, but to date there has been no proven evidence that hominins were involved in the accumulation of remains of *Stegodon* or other vertebrates.
The total surface area excavated from this layer between 2013 and 2018 is approximately 239m^2.The *in situ* coordinates of the total 17,258 excavated fossil specimens were recorded using a Total Station. Of these specimens, 55% has been identified to at least Class level. This study focuses on two subsamples from the Mata Menge assemblages. The first subsample

concentrates on the limb bones of *Stegodon* (n=18), the second represents all vertebrate fossils from a 1 x 2 m area (n=99).
Both subsamples comprise complete and fragmented bones. The examination of the fossilised remains focused on the impact of both biological and physical taphonomic agents. Macroscopic inspection and examination under a binocular microscope were employed, to determine post mortem bone modifications using a set of five criteria. These criteria focused on the size of the bones and bone fragments as well as the types and shapes of fractures and marks on the fossilised bones.
A majority of the limb bones were broken and reduced at both the distal and proximal ends of the bones. A significant number of the bones also had evidence of excavation damage. Preliminary findings from this surface examination suggest little evidence of deliberate cut marks or fresh fracturing on the *Stegodon* limb bones.
There were also indications for a significant amount of reworking of bones prior to final burial, as some bones from the 1 x 2 m concentration had evidence of intermittent dry bone breakage overtime and reduction in size, leading to the majority of the *Stegodon* and other vertebrate bones fractured to fragments <30mm in diameter. The depositional environment has likely had multiple burial and erosion cycles which could have contributed considerably to the fracturing, while some bones may have been (partly) fossilized when re-exposed and transported by streams prior to final burial.

Grant Information:
ARC Grant, University of Wollongong

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

A BIRD'S-EYE VIEW OF ANCIENT LANDSCAPES AT HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO, U.S.A.

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Hagerman Fossil Beds National Monument has produced a large avifaunal assemblage (n=785) with at least 12 families represented. This rich assemblage provides important data for environmental reconstructions at Hagerman. For example, deeper, fish-bearing waters are evident from the number of cormorants, while the diversity of rails supports the presence of emergent vegetation and both standing and flowing waters. Anatids are common but not diverse and dominated by larger taxa; their widespread presence suggests extensive, mature wetlands and wet meadows. Higher, drier grounds capable of supporting trees would have been present for heron, ibis, cormorant, owl, and other roosting birds. The inferred habitat requirements of these Pliocene birds supports other environmental proxies preserved here that are indicative of lake, wetland, and riverine environments. However, these fossil occurrences are spread across 17.6 km^2 and span close to one million years of paleontological history.
Here, the Hagerman Paleontology, Environments, and Tephrochronology (PET) Project considers distributions of these birds within and across three major depositional units (Beds I-III) to better reconstruct spatial-temporal changes in the Hagerman avifaunal community between approximately 4.0 and 3.07 Ma. Recently-acquired tephrochronology and tephrostratigraphy data, in conjunction with geospatial data of fossil bird occurrences, show that bird communities vary in composition and occurrence across and within these three roughly defined time slices or geolandscapes. For example, highest species richness and greatest habitat breadth, with birds indicative of wetland, woodland, and grassland environments, occurs in the eastern portion of Bed II and the southern end of the upper portion of Bed III. Such results provide data on the effects of a changing environment on avifaunal composition and distribution and a more accurate reconstruction of these ancient landscapes at Hagerman.

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 4:00 PM)

ECOLOGICAL FALLOUT AND TURNOVER IN THE DIVERSITY OF LATE QUATERNARY TERRESTRIAL PREDATORS OF AUSTRALIA

PRICE, Gilbert J., The University of Queensland, Brisbane, Australia; LOUYS, Julien, Griffith University, Brisbane, Australia; SOBBE, Ian H., The University of Queensland, Brisbane, Australia; RISTEVSKI, Jorgo, The University of Queensland, Brisbane, Australia; MOLNAR, Ralph E., University of California Museum of Paleontology, Berkeley, CA, United States of America

Australia's fossil record shows that its modern ecosystems are not analogous to those of the recent past, especially in terms of the variety and diversity of terrestrial predators. Modern ecosystems are largely dominated by mammalian carnivores including the Dingo (*Canis familiaris*), cat (*Felis catus*), and fox (*Vulpes vulpe*s). Some researchers have previously contended that Australia's late Pleistocene terrestrial predator guild was also dominated by mammals, principally two species of marsupial 'lion' (*Thylacoleo* spp.; 30-130 kg), two species of marsupial 'devil' (*Sarcophilus* spp.; 5-30 kg), and the Thylacine (*Thylacinus cynocephalus*; 15-30 kg). However, recent fossil records from northern and eastern Australia significantly challenge that assertion. Here we present new data on the reptilian terrestrial predator guild of the late Pleistocene. Our integrated field and geochronological studies have produced the continent's youngest fossil record of giant monitor lizards (*Varanus priscus*; 80-200+ kg) dating younger than 50 ka. Indicative dating of the type locality of the terrestrial ziphodont crocodile *Quinkana fortirostrum* (40 kg), suggests it may also be late Pleistocene. We also here report the discovery of another new genus and species of an unequivocal late Pleistocene terrestrial crocodile (250 kg). Coupled with fossil records from elsewhere that shows at least three species of giant monitor lizards were present during the late Pleistocene (70-250 kg), along with a giant snake (*Wonambi naracoortensis*; 150 kg), the large-bodied terrestrial predator guild of 'Ice Age' Australia was clearly dominated by reptiles. Their extinction, along with that of marsupial 'lions' in the late Pleistocene, left the Thylacine and modern 'Tasmanian' Devil (*S. harrisii*; 5-12 kg) as the largest (non-human) terrestrial predators until the middle Holocene. The introduction of the similarly sized but apparently more ecologically efficient Dingo (20-25 kg) around 4 ka was immediately followed by the mainland extinction of the Thylacine and Devil likely as a result of competition. In the absence of larger-bodied predators that could have potentially applied ecological suppression, the Dingo thrived and became particularly widespread. Cats and foxes subsequently filled the role of the small-bodied mesopredators of Australia following their introduction by Europeans in the late 18th century. Collectively, these new data demonstrate a major ecological and biological shift from reptile- to mammal-dominated terrestrial predators of the continent.

Grant Information:
Australian Research Council grants DP120101752 and DE120101533.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 9:45 AM)

VERTEBRATE RESPONSES TO PLEISTOCENE ENVIRONMENTAL CHANGE IN SOUTH-CENTRAL AUSTRALIA

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The Nullarbor Plain is a sparsely-treed expanse of arid shrub steppe in south-central Australia, which today acts as an arid barrier to the east–west dispersal of many mesic species. However, varying levels of relatedness expressed by southwestern and southeastern taxa suggest a complex history of interconnectedness across this region during moister intervals. The discovery in the early 2000s and subsequent paleontological analysis of the Thylacoleo Caves, a trio of caves in the center of the Nullarbor Plain, is providing a window onto the previously poorly-understood Pleistocene fauna and environmental history of this region. Here we report on changes in vertebrate species composition and relative abundances through a 1.5-m-deep sequence of infill sediments in one of these sites, Leaena's Breath Cave. From an analysis of around 17,000 taxonomically-identifiable specimens, we recognize a total of 151 species composed of 41 mammals, 81 birds, 26 squamates and 3 frogs. This makes Leaena's Breath Cave by far the most species-rich Pleistocene vertebrate deposit on the continent. The assemblage accumulated via a mixture of pitfall trapping and avian predators, including owls. Although the reversed magnetic polarity of sedimentary Unit 3 has been interpreted as indicating deposition during the early Pleistocene, luminescence dating of both quartz and feldspar grains suggests that the entire sequence was deposited during the middle Pleistocene. This raises the possibility that Unit 3 accumulated during one of the brief magnetic excursions within the Brunhes Chron. Distinct temporal trends are expressed by species that, in modern times, are: 1) associated with open habitats; 2) generally associated with trees; and 3) explicitly dependent on trees. Cluster analysis allows us to infer that the Leaena's Breath Cave sequence accumulated across four climatic phases marked by vegetation that varied from predominantly closed woodland to chenopod shrubland.

Grant Information:
Australian Research Council Future Fellowship grant FT130101728; National Geographic Research and Exploration grant #8736-10

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

AN UNUSUAL NON-SAUROLOPHID 'DUCK-BILLED' DINOSAUR FROM THE EARLY CAMPANIAN (CRETACEOUS) OF TRANS-PECOS TEXAS AND THE ANCESTRAL HADROSAURIAN CREST

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The Aguja Formation of West Texas preserves one of the southernmost Campanian terrestrial vertebrate faunas in North America. Here we report on an unusual hadrosaurid dinosaur specimen from the lower shale member of the Aguja Formation (lower Campanian) of Big Bend National Park. This animal is uniquely positioned phylogenetically and temporally to expand our understanding of the early evolution of the hadrosaurid supracranial ornamentation, adding to our understanding of the early evolution and diversity of the clade.
This taxon is characterized by autapomorphies of the facial skeleton and mandible, including a crest composed of broadly arched nasals similar to that of kritosaurins. The symphyseal processes are elongated and reflected dorsally, causing the dentaries to meet with a w-shaped anterior profile, and the skull appears to be unusually broad for a hadrosaur. A hypothesized shovel-shaped predentary may have been used in excavating and scooping up semiaquatic vegetation. This animal was previously attributed to *Kritosaurus*and is otherwise superficially similar to *Gryposaurus*. However, it differs from saurolophids in retention of key plesiomorphic character states in the maxilla and jugal.
Phylogenetic analysis reveals this hadrosaurid to be a non-saurolophid (i.e., outside of Saurolophinae + Lambeosaurinae) hadrosaurid allied to *Latirhinus*from the late Campanian of Mexico, which bears a similar, broadly-arched nasal. The recognition of this lineage points to the existence of a hitherto unknown diversity of 'duck-billed' dinosaurs outside of the saurolophine-lambeosaurine radiation, previously restricted to *Hadrosaurus foulkii*(Campanian of New Jersey) and *Eotrachodon orientalis*(uppermost Santonian of Alabama). Cranial crests were ancestral for early hadrosaurids and evolved before the saurolophid radiation. Ancestrally, crests were 'solid,' and consisted of arched nasals. These were retained among kritosaurins and subsequently modified into the diverse crest morphologies observed amongderived saurolophines. Lambeosaurine 'hollow-crested' crest morphology departed from the ancestral, 'solid-crested' pre-saurolophid condition early in the evolution of that clade.

Grant Information:
Study supported by the Ramón y Cajal Program (RyC-2015-17388) and CGL2016-73230-P grant from the Government of Spain, and CERCA Program from the Government of Catalonia.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 10:15 AM)

RECONSTRUCTING THE LATE PLEISTOCENE CLIMATE SEQUENCE AT ALEXANDRA CAVE, NARACOORTE, SOUTH AUSTRALIA, USING SINGLE-GRAIN OPTICALLY STIMULATED LUMINESCENCE DATING AND PALEOENVIRONMENTAL PROXIES

The drivers of the Australia-wide megafaunal extinction during the late Pleistocene remains poorly resolved. Hypotheses include individual or synergistic combinations of climate fluctuations, human impacts through hunting or habitat alteration by landscape burning. Moreover, the relationship between extinction dynamics and long term glacial - interglacial timescales is not yet understood. Using a series of complementary geochronology, paleoecological and geochemical techniques on a sedimentary sequence in Alexandra Cave, Naracoorte, this study provides improved reconstructions of past climates in south-east South Australia around the time of megafaunal extinction. Ten luminescence dating samples constrain the age of the sedimentary sequence to 17.7 – 106.3 ka. Paleoenvironmental reconstructions undertaken using charcoal, carbon isotopes and geochemical analysis reveal high fire frequency and precipitation during Marine Isotope Stage (MIS) 5, while MIS 4 and the Last Glacial Maximum were arid, with low fire frequency. MIS 3 was wet, with little fluctuation in the environment, with the exception of a change in biomass burning at 36 – 50 ka. These findings suggest that climate change likely played a minor role in the demise of megafauna locally, whereas changes in fire regime could have acted as a more significant driver or consequence of megafauna extinction.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

TESTING THE PHYLOGENY OF PERIPTYCHIDAE AND "ARCHAIC" PALEOCENE MAMMALS UNDER DIFFERENT OPTIMALITY CRITERIA

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It is now well established that the end-Cretaceous mass extinction had enormous repercussions for mammalian evolution. Following the extinction, during the Paleocene, mammals started to radiate, occupying new and diverse ecological niches. However, the phylogenetic relationships between the so-called "archaic" mammals of this time, and their position within Placentalia, remain contentious. The Periptychidae are a clade of distinctive "archaic" ungulates, composed of ~17 genera of small to large bodied, highly bunodont, terrestrial herbivores that were among the first placental mammals to appear after the end-Cretaceous mass extinction. Although the Periptychidae has been historically considered a distinctive "condylarth" subgroup, their higher-level relationships have been rarely tested. Here, we present an inclusive cladistic analysis to determine and test the phylogenetic affinities of Periptychidae and other key Paleocene groups within Placentalia under different cladistic optimality criteria. We scored 140 taxa for 503 dental, cranial and postcranial characters, incorporating new morphological and taxonomic data. The data were then subject to parsimony and Bayesian tree searching protocols. For the Bayesian analysis we employed a Mk + Γ model of morphological evolution, running 5000000 generations with samples every 200 generations and discarding 25% of the samples as burn-in. Stationarity was achieved and a 50 percent majority rule consensus tree from the sampled trees was obtained. The parsimony analysis recovered 48 most parsimonious trees. The two consensus trees derived from the different analyses are largely congruent and recover a monophyletic Periptychidae, although the parsimony consensus tree is better resolved. These results are consistent with simulation studies showing that parsimony tends to be more precise (more nodes reconstructed) than Bayesian analyses, although less accurate. The main topological differences between the results relate to the position of poorly known Puercan (earliest Paleocene) species. Our results affirm the monophyly of Periptychidae and its nesting within a group of "condylarths" positioned at the base of Laurasiatheria and closely related to Artiodactyla. Within Periptychidae we found support for the three major subfamilial divisions in both analyses. These results highlight the importance of using different optimality criteria when resolving a phylogeny and provide a new insight into how placental mammals were evolving after the end-Cretaceous extinction.

Grant Information:
CONICYT PFCHA/DOCTORADO BECAS CHILE/2018, European Research Council Starting Grant (ERC StG 2017, 756226, PalM), National Science Foundation (NSF EAR 1654952, DEB 1654949)
Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

GEOLOGICAL AND PALEONTOLOGICAL ASPECTS OF A NEW EARLY – MIDDLE PLEISTOCENE TERRESTRIAL VERTEBRATE FOSSIL-BEARING SITE IN WEST JAVA, INDONESIA

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A wealth of information from paleoclimatic, paleoenvironmental and paleoecological studies in relation to the evolution of vertebrate fossil fauna and their living environments of Java has become available over the past decades. However, this information is heavily based on discoveries from Central and East Java and does not significantly represent fossil faunas of West Java. This is due to the fact that the paleontological research in West Java is a lot more lacking than those in East Java. Vertebrate fossil studies represent West Java were so far still lags far behind although this area is a key area to reconstruct a more comprehensive paleoecology of Sundaland during the Quaternary. The attempts to use fossil faunal assemblages from West Java in regional paleoenvironmental reconstructions and studies on faunal evolution are hampered by the limited faunal record, the lack of accurate

dates, and the mixed nature of faunal assemblages. Therefore, additional empirical data of fossil records and its stratigraphic context are critical for understanding the chronology, evolution, and environmental conditions during the early occupation of terrestrial habitat of Java. In this study, our study focused in a fossil-bearing site located in Cisaar River, Jatiwangi, Majalengka, West Java. In order to establish a good biostratigraphic context of the study area, we performed systematic surveys in the Citalang Formation along the Ci Saar River and its tributaries. We also conducted two test excavations and collected fossil from the surface.
During the preliminary study, we recorded vertebrate fossil assemblage, including: *Bubalus paleokarabau*, cervids, *Stegodon trigonocephalus*, suids, crocodile and carnivores. The Vertebrate fossils in this area could be associated with the Early to Middle Pleistocene Ci Saat and Kedungbrubus Faunas in the Java vertebrate biostratigraphic scheme. We also unearthed a pair of Stegodon tusks from the black clay facies of the Early Pleistocene Citalang Formation. The tusks length reached 3.2 m, which are the longest and most complete Stegodon tusks material from West Java, and probably from Java. The tusks most likely belong to a primitive Stegodon lineage. Further result and implication will be discussed in the presentation.

Grant Information:
This research is funded by Institut Teknologi Bandung and LAPI ITB.

Technical Session VII (Thursday, October 10, 2019, 11:00 AM)

FILTER FEEDING IN LATE JURASSIC PTEROSAURS SUPPORTED BY COPROLITE CONTENTS

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Pterosaurs first appeared in the Late Triassic and constituted thereafter an important part of Mesozoic ecosystems until the end-Cretaceous mass extinction. Their diets, however, have hereto only been inferred from functional morphology, rare gut contents, and a single coprolite with enigmatic inclusions. We have described three coprolites found on a surface with abundant pterosaur tracks from early Kimmeridgian intertidal deposits of the Wierzbica Quarry in Poland. The morphology of the coprolites, and their association to the tracks, indicate a pterosaur producer. Synchrotron scans revealed that the coprolites are rich in foraminifera and other small remains including bivalves, ostracods and bristles (some possibly from polychaete worms). The high density of these shelly inclusions suggest that they were not accidently ingested but constituted an important food source for the pterosaur/s, perhaps along with unpreserved soft-bodied animals. The combined evidence from the coprolites and tracks suggest filter-feeding ctenochasmatids as the most likely tracemakers. If true, this significantly expands the bromalite record of this pterosaur group (previously known only from gastroliths). It also represents the first direct evidence of filter feeding in Jurassic pterosaurs and demonstrates that their diet was similar to that of the recent Chilean flamingo (*Phoenicopterus chilensis*).

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 3:00 PM)

NEOLITHIC HUMAN-INDUCED EXTINCTION OF PREVIOUSLY UNRECOGNIZED GIANT TESTUDINID TORTOISES ENDEMIC TO MELANESIA

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The Melanesian islands of Vanuatu and Fiji have yielded archeological remains of the large extinct terrestrial turtle *Meiolania damelipi* dated to 3000-2500 BP. These turtles were hunted by the Neolithic Lapita culture and are considered to represent the last surviving representatives of the stem-turtle lineage Meiolaniidae, a clade including bizarre, horned, ankylosaur-like turtles widespread in the Cenozoic record of Patagonia, Australia and multiple Oceanic islands. However, the meiolaniid affinities of the Vanuatu turtles have been disputed. New cranial remains, as well as a review of all available skeletal elements, now allow us to clarify the systematic affinity of this turtle. The material includes mostly limb and girdle bones, some shell fragments, and few cranial elements. The extensive upper and lower temporal emargination, the medially contacting prefrontals, the deep skull and lower jaw, the flattened centra of the cervical vertebrae, the presence of quadrangular neurals, the cartilaginous epipubis, and the proportions of the appendicular skeleton undoubtedly identify a testudinid. Testudinidae (commonly referred to as tortoises) is a globally distributed clade of terrestrial turtles which are known for their high dispersal abilities to islands (e.g., Galapagos tortoises). Yet, the presence of testudinids in Vanuatu and Fiji represents a major biogeographic enigma because the nearest living or extinct tortoises are 5300 km far. On the other hand, the South Equatorial Current flowing westward from South America and the Galapagos islands branches off southward right between Fiji and Vanuatu which may have facilitated an extreme dispersal. The material from Vanuatu and Fiji is too fragmentary for resolving the phylogenetic position within Testudinidae but given that there are no comparable extinct forms known from Southeast Asia or Oceania we exclude the possibility of human introduction. Instead, the remains clearly indicate a yet unrecognized extinct Melanesian clade of giant insular testudinids – the largest reptiles exterminated by humans in the area. The presence of numerous autapomorphic morphologies suggests a not too recent divergence from other testudinids and highlights the potential for discovering fossil evidence in Melanesia. Ongoing ancient DNA analysis may shed light on the origin of this species. Finally, we conclude that the latest representatives of meiolaniids come from nearby New Caledonia but their alleged Holocene age is unreliable.

Grant Information:
Volkswagen Foundation "Research in Museums" grant (90 978) to MR.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

SUBFOSSIL CROCODYLIANS FROM A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR).

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Madagascar is famous not only for its unique biodiversity, but also for the high levels of endemism of plants and animals. Despite this, even in the recent past, the island had many other extinct endemic animals such as giant lemurs, elephant birds, pygmy hippopotamus, tortoises and crocodiles. The extinction of many of these groups are thought to be the result of both human hunting and environmental change. Most research has focused on larger groups, such as lemurs and elephant birds – there is a corresponding lack of information for many other subfossil groups. In particular, crocodiles are relatively poorly known, yet likely had an interesting evolutionary history. Late Cretaceous crocodylians from Madagascar include more than seven different taxa. Subfossil crocodylians from the Late Pleistocene and Holocene do not appear to be descendants of these clades, and include two genera: the extinct *Voay robustus* and living *Crocodylus niloticus*. However, we do not know much about their geographic range, whether they lived at the same time and competed with each other in the same habitats, or the types of environments that they preferred. We present here a description of subfossil crocodile bones from the Central Highlands of Madagascar: Tsaramody (Sambaina Basin) - a newly discovered subfossil site that samples a wetland environment, and represents the highest-altitude known subfossil site on the island (1655 m). Both skull elements and postcranial elements are described. Subfossil crocodylians from Tsaramody appear morphologically different from those at other nearby sites (e.g., Ampasambazimba) as well as those recovered from the southwest (e.g., Tsimanampesotse), and suggests that the species boundaries between these taxa may be more complex than previously thought. A better understanding of Malagasy subfossil crocodylian taxonomy, as well as their past geographic and temporal ranges has great potential to elucidate their evolutionary history on the island, and the details of their extinction.

Grant Information:
National Geographic (#8667-09); Fulbright African Regional Research Program

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

REPTILE DIVERSITY OF MCEACHERN'S CAVE, A LATE PLEISTOCENE TO HOLOCENE FOSSIL DEPOSIT FROM VICTORIA, AUSTRALIA

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Australia comprises more reptile species than any other country on earth; however, the fossil record of Australian reptiles is poorly studied. This is

especially evident in Victoria, where, despite the presence of well-preserved fossil deposits, fossil reptiles have never been examined. Here we present the first faunal list of Victorian reptiles from McEachern´s Cave, a Late Pleistocene to Holocene fossil deposit. This site is located in the Lower Glenelg National Park and features a well-defined stratigraphy as well as consistent dating. Furthermore, the site was already studied in terms of mammal remains, revealing the presence of several megafauna mammals like e.g., giant wombats. For the present study, original cave material was sorted for reptile remains, unveiling a rich reptile fauna, especially within the Holocene deposits. Reptile remains were assigned to different species or morphotypes using qualitative features and reference skeletons of extant species. The fossil fauna seems to be similar to the present day fauna and is dominated by species of Scincidae and Elapidae. A remarkable find is a single pygopodid jawbone, which probably belongs to *Delma sp*., a genus that does not occur in the area today. Closely related extant species are strongly associated with grassland ecosystems and therefore the fossil could indicate the presence of grassland in the area surrounding McEachern´s Cave at ~7kya. In general, Australian Holocene deposits might represent the pre-European distribution of some squamate taxa and are therefore crucial to determine the effects of agricultural land modification on Australia's herpetofauna. The information from these recent fossil deposits can then be used to create baseline data to evaluate the current conservation status of different reptile species.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A NEW LATE PLEISTOCENE SUBFOSSIL SITE (TSARAMODY, SAMBAINA BASIN, CENTRAL MADAGASCAR) WITH IMPLICATIONS FOR THE CHRONOLOGY OF HABITAT AND MEGAFAUNAL COMMUNITY CHANGE ON MADAGASCAR'S CENTRAL HIGHLANDS

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Madagascar is a complex "biodiversity hotspot" with a rapidly dwindling biota. The Late Quaternary subfossil record includes many extinct species whose loss is attributed to natural climate change and human impacts. Investigation of the chronology of these extinction events is challenging because few localities document pre-Holocene communities not impacted by humans. Caves with extinct lemurs of large body size comprise some of Madagascar's richest subfossil sites, but they provide only a limited window into the island's past. Open highland sites have fewer primates, but they better document other megafauna, and allow the analysis of the role of the Central Highlands as refugia, and as corridors for the dispersal of vertebrates before and after human arrival. Here we present a new subfossil site, Tsaramody (Sambaina basin, central Madagascar), a high-altitude wetland area that preserves a vibrant late glacial and postglacial vertebrate community. Tsaramody bears testimony to fluctuations in the highland flora during the transition from glacial to postglacial conditions, and the composition of a highland vertebrate community before humans arrived. We compare its biota to those of other sites to begin to document the decline and disappearance of some of Madagascar's most neglected, but perhaps most important, ecosystems – wetlands dominated by hippopotamuses, crocodylians, and elephant birds.

Technical Session V (Wednesday, October 9, 2019, 4:00 PM)

EXTINCT BIRDS OF NEW ZEALAND: HOW ANCIENT DNA AND MORPHOLOGY IS RAPIDLY INCREASING THE NUMBER OF HUMAN DRIVEN EXTINCTIONS

RAWLENCE, Nicolas J., University of Otago, Dunedin, New Zealand

The arrival of humans in Aotearoa New Zealand resulted in the loss of 50% of its unique biodiversity due to hunting, habitat destruction and predation by introduced predators. New Zealand is unique in that the often confounding effects of humans and climate change can be clearly separated, and studied in isolation. The arrival of humans and the consequent extinctions occured at a time of relative climatic stability. New Zealand's rich Late Quaternary fossil record, spanning the past 60,000 years, and the recent archaeological record, contain the remains of many of New Zealand's extinct avain species. The advent of ancient DNA, combined with morphological analysis, has revolutionised our understanding of New Zealand's extinct avain biodiversity. The current rate of discovery of extinct Late Quaternary birds in New Zealand is unprecidented, with seven new species described since 2009. This talk will highlight several of these new taxa including the Kohatu Shag (*Leucocarbo septentrionalis*), Pouwa (*Cygnus sumnerensis*), Waitaha Penguin (*Megadyptes antipodes waitaha*), Richdale's Penguin (*M. antipodes richdalei*) and Warham's Penguin (*Eudyptes warhami*). These examples illustrate the vulnerability of insular island fauna, and consequent biological turnover events, and have implications for 're-wilding' ecosystems and how conservation paleontology can inform the management of threatened species.

Grant Information:
Royal Society of New Zealand Marsden Fund and the University of Otago

Technical Session VI (Thursday, October 10, 2019, 8:00 AM)

FOSSIL RECORD OF THE SOUTHERN BENT-WING BAT (*MINIOPTERUS ORIANAE BASSANII*) FROM QUATERNARY DEPOSITS AT NARACOORTE CAVES, SOUTH AUSTRALIA: IMPLICATIONS FOR CONSERVATION OF A CRITICALLY ENDANGERED SPECIES

REED, Elizabeth H., University of Adelaide, Adelaide, Australia

Quaternary fossil deposits of the Naracoorte Caves National Park (NCNP) are World Heritage listed for their record of vertebrate faunas spanning at least the past 500,000 years. The Naracoorte faunal assemblages are dominated by mammals and much of the previous paleontological research has focused on marsupials.Despite being a key element in the extant faunas of the region, the fossils bats have never been studied in depth.
Currently, there are 17 bat species living in the South East region of South Australia. At least two have been observed frequenting caves at Naracoorte. NCNP is a significant breeding and over-wintering site for the Southern Bent-wing Bat (*Miniopterus orianae bassanii*). This species is listed as Critically Endangered under the Commonwealth *EPBC Act* due to population decline and its reliance on only three breeding sites (Bat Cave at Naracoorte, Starlight Cave at Warrnambool and a site at Portland). Habitat clearance, human activities, invasive species and climate change have all been considered as contributors to decline. Teasing apart the discrete impacts of these factors is critical for developing appropriately targeted recovery strategies. Long-term data revealing patterns of bat community dynamics prior to human influence are needed to separate natural and anthropogenic impacts.
Here I present evidence from seven late Quaternary fossil deposits that shows continuous habitation of caves by Southern Bent-wing bats for at least the past 300,000 years. The use of particular caves as breeding or wintering sites has been consistent over this time, and mirrors precisely the patterns of cave use seen at Naracoorte today. This suggests that while the bats have been resilient to long-term change over multiple glacial cycles, the availability of appropriate cave habitat has been critical. Within-cave environmental conditions of some caves are directly influenced by surface climate. Projected temperature increases with anthropogenic climate change may render some currently inhabited caves unsuitable. Modern habitat fragmentation and human impact on wintering caves has severely limited the capacity of this species to expand or contract its range in response to future climate change. Population monitoring and localised habitat restoration measures may not be enough to prevent extinction of this species. Paleontological data may provide a useful tool for planning conservation efforts for this species.

Grant Information:
ARC Linkage project LP160101249

Technical Session XIII (Friday, October 11, 2019, 4:00 PM)

COMPLEXITY OF EARLY PERMIAN TERRESTRIAL VERTEBRATE COMMUNITY AT RICHARDS SPUR, OKLAHOMA IS REVEALED THROUGH NEUTRON TOMOGRAPHY

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The Dolese Brothers Limestone Quarry, Richards Spur, Oklahoma, preserves a highly fossiliferous early Permian infill in a series of Ordovician limestone and dolostone karst fissures. Speleothems confirm that this cave system represents a unique preservational environment for the Paleozoic, one that is distinct from the more typical Early Permian lowland deltaic/fluvial localities. The locality preserves exclusively terrestrial vertebrates, and most of the fossils have been impregnated with hydrocarbons derived from the underlying Woodford Shale. Diagenesis has most often produced dark colored skeletal elements preserved in gray clays and limestones, making them easily recognizable, but the process occurred under un-aerobic conditions that facilitated the formation of abundant pyrite around and inside the bones. This unique combination makes the fossils from the cave system often difficult to image using x-ray computed tomography (x-ray CT), but ideally suited for imaging using the quasi-parallel collimated bean of neutrons, as provided by the DINGO facility at the OPAL reactor at ANSTO, Australia. The superior image quality provided by this method has provided excellent information about the external and the internal anatomy of numerous new or little-known taxa from the locality, the richest and taxonomically most diverse assemblage of Paleozoic terrestrial vertebrates. The anatomical detail provided by neutron-CT have opened up new avenues for the study of morphological and taxic diversity at the locality. As a result, we have been able to recognize morphological differences among closely related taxa, significantly increasing our understanding of early Permian community structure. For example, among captorhinid eureptiles we can recognize at least three different species of *Captorhinus* preserved within the cave system. Similarly, among acleistorhinid parareptiles we can recognize at least three different species of *Delorhynchus,* and two different species of *Colobomycter,* and among mycterosaurine varanopid synapsids we can recognize two distinct but closely related taxa. Overall, the diversity at the locality has now exceeded 40 taxa of terrestrial vertebrates ranging in size from 150 mm to 1.5m in body length. This pattern is more in keeping with the type of taxic diversity and trophic structure usually found in modern tropical communities, rather than the relatively much lower diversity found in other coeval Paleozoic fossil localities.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

REFERRED SPECIMEN OF *CHUANJIESAURUS ANAENSIS* AS A NEW EARLY BRANCHING MAMENCHISAURID SAUROPOD TAXON FROM THE MIDDLE JURASSIC OF CHINA

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Chuanjiesaurus anaensis from the Middle Jurassic Chuanjie Formation in Yunnan Province, southwest China was named by Fang et al. in 2000 and received a restudy by Sekiya in 2011. Here we present a revision of its referred specimen (LCD 9701-1), and demonstrate that LCD 9701-1 is differentiated from the holotype by numerous features and should be regarded as a new taxon. The new taxon possesses a unique combination of characters, such as caudal transverse processes persisting till the 10th caudal (15th in *Chuanjiesaurus*); weakly developed posterior condylar ball in anterior caudals (well developed in *Chuanjiesaurus*); ulnar anterolateral and anteromedial processes sub-equal in length and forming an angle of about 45 degrees (unequal and 60 degrees in *Chuanjiesaurus anaensis*); proximal width of metacarpal II 7% the length of radius (lowest value among mamenchisaurids); pubic distal width approximately 40% of its total length (greatest value among mamenchisaurids). Cladistic analysis including this new taxon recovers that the new taxon represents the earliest branching of the Mamenchisauridae clade. Eight characters support the new taxon as a member of Mamenchisauridae. In contrast, the (*Mamenchisaurus* + *Chuanjiesaurus anaensis*) clade is the latest branching of Mamenchisauridae and supported by two synapomorphies. This discovery enriches the diversity of early branching sauropods. Some changes such as the development of posterior condylar ball in anterior caudals (the centra of anterior caudals are procoelous with the posterior condyle balls slightly extend in new taxon; the centra of anterior caduals are amphicoelous in *Omeisaurus*; the centra of anterior caudals are procoelous with the posterior condyle balls strongly extend in *Chuanjiesaurus* and *Mamenchisaurus*) indicate the evolution of Mamenchisauridae is a more complicated scenario than realized before.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

SHIFTING PATTERNS OF FUNCTIONAL INTEGRATION DURING THE EVOLUTION OF FLIGHT IN THEROPODS

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The transition to powered flight in theropods was one of the most significant innovations in locomotion in evolutionary history; it allowed birds to exploit new ecological niches and survive one of the worst mass extinctions in Earth's history. This transition shifted the primary mode of locomotion from the hind limbs of non-avian theropods to the forelimbs of birds and functionally decoupled the tail from the hind limb in birds, allowing it to be used as a rudder in flight. Previous work hypothesized that non-avian theropods had one functional module of locomotion made up of the hind limbs, hips, and tail, while birds transitioned to three modules consisting of the forelimbs, hind limbs, and tail separately. We tested this hypothesis by analyzing shifts in patterns of morphological integration across the evolution of flight using matrix correlation analyses. We took 7-10 measurements of hip, forelimb, and hind limb elements of 33 species of birds and 7 species of non-avian theropods and constructed theoretical correlation matrices to compare with observed correlation matrices. After removing the effects of size, we found that non-avian theropods and birds have different integration patterns between their forelimbs, hind limbs, and hips. This is most likely caused by differences in hind limb musculature and functional pressures; forelimb elements are much more integrated in birds than in non-avian theropods. The one-to-three functional module hypothesis was most supported, however we also found evidence that although they do not form a single functional module, the hips and forelimbs of birds are more integrated than in theropods due to the wings and rudder acting in concert during flight.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

HOMOLOGY OF THE MICRORAPTORINE LATERAL PUBIC TUBERCLE

RHODES, Matthew M., University of Alberta, Edmonton, AB, Canada; CURRIE, Philip J., University of Alberta, Edmonton, AB, Canada

Among dromaeosaurid theropods, Microraptorinae is distinguished by a prominent lateral pubic tubercle at midshaft of the pubis. This tubercle was tentatively identified as a muscle attachment site, but has been discussed otherwise only in the context of noting its presence or absence in paravians. Any potential anatomical or functional roles require establishment of its relationship to other pubic structures. Preservation of a lateral pubic process (hypertrophied lateral pubic tubercle) in the microraptorine *Hesperonychus elizabethae* and other taxa in its subfamily allows a detailed assessment of homology. Comparison to the closest living relatives (crocodylians and birds) permits soft tissue reconstruction for a more comprehensive anatomical understanding.
Direct observation of the lateral pubic process of *H. elizabethae* shows that it has a texture and position that is inconsistent with muscle attachment. Osteological correlates of abdominal, pelvic, and caudal muscles associated with the pubis can be identified elsewhere on the specimen. However, pubogastralial ligaments in crocodylians connect the gastral basket and pubis in similar positions. Thus, the microraptorine lateral pubic tubercle is reinterpreted as an attachment site for pubogastralial ligaments. Other well-preserved dromaeosaurids have gastralia linked to this region, and more plesiomorphic theropods have robust pubic boots with anterior projections inferred as anchors for pubogastralial ligaments. The unique morphology in microraptorines is explained by its position proximal to the pubic apron. The lateral pubic tubercle therefore served to anchor the cuirasse and accommodate locomotory musculature arising from the pubic apron. Secondarily, the process forms a pulley that diverts this musculature to avoid interference with the pubogastralial ligaments. Determining the homology of the microraptorine lateral pubic tubercle allows for exploration of its functional consequences and implications for the evolution of early birds with gastralia.

Grant Information:
Dinosaur Research Institute, Faculty of Graduate Studies and Research (University of Alberta), Government of Alberta, NSERC

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

MANAGEMENT OF COLLECTIONS CARE PROJECTS: REFINING THE APPROACH TO CURATION WORKFLOWS AND PERSONNEL TRAINING

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The international community of specimen and data stewards is beset with a sheer volume and vast breadth of work to tackle at their respective institutions. Inventorying collection needs can open up the discussion of project priorities between staff (technicians, collections managers, curators, and administrators), but can also pave the way for potential funding sources that augment efforts to preserve and increase access to collections for posterity. Identifying and prioritizing specific projects is essential for optimizing use of personnel, time, space, and available resources.
Quality management of collections care projects requires an understanding of the processes to be performed and their sequence of execution, documentation and refinement of established workflows, and an astute sense of how to train staff and volunteers to implement best practices accurately and efficiently. Prior to evaluating the management of collections care projects, existing staff and volunteers were assigned projects and given guidance and resources on an as needed basis, resulting in sporadic achievements of varying qualities and quantities. Upon closer critique, the sequence of decisions was flipped to first prioritize feasible projects, document workflows, acquire needed resources, and then select personnel to execute the defined project within an allotted time frame. Prioritizing projects can be assessed on the basis of administrative, research, and physical needs. At the core of usable workflows are a succinct recording of the sequence of tasks to be performed, definitions of specimen and data standards, and descriptions of preventive conservation practices.
Training personnel to execute workflows involves imparting a philosophy of collections care stewardship that equips them to make independent decisions in light of best practices. Exemplary workflow topics include: specimen handling, condition assessments, collections organization, taxonomic and element identification, writing locality descriptions, cataloging specimens, specimen labeling and archival housing, and digital imaging of specimens and accessory data. Useful workflows will address essential skill sets that can be adopted and amended by the user through time. Assessing and refining the management approach to collections care projects will shed light on established methods, elucidate priorities, and make strides toward standardizing the knowledge base of personnel who make decisions affecting the quality of primary and secondary scientific data held in public trust.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

AFFINITIES OF AUSTRALIAN TRIBOSPHENIC MESOZOIC MAMMALS

RICH, Thomas H., Museum Victoria, Melbourne, Australia; FLANNERY, Timothy, Australian Museum, Sydney, Australia; EVANS, Alistair R., Monash Univ, Monash University, Australia; WHITE, Matt, University of New England, Armidale, Australia; ZIEGLER, Timothy, Museums Victoria, Melbourne, Australia; MAGUIRE, Alanna, Melbourne, Australia; VICKERS-RICH, Patricia, Swinburne University of Science & Technology, Hawthorne, Australia

Australian tribosphenic Mesozoic mammals have previously been known only from lower dentitions. One and perhaps a second fragmentary specimen of tribosphenic upper dentitions have been found at the late Early Cretaceous Flat Rocks site in Victoria, Australia.
Specimen 2009 clearly consists of two tribosphenic upper molars. It has prominent stylar cusps and an outline in occlusal view suggestive of a metatherian. A plausible occlusal fit can be made with the corresponding surfaces of the ausktribosphenid *Boishops,* a specimen of which is also known from the Eric the Red West site.
Ausktribosphenids havebeen suggested to be eutherians or monotremes. No one has ever suggested affinities for them with the metatherians for quite good reasons. Should an upper molar with metatherian-like features be found conclusively to have occluded with a lower molar that is clearly not a metatherian, this would support the Australosphenidia Hypothesos that the southern hemisphere hosted in the Mesozoic a group of tribosphenic mammals that were neither metatherians nor euitherians.
Specimen 2015 has been interpreted in two starkly contrasting ways. Based on the layout of the cusps as the specimen was found, a resemblance has been noted to the disposition of a group of cusps on the buccal margin of the M2/ of the presumed monotreme *Kollikodon.* The nature of the cusps in the two are quite different suggesting that if there is an affinity between them, it is a remote one. The alternative is that the specimen consists of a single molar fragment and three premolars. That hypothesis requires that the fosil has been broken and the molar shifted anteriorly to lie alongside the premolars. Another difficulty of this hypothesis is that he roots of the two anterior premolars are fused at their bases. Rare though this is, fusion of premolars is known in mammals.
Fragmentary though they are, they clearly differ markedly from one another and neither specimen fits comfortably into the previously recognised 3 categories of Australian Mesozoic mammals: monotremes, multituberculates and ausktribosphenids. That persuasively points to a greater diversity of them yet to be discovered.

Grant Information:
Committee for Research & Exploration of the National Geographic Society

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 11:30 AM)

THE FUNCTIONAL IMPLICATIONS OF GIGANTISM AND REMARKABLY LOW ELBOW MOBILITY WITHIN THE WEIRD EXTINCT MARSUPIAL MEGAFAUNA FAMILY PALORCHESTIDAE (DIPROTODONTIA: VOMBATOMORPHIA)

RICHARDS, Hazel L., Monash University, Melbourne, Australia; ADAMS, Justin W., Monash University, Melbourne, Australia; FITZGERALD, Erich M., Museums Victoria, Melbourne, Australia; EVANS, Alistair R., Monash University, Melbourne, Australia

Reconstructing the paleobiology of extinct taxa is challenging, particularly when they have no living representatives and their anatomy differs greatly from animals alive today. The Palorchestidae were a rare and especially bizarre group of Australian megafauna known from the Oligocene through to their disappearance in the late Pleistocene. Distantly related to the modern wombat, they are best known for their 'tapir-like' crania and supposed flexible proboscis. In addition to this unusual skull, their postcranial skeleton differed markedly from that of related diprotodontian marsupials. Their robust, oddly-proportioned forelimbs had near-flat humeroulnar articulations and bore huge narrow claws – a character combination that raises fundamental questions about how palorchestids used their limbs during life and the paleoecological niche they occupied.
We used newly-described postcranial material from *Propalorchestes* sp. (Oligo-Miocene)*, Palorchestes parvus* (Plio-Pleistocene) and *Palorchestes azael* (Late Pleistocene) to estimate body masses for these taxa, and virtual range-of-motion analysis to quantify their elbow mobility. This enabled empirical comparisons with a broad range of both related marsupials (including the giant diprotodontid *Diprotodon*) and unrelated potential functional analogues such as bears and giant sloths.
Stylopodial circumferences yielded approximate body mass values of 150 kg, 360 kg and 1160 kg, respectively, for individuals of each species. Our virtual models of humeroulnar mobility found the *P. azael* elbow to have the lowest mobility of any taxon measured, a specialisation that may have increased stability during forelimb use in food acquisition. We found that forelimb shape and mobility within the palorchestid lineage diverged markedly from their diprotodontid sister taxa like *Diprotodon*, despite these groups ultimately attaining similarly large body sizes (> 1000 kg). That members of the two groups overlapped in size, time and geographic space has interesting implications for niche partitioning and is additional evidence for a novel palorchestid paleobiology. This work highlights the extent of the marsupial ecomorphological diversity that was lost during the late Quaternary extinctions in Australia.

Grant Information:
This research was supported by an Australian Government Research Training Program Scholarship and Robert Blackwood Partnership PhD Top-Up Scholarship (HLR).

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

***PARAPTENODYTES*-LIKE FOSSIL PENGUINS FROM NEW ZEALAND – A BIOGEOGRAPHIC CLUE FROM THE LATE OLIGOCENE?**

RICHARDS, Marcus D., University of Otago, Dunedin, New Zealand; MATTS, Katie A., University of Otago, Dunedin, New Zealand; FORDYCE, Robert E., University of Otago, Dunedin, New Zealand

Late Oligocene – Early Miocene penguins are known from South America and New Zealand, but no shared close relatives have been demonstrated. Here

we report two specimens from the Duntroonian Stage (early Chattian, Late Oligocene) of New Zealand that provide a potential link.
Three closely related taxa, phylogenetically-ordered stemward to crownward, are *Archaeospheniscus*, *Paraptenodytes*, and *Platydyptes* – stem-genera near to the base of crown penguins. These penguins were medium to large in size, comparable to extant *Megadyptes* to *Aptenodytes spp.* in size range. *Paraptenodytes* is endemic to Patagonia, with *Paraptenodytes robustus* and *P. antarcticus* from the Late Oligocene and Early Miocene, respectively. *Archaeospheniscus* and *Platydyptes* are known only from New Zealand.
New *Paraptenodytes*-like specimens (OU 21980 and OU 22661) from Hakataramea Valley, New Zealand are from the Kokoamu Greensand (Duntroonian), and coeval with *Archaeospheniscus* and the earliest *Platydyptes*. OU 21980 has a partial coracoid and proximal humerus. OU 22661 is more-complete, similar in size to modern *Aptenodytes patagonicus*, with various axial, pectoral girdle, wing and leg elements preserved, but not the tarsometatarsus. These new specimens differ from *Archaeospheniscus* and *Platydyptes* in humeral features that are shared with *Paraptenodytes*: a relatively smaller humeral head, a smaller shallow m. pectoralis fossa, and a more inflated, caudally-skewed articular surface apex on the humeral head. Overall, the taxonomically-informative humerus shows a close phenetic similarity, and shares key diagnostic features, with *Paraptenodytes* – though the humeral shaft of OU 22661 is more sigmoidal. This shaft curvature suggests the New Zealand specimens are positioned stemward to *Paraptenodytes*. Penguins of *Megadyptes* size and larger, except for the robust *Platydyptes*, disappear from the New Zealand fossil record by the Waitakian Stage (late Chattian, latest Oligocene). The new specimens increase the Kokoamu Greensand penguin assemblage to 8+ species.

Grant Information:
National Geographic Society Research Fund (grant number 3542-87)

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

NEW CRESTED PTEROSAUR MATERIAL FROM THE LOWER CRETACEOUS (ALBIAN) TOOLEBUC FORMATION OF QUEENSLAND, AUSTRALIA, AND THE EVOLUTION OF AUSTRALIAN PTEROSAURS

RICHARDS, Timothy M., The University of Queensland, Brisbane, Australia; STUMKAT, Paul E., Stumkat Studios, Killarney, Australia; SALISBURY, Steven W., The University of Queensland, Brisbane, Australia

Pterosaur fossils from Australia are exceptionally rare, comprised entirely of isolated and often fragmentary bones. Since the discovery of the continent's first pterosaur fossils some forty years ago, only fifteen specimens have been described. Moreover, of all the specimens described so far, only two are sufficiently informative to be recognised as new species. To date, the Lower Cretaceous (middle Albian) Toolebuc Formation of central-western Queensland is the most productive horizon for Australian pterosaurs. Here we report on the discovery of new pterosaur material from the Toolebuc Formation near Richmond, north-west Queensland. The material includes a partial skull and a partial, crested mandible, both of which present features that indicate affinities with Ornithocheiridae. These include characteristics of the maxillary and mandibular rostrum and associated crests, and the size, spacing and orientation of alveoli. The presence of ornithocheirid or 'ornithocheirid-like' pterosaurs has previously been reported from the Lower Cretaceous of Australia and is consistent with their reported cosmopolitan distribution during this period. However, the deep crests and overall blade-like nature of the mandible appear to be unique among ornithocheirids, and may warrant the erection of new genera. In contrast to other Mesozoic vertebrates from Australia, phylogenetic analysis reveals that there is no evidence of an endemic Australian radiation within Ornithocheiridae. Instead, Australian ornithocheirids show affinities to ornithocheirids from South America. Importantly, these new discoveries provide the first unequivocal evidence for the existence of large crested pterosaurs in Australia.

Grant Information:
Australian Government's Australian Biological Resources Study (ABRS) National Taxonomy Research Grant Programme (NTRGP)

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

RESOURCE PARTITIONING IN AN AMPHIBIAN COMMUNITY DURING THE LATE QUATERNARY

RICKER, Adrienne C., University of California Santa Cruz, Santa Cruz, CA, United States of America; KOCH, Paul L., University of California Santa Cruz, Santa Cruz, CA, United States of America; MUELLER, Johannes, Berlin, Germany

Amphibians are currently under extreme pressure, with global climate change, local habitat change, and emerging diseases, among others, contributing to declines in diversity worldwide. To better understand the response of amphibians to these complex issues, there is a need for more research investigating the influence of climate change on amphibian communities. The fossil record can provide a deeper historical context to better understand species responses to current and future environmental change. Stable isotope analysis, in particular, can be used to understand the habitat use, diet, and life-history of extinct animals. Unfortunately, stable isotope studies on amphibians are rare for both modern and fossil taxa, especially anurans. The fossil locality, Pisede, located in northeastern Germany provides a unique opportunity to study past amphibian communities, with 85,000+ anuran specimens recovered and housed at the Museum für Naturkunde, Berlin. Although there currently are no absolute dates for the site, it is thought that it spans the Pleistocene-Holocene transition and may even represent the Last Glacial Maximum. Here we report $\delta^{13}C$, $\delta^{15}N$ and $\delta^{18}O$ values of bone collagen from Pisede *Rana temporaria*, *Rana arvalis,* and *Bufo bufo* specimens.
Preliminary results indicate excellent collagen preservation (CN ratio: 3.17-3.32). The $\delta^{15}N$ values differed significantly among the three species (ANOVA, $p < 0.001$). A post-hoc Tukey test indicated that mean $\delta^{15}N$ value of *B. bufo* (9.9‰) differs from *R. temporaria* (5.7‰) and *R. arvalis* (6.3‰), but *R. temporaria* and *R. arvalis* are not significantly different from each other. *B. bufo* exhibited the largest range in $\delta^{15}N$ values (7.3 – 12.4‰), which is representative of the varying trophic levels that *B. bufo* occupies. Neither mean $\delta^{13}C$ nor mean $\delta^{18}O$ values are significantly different among the three species (ANOVA, $p > 0.05$). *B. bufo* exhibited the largest range in $\delta^{18}O$ values (8.5 – 10.7‰), which may be representative of the species' use of both terrestrial and aquatic habitats. Interestingly, *B. bufo* had the lowest range in $\delta^{13}C$ values (-21.42 - -20.09‰), while *R. temporaria* had the largest (-22.17 - -19.08‰).
Continuing work will expand the number of Pisede anuran specimens analyzed, the analysis of co-occurring taxa, and radiocarbon dates for the site. In addition, the analysis of modern conspecifics will inform on the potential for the use of fossil frogs as isotopic proxies of paleoprecipitation.

Grant Information:
Paleontological Society Stephen Jay Gould Student Award

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

DESCRIBING ENAMEL IN SQUAMATES: UTILIZING NON-DESTRUCTIVE CT SCANS TO CHARACTERIZE ENAMEL IN EXTANT AND EXTINCT LIZARD SPECIES

RIEGLER, Mitchell, University of Florida, Gainesville, FL, United States of America; STANLEY, Edward L., University of Florida, Gainesville, FL, United States of America; BLOCH, Jonathan I., Florida Museum of Natural History, University of Florida, Gainesville, FL, United States of America

Lizards represent a geographically and temporally diverse group of animals, occupying almost every biome on Earth since the Mid-Cretaceous (100 Ma). Their potential to answer ecological questions (i.e., response to climate change) via geochemical proxies (i.e., $\delta^{13}C$, $\delta^{18}O$) has largely been unexplored, but improved technologies are making this challenge more achievable. Most geochemical analyses of fossil materials utilize mammalian enamel, a dense material that resists diagenesis, and is often plentiful enough to be analyzed geochemically. It has yet been shown that these enamel characteristics (i.e., density, thickness, abundance) exist within squamate taxa. Utilizing high resolution X-ray computed tomography scans of lizard material, we quantified squamate enamel thickness, density, location within the tooth, and volume using the segmenting software VGSTUDIO MAX 3.2. Three extant lizard taxa were selected as a base of comparison; *Tupinambis teguixin* (tegu) was selected for its pluerodont/heterodont dentition, *Fucifer bifidus* (chameleon) was selected for its acrodont dentition, and *Dracaena guianensis* was selected for its molariform dentition. Three extinct taxa (*Proxestops sp.,* Amphisbaenia, *Saniwa sp.*) collected from Bighorn Basin, Wyoming deposits, all in close temporal association with the Paleocene-Eocene Thermal Maximum (PETM), were selected to determine if usable quantities of fossil enamel for geochemical analyses existed. All scans were compared to a mammal species (*Tadarida brasiliensis)* to determine that the density of lizard enamel is comparable to mammalian enamel.
The extant scans illustrated distinct differences in enamel characteristics between dentition type. The tegu had a dense enamel tip, with softer material closer to the root. In addition, replacement teeth were substantially denser than in-place teeth. The chameleon had the least dense enamel, but had a dense, enamel like material running along from the tip of the tooth around the labial surface to the ventral portion of the dentary. *Dracena* had more mammalian like enamel, with a thick (>100 μm) outer shell wrapping the entire tooth exterior. All lizards were within 8% the density of the mammalian comparison. The fossils, all isolated dentaries, show *Dracena* like enamel in

Proxestops, with dense and abundant enamel in the two other taxa. Results from these data provide a guide for geochemical analyses of lizard tooth enamel, while limiting sample waste and contamination.

Grant Information:
Fossils were collected under BLM permits, PA04-WY-113 and PA10-WY-185.
Collection was funded by grants from NSF: EAR-0640076, EAR-0719941, BCS 1440742, and BCS 1440558

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

DIVERGENT MAMMALIAN BODY SIZE IN A STABLE EOCENE GREENHOUSE CLIMATE

RING, Simon, University of Tübingen, Tübingen, Germany; BOCHERENS, Herve, University Tübingen, Tübingen, Germany; WINGS, Oliver, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany; RABI, Marton, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany

The response of mammals to climate change during the Cenozoic is of major interest to paleobiology and conservation. A relationship between body mass and climate has been repeatedly inferred for abrupt global warming events during the Eocene and substantial global-scale Cenozoic cooling was accompanied by a progressive increase in the size of mammals. However, testing the robustness of this relationship has been hindered by the paucity of suitable fossil material covering large temporal ranges. Here we analyze the former German lignite mine of Geiseltal, which spans between 1 and 5 Myrs of the middle Eocene (Lutetian), and generate the most extensive single-site mammalian morphological record outside North America. We show that the two dominant herbivores, propaleotheriid horses and tapiromorphs, differ significantly in their body size trajectories despite a consistently humid, subtropical climate. While measured bioapatite samples exhibit $\delta^{18}O$ and $\delta^{13}C$ isotopic signatures characteristic of a tropical evergreen forest, body mass of horses and tapiromorphs diverges rapidly across the same time interval, from an initial mean body size gap of 110 kg to 220 kg at the end of the record. We attribute this divergent body size evolution to a disparity in life history. The fast-slow life history concept predicts that small-sized early horses had high reproduction / biomass-production rates whereas tapiromorphs, the largest herbivores of the European Eocene, lived and reproduced more “slowly” due to the lack of comparably-sized predators. These discrepant life histories likely resulted in an opposing body-size response to selective pressures by maximizing metabolic/reproductive advantages. Our results therefore provide unique insight into the relationships of body size and lifestyle in extinct mammal faunas and suggest that modern ecosystem structuring did not evolve before the Eocene. This is also consistent with the view that intrinsic biotic processes dominate over climate forcings in driving animal ecomorphology outside abrupt climate events. Finally, our work also has implications for regional biochronology and the formation of the Geiseltal fossil site.

Grant Information:
Volkswagen Foundation "Research in Museums" grant (90 978) to MR.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

A REASSESSMENT OF THE PHYLOGENETIC CHARACTERISTICS OF CROCODYLIA USING A SUPER-MATRIX APPROACH

RIO, Jonathan P., Imperial College London, London, United Kingdom; MANNION, Philip D., London, United Kingdom; SUTTON, Mark, Imperial College London, London, United Kingdom

The crown-group Crocodylia is a speciose and globally distributed clade, composed of 26 extant and approximately 150 extinct species extending back to the Late Cretaceous. Despite a substantial increase in the number of fossil crocodylian species described in recent decades, there has not been a proportional increase in character sampling, and few studies have included more than 80 in-group taxa. This hinders resolution in large parts of the crocodylian tree and the testing of phylogenetic hypotheses. In particular, the relationship of *Gavialis gangeticus* and *Tomistoma schlegelii* has been a persistent problem, with topological differences between morphological and molecular datasets resulting in a 40 million year discrepancy in the proposed origin of the gharial lineage. We have assembled the largest and most comprehensive dataset to date for Crocodylia, which comprises 363 morphological characters scored for 146 species (23 extant and 123 extinct taxa). This dataset represents a global sampling of crocodylian taxa, 85% of which were scored based on direct examination of specimens. All existing characters were critically reviewed from personal observations and an extensive literature review, resulting in extensive modifications to most characters, and the identification of 48 new characters. We identify new anatomical similarities in the orbitotemporal canals of the basal gavialoid taxa *Thoracosaurus* and *Eosuchus*, which differ from the condition observed in other gavialoids (*Eogavialis*, *Gryposuchus*, *Piscogavialis*¸ and *Gavialis*). The latter share a condition with Crocodylidae (i.e., crocodylines and tomistomines), in which a large fossa extends across the posterior wall of the supratemporal fenestra from the medial edge of the orbitotemporal canal. This, and other revised novel characters, appear to support the view that ‘thoracosaurs’ might not be closely related to *Gavialis*, an important first step in closing the temporal gap between morphological and molecular analyses. Our dataset includes 35 continuous characters, derived by quantifying discretely coded characters in existing datasets. We find that the majority (30) of these are normally distributed, showing a continuous spectrum of values. This supports their treatment as continuous in phylogenetic analyses, and raises the question of whether the character states for other discretely coded characters are arbitrarily drawn.

Grant Information:
This research was supported by a NERC DTP scholarship.

Technical Session VII (Thursday, October 10, 2019, 9:15 AM)

A NEW ZIPHODONT EUSUCHIAN FROM THE PLEISTOCENE OF QUEENSLAND, AND IMPLICATIONS FOR AUSTRALASIA’S ZIPHODONT CROCODYLIAN DIVERSITY

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Ziphodonty, or dentition containing labiolingually compressed and serrated teeth, is a condition that has evolved multiple times within Crocodylomorpha, with ziphodont crocodylomorph remains known globally from Mesozoic and Cenozoic sediments. During the Cenozoic, most currently recognized ziphodont crocodylomorphs disappeared by the end of the Miocene, except in Australasia, where some eusuchian ziphodonts survived well into the Pleistocene. For almost 40 years, virtually all ziphodont crocodyliform material from the Australian Cenozoic has been referred to *Quinkana*, a genus of small to medium-sized crocodylians. However, a recently discovered specimen from Queensland represents a new genus and species that significantly alters our understanding of Australasian ziphodont crocodylian diversity and evolution. This new taxon, represented by a mostly complete skull, a left mandible, and a partial osteoderm is from a large-bodied (~3.5 m long) individual. It displays a unique combination of features, such as a relatively broad and moderately tall rostrum with complete overbite dentition; tall maxillary alveolar processes; distinct but non-functional notches at the lateral premaxillary-maxillary sutures; laterally positioned orbits; an internarial bar; a pair of concavities located posteriorly on the maxillae; squamosal ‘horns’; a distinctive ‘B’ shaped secondary choana; and, a posteroventrally facing basioccipital plate. Ziphodonty is demonstrated by the presence of a maxillary tooth that bears true denticles on its carinae. Several of the above-mentioned characters are consistent with trophic adaptations suggesting it was a terrestrial predator. The phylogenetic position of the new taxon was assessed using an extensive dataset that contains most hitherto known Australasian extinct crocodylians. Results of the analysis show that the new taxon is nestled within the Mekosuchinae, and was recovered as a sister taxon to *Quinkana*. Dating of the specimen demonstrates that it lived ~120 ka, making it the youngest dated ziphodont crocodylian globally. The type species of *Quinkana*, *Q. fortirostrum*, is also from the Pleistocene, and along with other crocodylians such as the new ziphodont taxon, *Crocodylus*, *Pallimnarchus*, large varanids, and madtsoiid snakes illustrate a carnivorous fauna dominated by reptiles, seemingly in contrast with other continents where mammalian carnivores occupied the apex predator roles during the Quaternary.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

INTRAFORMATIONAL STRATIGRAPHIC CORRELATION OF VERTEBRATE LOCALITIES WITHIN THE UPPER CRETACEOUS KAIPAROWITS FORMATION TIED TO HIGH-PRECISION U-PB CA-ID-TIMS ZIRCON DATING OF 11 BENTONITE MARKER HORIZONS: IMPLICATIONS FOR EVOLUTIONARY AND ECOLOGICAL PATTERNS

ROBERTS, Eric M., James Cook University, Townsville, Australia; BEVERIDGE, Tegan, James Cook University, Townsville, Australia; RAMEZANI, Jahan, MIT, Boston, MA, United States of America; TITUS, Alan, BLM, Kanab, UT, United States of America

The Upper Cretaceous Kaiparowits Formation in southern Utah has produced a remarkable number of new macrovertebrate fossil localities over the last 18 years, which has resulted in the description of >20 new dinosaur species and recognition of an unusually rich diversity and abundance of crocodiles and turtles. Moreover, the formation represents one of the best-sampled microvertebrate bearing Cretaceous successions in North America, with continuous collecting efforts extending back into the 1980s. These richly fossiliferous continental sedimentary deposits of the Kaiparowits Formation are particularly important because they are closely contemporaneous with portions of other well-sampled mid-late Campanian continental vertebrate faunas of Laramidia preserved across the Western Interior Basin. However, the Kaiparowits Formation is exposed across a vast, ~70 km N-S transect of difficult to access wilderness with large roadless sections, making intraformational correlations between widely spaced fossil localities difficult. Over the last three years, our team has identified as many as 13 bentonite horizons through the 870+ meter thick succession that provide key marker horizons for correlation. We have systematically dated (or redated in many cases) 11 of these bentonites using high-precision U-Pb zircon geochronology (via chemical abrasion isotope dilution thermal ionisation mass spectrometry [CA ID TIMS]). Dating was focused in two primary stratotype sections, one in the north and one in the south, to act as tie points for systematically correlating dozens of legacy and recent vertebrate fossil localities. The new dating has significantly reduced uncertainties associate with the earlier dating. Here we present these new ages and a better-resolved internal stratigraphic framework, allowing us to more precisely and accurately estimate the temporal ranges of taxa from the Kaiparowits Formation. This work has significant implications for understanding the evolutionary and ecological history of this important fauna.

Grant Information:
National Science Foundation-EAR-1424892

Technical Session IX (Thursday, October 10, 2019, 3:30 PM)

ELUCIDATING CRYPTIC AXIAL SKELETAL REGIONALIZATION IN REPTILIA: IMPLICATIONS FOR VERTEBRATE EVOLUTIONARY-DEVELOPMENTAL HISTORY

ROBERTS, Lucy E., University of Cambridge, Cambridge, England; HEAD, Jason J., University of Cambridge, Cambridge, United Kingdom

Reptiles exhibit extreme plasticity in axial skeleton morphology, however, regionalization has been considered conservative across the clade, in the traditional perspective of linearly increasing axial regionalization throughout Vertebrata from low-to-no regionalization in basal gnathostomes to highly regionalized axial skeletons in crown mammals. To investigate the history of axial skeletal regionalization in Reptilia, we combined Maximum Likelihood model selection with geometric morphometric analysis of vertebral shape covariation in representatives of major reptile clades to determine numbers of intracolumnar regions and regional boundaries. We then placed regionalization patterns within a phylogenetic context along with developmental data from model taxa to form hypotheses on the evolutionary-developmental history underpinning axial skeleton evolution across Reptilia. Our results reveal complex patterns and histories of regionalization than previously recognized in both stem and crown lepidosaurs and archosaurs. Limbed, non-serpentiform squamates possess a common pattern of four regions with generally consistent boundary positions along the vertebral column. Some clades of serpentiform squamates, including Pygopodidae, share similar four-region patterns, whereas other clades, including varanids and elongate, legless squamate taxa, such as legless skinks and dibamids, have more variable, more highly regionalized, vertebral morphologies. Archosauria encompasses two major patterns of vertebral evolution. Pseudosuchian regionalization is retained from stem archosaurs, suggesting a conserved *Hox* code in the clade. Regionalization across Avemetatarsalia is much more variable, especially between avian theropod clades, with low regionalization in clades including Passeriformes and higher regionalization in others, including Anseriformes. These results demonstrate a much more complex history of axial skeletal evolution across Vertebrata than generally recognized, and offer insight into the evolutionary-developmental history, and therefore underpinning causes of vertebral diversity, across Reptilia.

Grant Information:
NERC ESS Studentship to LER

Technical Session XI (Friday, October 11, 2019, 9:45 AM)

QUATERNARY EXTINCTIONS AND NON-EXTINCTIONS ON THE ISLAND OF SRI LANKA AND THEIR RELATIONSHIP TO LATE PLEISTOCENE *HOMO SAPIENS*

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Sri Lanka, and indeed South Asia more broadly, has been relatively neglected in the context of the Middle and Late Pleistocene extinction of Quaternary vertebrates. This is despite the fact that it has yielded some of the earliest global evidence for the specialized exploitation of tropical landscapes by our species, has been variously isolated as a consequence of changing sea-level, and sits at the centre of climatic influences of the Indian Ocean Monsoon system. Here, we report evidence for the extinction and persistence of different mammalian taxa during the Quaternary in Sri Lanka, focusing on cave and rockshelter archaeological sites in the Wet Zone rainforests of the island and fluvial geological deposits from the Ratnapura Beds. While the former case studies suggest the long-term, sustainable exploitation of small, and some large, mammalian taxa by growing populations of *Homo sapiens*foragers, the latter implies that a number of large mammals disappeared from Sri Lanka prior to the Last Glacial Maximum. We argue that with further dating work, excavation, and multidisciplinary methodologies, Sri Lanka could act as the ideal Asian-Pacific 'laboratory' setting for discerning the relative significance of island isolation, human hunting, and climatically-induced environmental change on diverse vertebrate taxa with difference niches and vulnerabilities.

Grant Information:
We would like to thank the Max Planck Society, National Geographic, and the University of Jayawardenepura, Sri Lanka for funding.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

BONY LABYRINTH MORPHOLOGY OF THE PANTODONT *CAENOLAMBDA PATTERSONI*

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Pantodonts are a clade of early Cenozoic herbivores that are some the earliest mammals to have achieved a large body size. Pantodonts exhibit significant cranial and postcranial morphological diversity, with some species likely having been terrestrial, semi-aquatic, or even arboreal. Despite this diversity, the sensory capabilities and locomotor habits of pantodonts remain poorly understood, in large part because of the inaccessibility of some of the relevant anatomy. The advent of mostly non-destructive imaging techniques such as computed tomography (CT) has alleviated some of these difficulties and allowed for the reconstruction and visualization of a variety of anatomical structures. Two such structures of interest are the cochlea and semi-circular canals, located in the bony labyrinth of the inner ear. Previous research has concluded that the size and shape of the cochlea and the size and orientation of the semicircular canals are correlated with hearing capabilities and locomotion, respectively. To date, the bony labyrinth of only one pantodont—the potentially arboreal South American *Alcidedorbignya inopinata*—has been reconstructed. Here, we present the first description of the bony labyrinth of *Caenolambda pattersoni*, a relatively unspecialized and likely terrestrial pantodont from the late Paleocene of North America. Based on our scans of the holotype skull, the bony labyrinth of *C. pattersoni* is small relative to the size of the skull. Partial reconstructions of both cochleae reveal that each has approximately 1.5 turns (equating to ~540º), suggesting that *C. pattersoni* had a limited acoustic range and was unlikely to have been able to detect low frequency sound. The reconstructed left anterior and posterior semicircular canals are positioned at 90° to each other, suggesting that *C. pattersoni* may have been an unspecialized terrestrial locomotor, although the lateral semicircular canals must be reconstructed before more robust inferences can be made. Our research is ongoing and will eventually include segmentation and reconstruction of more of the cochleae and semicircular canals, including the lateral semicircular canals.

Grant Information:
Royal Tyrrell Museum Cooperating Society Student Research Program

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

PALEONTOLOGY EDUCATION THROUGH PALEOART: A TWO-YEAR EXPERIENCE IN A BRAZILIAN HIGH SCHOOL

RODRIGUES, Taissa, University Fed. Espirito Santo, Vitoria, Brazil

Brazil is home to a wealth of fossils, and Federal directives recommend teaching Paleontology within the required middle and high school-level Science contents. However, most textbooks only briefly cite key fossils (such as *Archaeopteryx*) and teachers are either overwhelmed by the amount of contents and/or undertrained in Paleontology. With this problem in mind, we developed the project 'Paleontology: window into the past diversity' in partnership with a state-run high school. The project was financed, enabling the acquisition of notebooks and supplies, and of scholarships for the students and their science teacher, undergraduate assistants, and the project coordinator.
Ten students between ages 15 and 18 were chosen, and the first three months of the project were dedicated to theoretical and exercise lessons on paleontology and biological drawing. Students were then separated in smaller groups and each was asked to search for information on the biota and environment of a given time period. After that, they constructed scale models of these biotas. Materials used to build the models included a wooden base (about 32 x 32 cm), paint, and colored cold porcelain, which is cheap, easy to shape, and hardens upon contact with air resulting in a permanent form. Students also used sticks for support, and transparent resin, papier-mâché, and sand for texture.
As positive outcomes, eleven models were produced. Initial difficulties on scaling animals were discussed and improved in later models. Anatomical accuracy varied depending on individual abilities but the overall result exceeded expectations. Interestingly, students used mostly bright colors for marine vertebrates (fishes, reptiles) but not for terrestrial ones (reptiles, mammals).
The main difficulty was maintaining a cohesive group. In total, 21 students participated, as some opted out or concluded high school and had to be replaced. Although expected, such changes were challenging because the group's familiarity on the topic was not homogeneous. Also, seldom all students were able to attend the meetings at once. One student reported that, even with the scholarship, they could not afford to attend meetings when they were held at the university. Therefore, we recommend that future, similar projects give preference for smaller groups (6 to 7), composed by students of the same grade, and, as often as possible, include scholarships aiming inclusiveness.

Grant Information:
This project was funded by a joint FAPES/CNPq/Serra municipality grant (TO n. 374/2016).

Technical Session VIII (Thursday, October 10, 2019, 4:00 PM)

NEW FOSSILS FROM ASIA WIDEN EARLY ANTLER DIVERSITY AND YIELDED OLDEST ANTLERS KNOWN

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Antlers are unique organs with a very complex physiology including periodic regeneration and they are the autapomorphy of deer (Cervidae, Artiodactyla). The fossil record of antlers is crucial for the understanding of evolution and phylogeny of these animals. Especially exciting are the earliest records from the Lower Miocene of European sites, pointing not only to the time and place of cervid origination, but also providing information on the early evolution of these organs themselves. In this regard, a well dated stratigraphical background is pivotal.
Recently, a current Sino-U.S.-American collaboration discovered Miocene stem cervid antlers from well dated limnofluvial deposits in central Nei Mongol in northern China. Among those small fossil antlers, there are some even predating the previously oldest antlers, there is a morphological diversity comprising all morphotypes known so far (bifurcate, trifurcate, palmate, multipointed, crown-like) and more, and clear shedding scars on almost every specimen indicate regular antler cycles at that time.
Accordingly, these new Chinese antlers throw a different light on the origin and early evolution of cervids and are of cardinal importance. The wealth of specimens and shapes supports the hypothesis on origination and early radiation in Asia. Moreover, the represented morphotypes help to draw a more complete picture on early antler shape variability, and, in this context, contribute to clarification that crown cervid antlers are not 'true' antlers, but stem from a highly specialized form.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

SPECIALISATION OF CANINE SHAPE AND SHARPNESS IN POTENTIALLY SYMPATRIC SPECIES OF *DINOFELIS* (CARNIVORA: MACHAIRODONTINAE).

ROVINSKY, Douglass S., Monash University, Clayton, Australia; ADAMS, Justin W., Monash University, Clayton, Australia; EVANS, Alistair R., Monash University, Monash University, Australia; POLLOCK, Tahlia I., Monash University, Monash University, Australia

Widely researched and represented in the popular media, the sabretoothed cats *Smilodon* and *Homotherium* are stars of the fossil world. Their relative *Dinofelis*, however, is far less well known. Here we present a specimen of *Dinofelis barlowi*, with well-preserved maxillary dentition, from the new Plio-Pleistocene Legaga paleocave site (South Africa). This specimen is included along with the potentially sympatric *Dinofelis piveteaui* in an analysis comparing specialisation of canine shape and sharpness. We analysed 3D scans of both *Dinofelis* spp. maxillary canines along with over a dozen felid species via 2D geometric morphometrics to investigate cross-sectional shape at mid-height. Additionally, we implemented a novel method quantifying canine edge sharpness. The machairodontines plot together in both analyses to the exclusion of crown felids. Both species of *Dinofelis* expressed canines that were sharp, but also more robust when compared to the rest of Machairodontinae. The canine of *D. barlowi* was lenticular in cross-section, but only relatively labiolingually compressed compared to those of the true sabretooths *Smilodon* or *Homotherium*. *Dinofelis piveteaui* had a unique canine shape retaining the robusticity seen in *D. barlowi* while also possessing expanded and very sharp mesial and distal edges. This novel shape is reflective of the taxa's unusual mixture of conical-toothed and derived sabretoothed morphology, and potentially reflects a feeding strategy differing from both *D. barlowi* and the true sabretoothed cats.

Grant Information:
Monash Mbio Postgraduate Discovery Scholarship, Monash-Museums Victoria Scholarship (DSR); RTP Stipend - Australian Gov't, Monash Graduate Excellence Scholarship (TIP)

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 10:30 AM)

FOSSIL COLOUR RECONSTRUCTION IN DINOSAURS AND CLOSE RELATIVES

ROY, Arindam, The University of Hong Kong, Hong Kong, Hong Kong (CN); PITTMAN, Michael, The University of Hong Kong, Hong Kong, Hong Kong (CN); SAITTA, Evan T., Field Museum of Natural History, Chicago, IL, United States of America; KAYE, Thomas G., Foundation for Scientific Advancement, Sierra Vista, AZ, United States of America

Modern birds, the only surviving lineage of dinosaurs are represented by 10,000+ species that populate diverse ecological niches. They display an astonishing range of colours and colour patterns which are highly correlated with their ecology and behaviour. The colour gamut of avian plumage is produced by complex interactions between pigments and feather structures. The pigment melanin - a major player in producing colours and complex patterns in bird feathers is typically stored in rod- to sphere-shaped, membrane-bound vesicles called melanosomes. Fossilised melanosomes have been discovered in filaments, feathers and scales of non-avian dinosaurs, early birds and pterosaurs globally. The relationships between the shape, arrangement, and packaging of modern avian melanosomes with melanin chemistry have become key to reconstructing the colour patterns in fossil plumage, including ancient countershading camouflage. This has in turn enabled pivotal predictions to be made about the ecology and behaviour of these extinct animals.
Currently, there is no single formalized methodological framework that allows existing and future reconstructions of fossil colour to be compared between one other. This is largely related to information loss due to incomplete preservation, complexities in the characterization of integumentary structures, and the lack of contextualisation of detailed molecular diagenetic pathways of pigmentary systems with the morphology of pigment-bearing melanosomes. Here we collate integumentary and pigmentary information of extant and extinct animals available from the literature and critically interrogate the different methodologies used to collect it. We use this insight to reveal gaps in our knowledge of the pathways for organic preservation of pigments in fossils and suggest ways to address them.

We propose a synthetic and overarching framework that aims to reconstruct paleocolour more accurately and consistently by accounting for as many contributing factors as possible: types of integumentary structures, chemical signatures of pigments, melanosome morphology and arrangement, melanin concentration, macroscopic colour patterns, and taphonomic pathways of pigments.

Grant Information:
This project was funded by Hong Kong PhD Fellowship (HKPF PF16-09281).

Technical Session VII (Thursday, October 10, 2019, 9:00 AM)

A NEW ALLIGATORINE FROM THE MIDDLE EOCENE OF UTAH AND THE ORIGINS OF MODERN ALLIGATOR

RUBIN, Margaret, University of Iowa, Iowa City, IA, United States of America

Extant *Alligator* comprises two species – the American (*A. mississippiensis*) and Chinese (*A. sinensis*) alligators – but it has a fossil record extending back to the late Eocene. Nevertheless, a gap separates *Alligator* from its closest published relative, late Paleocene (Tiffanian) *Wannaganosuchus brachymanus*, which like other early Paleogene alligatorines was small (≤ 2 m), short snouted, and with adaptations for durophagy, such as a robust palate and enlarged distal maxillary and dentary teeth. Here, we describe a new species from the middle Eocene (Uintan) Uinta Formation of Utah that fills the stratigraphic gap and represents an intermediate form between earlier durophagous alligatorines and more generalized modern species. It resembles earlier alligatorines in many ways – its snout was comparatively short, its suborbital fenestrae were relatively small, its narial chamber was not inflated, and its orbital margins were not upturned – but it lacks the enlarged cheek teeth that characterized earlier alligatorines. The nasals project into the narial space, but do not completely subdivide the naris. A phylogenetic analysis recovers the new Uintan form as the sister lineage to *Alligator*. The living American alligator is an ecological generalist, but it arose from more specialized ancestors; the transition from specialist to generalist largely occurred after generalized crocodyloids disappeared from North America, suggesting that it was in response to niche availability, but the new form co-occurred with some of these crocodyloids, suggesting that the transition was already underway before the sharp contraction of crocodylian diversity in the northern continents after the middle Eocene.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW CONTRIBUTIONS TO THE CERATOPSID RECORD OF THE DINOSAUR PARK FORMATION FROM RECENT FIELDWORK ALONG THE SOUTH SASKATCHEWAN RIVER, ALBERTA, CANADA

RUFOLO, Scott J., Canadian Museum of Nature, Ottawa, ON, Canada; MALLON, Jordan, Canadian Museum of Nature, Ottawa, ON, Canada; CURRIE, Margaret, Canadian Museum of Nature, Ottawa, ON, Canada; DUDGEON, Thomas W., Carleton University, Ottawa, ON, Canada; MCDONALD, Alan, Canadian Museum of Nature, Ottawa, ON, Canada; SWAN, Susan, Canadian Museum of Nature, Ottawa, ON, Canada; WYENBERG-HENZLER, Taia C., Carleton University, Ottawa, ON, Canada

The Dinosaur Park Formation (DPF) of southern Alberta, Canada – well-known for the many dinosaur specimens discovered in the intensively researched exposures within Dinosaur Provincial Park along the Red Deer River – provides an invaluable window into the Late Cretaceous world (~77-75.5 Ma, Campanian Age). Other regions of the province, however, also harbour significant outcrops of this important deposit. Ongoing fieldwork initiated by the Canadian Museum of Nature (CMN) in 2013 focuses on the valley of the South Saskatchewan River around 80 km to the southeast, near the hamlet of Hilda, bringing to light new material concerning the dinosaur fauna that inhabited the proximate coastal terrain forming the western edge of the Western Interior Seaway.
Presented here are the results of initial work concerning two 2015 finds related to the horned-dinosaur family Ceratopsidae. The first is a newly identified occurrence of the Hilda mega-bonebed, a feature consisting of over a dozen distinct concentrations of ceratopsid bones near the hamlet of Hilda. Determined in the 1990s to be components of a single depositional event covering ~2.3 km^2, this earlier work estimated that each concentration contained scores of individual animals, likely *Centrosaurus apertus*. Mapping of the CMN bonebed, although still only partially excavated, has already revealed a dense monodominant assemblage of *Centrosaurus* remains averaging well over 20 bones/m^2. Well-preserved cranial elements confirm the presence *C. apertus*. Additionally, the abundant skeletal material appears to represent associated, semi-articulated elements. This is a taphonomic feature previously unnoted for other component bonebeds of the broader Hilda-area assemblage.
The second discovery detailed here, an isolated *Chasmosaurus* skull uncovered in stratigraphically older deposits near the bonebed, is significant for the fact that it represents a rare long-horned variety considered to be a distinct species by some authors (*C. canadensis*). The taxonomy of *Chasmosaurus* is problematic, only two species generally regarded as being valid (*C. russelli* and *C. belli*). The status of the long-horned morph is uncertain, a recent review assigning the few known specimens to *Chasmosaurus* sp. due to a lack of diagnostic features and unknown stratigraphic position for previously described specimens. The CMN skull occurs within the lower DPP and serves to anchor a more detailed examination of the status of *C. canadensis* as a valid taxon.

Technical Session I (Wednesday, October 9, 2019, 11:45 AM)

THE EVOLUTION OF SEALS (FAMILY PHOCIDAE) IN THE SOUTHERN OCEAN: NEW FOSSIL EVIDENCE FROM NEW ZEALAND

RULE, James P., Monash University, Melbourne, Australia; ADAMS, Justin W., Monash University, Melbourne, Australia; EVANS, Alistair R., Monash University, Melbourne, Australia; TENNYSON, Alan J., Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand; SCOFIELD, Paul R., Canterbury Museum, Christchurch, New Zealand; FITZGERALD, Erich M., Museums Victoria, Melbourne, Australia

The origin of southern true seals (Subfamily Monachinae) is one of the greatest unsolved mysteries of pinniped paleontology, in part due to a poor fossil record. Current biogeographic hypotheses identify the North Atlantic as the centre of dispersal of Phocidae (true seals), including monachines. However, data from the fossil record of Australia and New Zealand has so far been missing from such analyses, which represents a critical gap on the margin of the Southern Ocean.
We present new fossil Phocidae from the Pliocene of Taranaki, New Zealand (3.4-3.0 Ma). Consisting of multiple specimens, including complete crania, the sample provides evidence of a single species of small sized (<2 m total length) monachine seal. This taxon possesses broad postcanine dentition and unspecialised ear morphology. Morphological data (148 characters) was collected from all extant and 16 fossil phocids, and 5 outgroup taxa. Molecular data (16 nuclear genes, 12 molecular genes) were downloaded from Genbank for all extant phocids, *Odobenus,* and *Arctocephalus*. Parsimony and Bayesian (combined evidence) analyses demonstrate a monophyletic Phocinae and Monachinae, supporting recent work. The Taranaki phocids, along with fossil phocids from Beaumaris (Miocene-Pliocene of Australia), were found to be early diverging monachines.

This demonstrates that there was a greater diversity of Monachinae on the fringes of the Southern Ocean during the Neogene. Further, a biogeographic analysis suggests that the Southern Ocean played a larger role in monachine evolution than previously thought, with several groups of monachines originating in the Southern Ocean. Interestingly, only small-sized phocids appear in the pre-Pleistocene fossil record of the Southern Ocean, contrasting with the larger phocids that exist there today. This highlights the importance of southern higher latitude environments to the evolution of true seals.

Grant Information:
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Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A NEW NEOSUCHIAN CROCODYLOMORPH (REPTILIA, MESOEUCROCODYLIA) FROM THE MIDDLE CRETACEOUS LONGJING FORMATION, YANJI BASIN, NORTH-EASTERN CHINA

RUMMY, Paul, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; XU, Xing, Institute of Vertebrate Paleontology & Paleoanthropology, Beijing, China; WU, Xiao-chun, Canadian Museum of Nature, Ottawa, ON, Canada; JIN, Feng, Yanji Paleontology Research and Protection Center, Yanji, China; WEN, Dexiu, Yanji Paleontology Research and Protection Center, Yanji, China; WANG, Bing, Yanji Paleontology Research and Protection Center, Yanji, China

Numerous dinosaurian, crocodyliform, and testudine fossils have recently been recovered from the Longjing Formation in Yanji Basin, adding new significant data on the temporal and spatial distribution of the mid-Cretaceous dinosaur fauna in Northern China. Among them are fossil remains (IVPP-YJDM 00009) representing a new genus and species of crocodyliform. The

specimen consists of 26 bone fragments, including a partially-preserved braincase. It is the third crocodyliform to be found in Jilin Province, after *Paralligator sungaricus* Sun 1958 and *Rugosuchus nonganensis* Wu 2001. Specimen IVPP-YJDM 00009 is small in size. Some of the distinctive features include a heavily ornamented frontal lamina with interorbital midline ridge and preorbital groove; supratemporal fenestrae borders with the frontal, parietal, postorbital and the squamosal; dorsolaterally 90° bent postorbital bar; jugal that extends the triradiated infratemporal fenestrae; diastematic fossa on the dentary symphysis; amphicoelous vertebrae; proximally bent fibular head; relatively broad scapula shaft as well posteromedially raised keel of the osteoderms. Four numerical cladistic analyses have placed this new crocodyliform as a neosuchian, with paralligatorid affinities. The clade includes *Rugosuchus nonganensis* Wu 2001 and various species of the genus *Shamosuchus* from Mongolia, and its discovery contributes to vast importance in understanding the biogeographic evolution of Paralligatoridae in Central Asia.

Grant Information:
National Natural Science Foundation of China (Grant No. 41688103), the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant No. XDB18030504)

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A NEW ANKYLOSAUR DINOSAUR SKELETON FROM THE UPPER JURASSIC OF PORTUGAL

RUSSO, João, FCT-NOVA, Lourinhã, Portugal; MATEUS, Octávio, FCT-NOVA, Lourinhã, Portugal

Ankylosaurs are very rare in Upper Jurassic and their record is restricted to five genera. Among them, is the poorly known *incertae sedis Dracopelta zbyszewskii* from the Upper Tithonian of Portugal.
Here we present a new specimen recovered in the coastal cliffs near the beach of Porto da Calada, about 40 km North of Lisbon, in a light gray, fine to medium grained sandstone, close to the top of the Lourinhã formation, Upper Tithonian. It consists of a nearly complete skull, with maxillary teeth, at least eleven articulated dorsal vertebrae with proximal half of ribs, ten articulated anterior caudals, mostly complete and articulated synsacrum, several fragments of disarticulated and broken ribs, both femora articulated in the acetabulum, partial ilia with attached pelvic shield, right humerus missing the proximal end, partial right scapulocoracoid, over 180 osteoderms (lateral, caudal and dorsal, most in situ) of various size (0.5-18 cm), at least 40 ossified tendons mostly attached to the vertebrae, and partial pelvic shield. This specimen (FCT-UNL 702), still under preparation, is one of the most complete Jurassic ankylosaurs.
Many of the ankylosaurian traits are present: medially inset maxillary tooth row; dorsal expanded proximal T-shaped ribs; posteriormost dorsal vertebrae fused to form a rod; horizontal hypertrophied preacetabular process, showing attachment scar of a posterior dorsal rib; robust humerus with deltopectoral crest extending mid shaft; distally positioned ridge-shaped fourth trochanter; extensive dermal armor (scutes, lateral plates and pelvic shield); and large hollow-based lateral plates.
The femoral head is separated from greater trochanter by a distinct slope which is diagnostic of Nodosauridae, but contrary to these, the posterior width of the skull is twice the width across the orbits. The phylogenetic position of the Portuguese specimen is not yet fully understood, but likely close to the split between the two major clades: Nodosauridae and Ankylosauridae. Also, it is still unclear if this is a second specimen of the sympatric and coeval *D. zbyszewskii*.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

FUNDING MEANINGFUL RESEARCH EXPERIENCES ENCOURAGES UNDERGRADUATES TO PURSUE DEGREES IN PALEONTOLOGY AND GEOSCIENCE

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Minority students are highly underrepresented in the geosciences, especially in vertebrate paleontology. Additionally, the number of new students entering a geology or paleontology major in the United States is not keeping up with industry demand. In order to address these issues, Wake Technical Community College (WTCC) geology faculty partnered with faculty at North Carolina State University (NCSU) from 2012-2019 and with researchers at the North Carolina Museum of Natural Sciences (NCMNS) from 2016-2019 to provide paid summer research internships to community college geology students who have only completed one or two geology courses. Student interns perform meaningful research, including planning, data collection, and analysis under the mentorship of faculty, researchers, and graduate students at our partner institutions, and then produce a poster that is presented at both local and national/international meetings, including both the Geological Society of America (GSA) and the Society of Vertebrate Paleontology (SVP). Successful student interns come from diverse backgrounds including a variety of minority populations. The experience for most student interns has been transformative and has led to them continuing their education in a geoscience field. We find that meaningful paid research experiences early in a student's career can encourage minority and underrepresented student groups to choose a major and career in geoscience or paleontology.

Grant Information:
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Technical Session XII (Friday, October 11, 2019, 9:45 AM)

SEXUAL DIMORPHISM IN NON-AVIAN DINOSAURS AND OTHER EXTINCT TAXA: THE IMPORTANCE OF EFFECT SIZE STATISTICS IN PALEONTOLOGY

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Despite many published reports of sexual dimorphism in extinct taxa, such claims in non-avian dinosaurs have been significantly underrepresented in recent years and have often been met with sharp criticism. Given that dimorphism is widely prevalent in sexually reproducing organisms, such a consensus would suggest that either this diverse group exhibited a highly unusual biology or that research bias is at play. Here we show that so-called 'species recognition' and 'mutual sexual selection' hypotheses for non-avian dinosaurs are poor explanations, and that there are multiple lines of evidence for sexual selection and variation of structures consistent with secondary sexual characteristics. We also show how univariate significance testing approaches, especially tests for bimodality, are uninformative and prone to false negatives. Instead, we propose a novel methodology for studying sexual dimorphism in the fossil record that focuses on traits likely to be secondarily sexual and tests against all alternate hypotheses for variation in those traits using multiple lines of evidence. Notably, we utilize effect size statistical approaches that are appropriate for low sample sizes, rather than significance testing, to analyze potential divergence of growth curves in these traits, constrain maximum and minimum estimates for dimorphism magnitude, and gauge support for sex-based growth models. Thus, it is more appropriate to compare estimates for the magnitude of and support for dimorphism between datasets than to attempt to decisively reject or fail to reject dimorphism in a single species. This approach allows for the study of sexual selection across phylogenies and time. We discuss our approach with both simulated and empirical crocodilian and avian data.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

NEW DINOSAUR, PTEROSAUR, AND CROCODYLIFORM FOSSILS FROM THE UPPER CRETACEOUS (CENOMANIAN) BAHARIYA FORMATION OF THE BAHARIYA OASIS, EGYPT

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The Upper Cretaceous (Cenomanian) Bahariya Formation of the Bahariya Oasis in the Egyptian Western Desert has yielded a diverse fossil vertebrate assemblage, including the type specimens of the non-avian theropods *Spinosaurus*, *Carcharodontosaurus*, and *Bahariasaurus*, the titanosaurian sauropods *Paralititan* and *Aegyptosaurus*, and the crocodyliforms *Libycosuchus*, *Stomatosuchus*, and *Aegyptosuchus*. Recent paleontological fieldwork within the oasis has resulted in the discovery of new fossil

vertebrate-bearing localities in multiple horizons of the Bahariya Formation. The recovered fossils, still under study, include the following: (1) a quadrate of an as-yet unidentified large-bodied archosaur, with a dorsomedial expansion, a relatively small pterygoid flange, and mediolaterally elongate articular condyles; (2) a well-preserved cervical vertebra of an abelisaurid theropod that is relatively short and that has a neural spine that is taller than its epipophyses, suggesting a robust neck comparable to those of the Patagonian abelisaurids *Carnotaurus* and *Ekrixinatosaurus*; (3) an associated partial skeleton of a medium-sized non-avian dinosaur, probably a juvenile sauropod; (4) a left first wing phalanx of a medium-sized pterosaur, which has an ossified, medium-sized extensor tendon process with a shallow, open saddle and that bears large cotyles with the posterior process at the proximal end of the phalanx suggesting tight articulation with metacarpal IV; and (5) a right dentary of a crocodyliform that possesses enlarged teeth in the first and fourth alveoli, with the latter followed by seven smaller teeth. These new discoveries include the first record of Pterosauria from Egypt and possibly the first definitive abelisaurid material from the Bahariya Formation. Furthermore, the crocodyliform dentary appears to represent a taxon not previously reported from this stratigraphic unit, with potential affinities to Peirosauridae (including 'trematochampsids') or Mahajangasuchidae.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

TAXONOMY AND PHYLOGEOGRAPHY OF TWO EXTINCT NORTH AMERICAN QUATERNARY CARNIVORANS

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The Late Quaternary is associated with the extinction of 72% of North American megafauna genera. Many Pleistocene taxa have been subdivided into a number of species/subspecies based on morphological data from fossil assemblages, however, molecular studies (including ancient DNA from extinct organisms) often fail to recapitulate these proposed subdivisions, instead suggesting morphological variation is more likely due to sexual dimorphism (e.g., *Bootherium*) or the result of distinct ecotypes (e.g., *Bison*, *Ursus*). Here we focus on two extinct North American Pleistocene carnivoran taxa, the giant short-faced bear (*Arctodus simus* sspp.) and lions (*Panthera leo* sspp.), which both have proposed taxonomic subdivisions within North America. We tested the taxonomic subdivisions of the two aforementioned taxa using full mitochondrial genome sequences obtained from Late Pleistocene and early Holocene sub-fossil specimens from across North America. We also investigated the phylogeographic structure of these two taxa, attempted to correlate this structure with the paleoenvironment and life history, and explored implications for our understanding of megafaunal responses to climate and environmental change during the Late Quaternary.

Grant Information:
NSF 1425059, ARC FL140100260

Technical Session II (Wednesday, October 9, 2019, 11:00 AM)

AN EXCEPTIONALLY PRESERVED SMALL-BODIED ORNITHOPOD DINOSAUR FROM THE LOWER CRETACEOUS (UPPER ALBIAN) WINTON FORMATION OF ISISFORD, CENTRAL-WESTERN QUEENSLAND, AUSTRALIA, AND THE DIVERSIFICATION OF GONDWANAN ORNITHOPODS

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Ornithopod dinosaurs form a ubiquitous component of the Cretaceous continental vertebrate faunas of Australia. Although represented by numerous specimens from sites across southern Victoria, northwestern New South Wales, and parts of western Queensland, the majority of specimens are very incomplete. Of the named taxa, most (*Atlascopcosaurus, Galleonosaurus*, *Leaellynasaura*, *Qantassaurus*, *Weewarrasaurus*) are based on craniodental remains, whereas others (*Diluvicursor*) are based on partial postcrania. The only taxon known from both cranial and postcranial elements, *Muttaburrasaurus*, exhibits unusual morphologies that have rendered its affinities contentious. Unfortunately, the nature of Australian ornithopod material has long obfuscated the phylogenetic relationships of these dinosaurs and their relevance to broader patterns of ornithopod evolution and paleobiogeography.

Here we report a new ornithopod from the Lower Cretaceous (upper Albian) Winton Formation of Isisford, central-western Queensland, Australia. The new taxon is represented by a nearly complete skull and mandible and at least three partial postcranial skeletons. The material represents the most complete small-bodied ornithopod from Australia and includes one of the world's best-preserved basal ornithopod skulls. The new form is the first non-dryomorphan ornithopod from Gondwana with an edentulous premaxilla; moreover, the antorbital fenestra is greatly reduced as in *Muttaburrasaurus* and styracosternans. The dentition is intermediate between that of *Muttaburrasaurus* and other small-bodied ornithopods from Australia and South America. Characters of the ilium and pes are shared with multiple Gondwanan Cretaceous ornithopods.

The Isisford taxon sheds new light on clade-level diversity at the base of Ornithopoda and helps resolve the relationships of Gondwanan non-hadrosauriform ornithopods. Phylogenetic analysis recovers the new taxon within a diverse clade of Gondwanan ornithopods that includes taxa from Australia, South America, and Antarctica and that is the sister taxon of the predominantly Laurasian Clypeodonta (*Hypsilophodon* + Iguanodontia). Gondwanan ornithopods diverged from clypeodontans during the Middle–Late Jurassic, with their greatest diversification likely to have occurred during the Cretaceous. Morphological diversity within the Gondwanan ornithopod radiation appears to mirror that of clypeodontans, encompassing small- to large-bodied forms, highlighting the potential for further discoveries.

Grant Information:
Australian Research Council; Land Rover Australia; Isisford, Longreach & Winton shire councils; Qld Museum; Carnegie Museum of Natural History; University of Queensland

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

A NEW MIOCENE CROCODYLIFORM FROM THE ISLAND OF NOSY MAKAMBY, NORTHWESTERN MADAGASCAR

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Madagascar's crocodyliform fossil record includes a diversity of bizarre Late Cretaceous basal meseoeucrocodylians and two Quaternary crocodylids - one that went extinct during the Holocene (*Voay robustus*) and modern *Crocodylus niloticus*. The Late Cretaceous forms are unrelated to those of the Quaternary, and the near lack of Cenozoic vertebrate fossils obscures the origin and early evolution of historically extant Malagasy crocodylians.

Recent discoveries from nearshore marine deposits have begun to clarify the Cenozoic histories for other groups, including sharks, bony fish, turtles, sirenians, and the island's first fossil cetacean. We report here Miocene crocodyliform material from the island of Nosy Makamby, northwestern Madagascar, including osteoderms, vertebrae, a partial lower jaw, and anterior snout. It preserves a combination of character states inconsistent with any previously-described Malagasy crocodyliform. Unlike Late Cretaceous taxa, the vertebrae are procoelous. Unlike *V. robustus* and *C. niloticus*, the rostrum is slender with parallel lateral margins and the mandibular symphysis is extensive. This indicates a complex biogeographic history of Malagasy crocodyliforms, with multiple dispersal events following extinction of the Late Cretaceous fauna. The Nosy Makamby form is broadly similar to slender-snouted crocodylians from the Cenozoic of Africa (e.g.,, *Eogavialis*), although the anterior dentary alveoli show greater disparity in diameter and are not as evenly spaced in the Nosy Makamby form. A close relationship between African and Malagasy stenorostrine forms would be consistent with a marine, or at least marine-tolerant, origin for modern gharials, both of which only occur in fresh water.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

CRANIAL ENDOCASTS OF COLUGOS, AND THEIR RELEVANCE TO UNDERSTANDING THE EARLY PHASES OF THE EVOLUTION OF THE BRAIN IN EUARCHONTA AND PRIMATES

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In order to better understand what is primitive in terms of the morphology of the brain for Primates it is essential to understand the form of the brain in primates' closest extant relatives: Dermoptera (colugos) and Scandentia (treeshrews). Treeshrews are often viewed as modern proxies for early primates because they are small-bodied and have lissencephalic brains. However, a previous study concluded that the endocranial morphology of treeshrews is derived and unlike that of primitive primates (plesiadapiforms). Dermopterans are also extant animals, closely related to primates, albeit much larger than treeshrews and with gyrencephalic brains. Little is known about the endocranial morphology of colugos despite their important position in Euarchonta.
Although dermopteran endocasts contrast with those of scandentians in being gyrencephalic, the relative neocortical surface area (~36%) is within the range of Scandentia (33.6%-39.8%), similar to early fossil euprimates (e.g., 31-36% in adapoids), and much higher than in plesiadapiforms (~20-22%). The olfactory bulbs are relatively smaller than observed in scandentians or plesiadapiforms, accounting for only 3.8% of the total volume; this is greater, however, than in adapoids (1.2-2.4%). To examine patterns in shape, a set of 30 endocranial landmarks were placed on endocasts derived from microCT data for 22 treeshrews: *Ptilocercus* (n=5), *Tupaia* (n=15), and *Dendrogale* (n=2), both species of dermopterans: *Cynocephalus volans* (n=1) and *Galeopterus variegatus* (n=1), and two plesiadapiforms: *Ignacius graybullianus* (n=1) and *Microsyops annectens* (n=1). Procrustes shape variables were examined in a Principal Components Analysis. The results show that dermopterans occupy their own shape-space, distinct from both treeshrews and plesiadapiforms. This is largely due to differences in the overall shape of the cerebellum and due to an anterior-dorsal shift in the highest point of the neocortex. These results highlight the distinctive nature of the dermopteran endocast, which lacks clear similarities in shape or proportions to those of plesiadapiforms. Although there are some general resemblances to early euprimate endocasts, these similarities are in features are either very prone to parallelism (e.g., reduction in the size of the olfactory bulbs) or are likely related to increased overall size (e.g., presence of neocortical sulci). These results highlight the problematic nature of using modern taxa as models for the early phases of primate or euarchontan brain evolution.

Grant Information:
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Technical Session XV (Saturday, October 12, 2019, 9:15 AM)

A NEW RHAETIAN BONEBED FROM GERMANY: IMPLICATIONS FOR THE END-TRIASSIC EXTINCTIONS IN THE MARINE REALM

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The mass extinction at the end of the Triassic is arguably the least understood of the Big Five extinction events, partially because of dating and correlation issues and partially because of scarce Rhaetian fossil localities. Among these, the classical Rhaetian bonebeds (condensation horizons) of the European marine epicontinental Triassic have been important because of their taxon sampling from fully marine to terrestrial environments. Yet, the stratigraphic position of these bonebeds relative to the Triassic-Jurassic boundary is rarely well constrained. The newly discovered Rhaetian bonebeds of Bonenburg (eastern Westphalia, Germany) improve this situation by their biostratigraphically (palynomorphs, chonchostracans) well constrained late Rhaetian age combined with an abundant and diverse vertebrate fauna. Bonenburg also provides a thick Triassic-Jurassic boundary section, including the latest Triassic (201.5 ma) Event Beds which directly overlie the bonebeds. Among the fish remains, chondrichthyan teeth and fin spines represent typical Rhaetian taxa (e.g., *Grozonodon candaui*, *Lissodus minimus*, '*Hybodus*' *cloacinus*, *Nemacanthus monilife*r, and *Rhomphaiodon minor*) which do not survive into the Jurassic. Large *Ceratodus* sp. lungfish teeth record continental input. Tetrapods are represented not only by amniotes, but surprisingly also by temnospondyls. Plagiosaurids are common, and abundant remains of large capitosauroid temnospondyls are the youngest record globally. Amniotes are represented by ichthyosaurs, sauropterygians, the possible choristodere *Pachystropheus*, saurischian dinosaurs, and the cynodont *Lepagia*. The most abundant ichthyosaur remains are extremely short (length < 20% of height) but large vertebrae of the *Shonisaurus* type and the cortical fragments of giant ichthyosaur jaw bones. Sauropterygians are represented by at least three taxa of plesiosaurs including *Rhaeticosaurus*, but also by non-plesiosaurian pistosauroids such as a large (30 cm) humerus and vertebrae.
The Bonenburg faunal record thus offers a contradictory signal regarding the nature and severity of the extinctions. The finds indicate that many chondrichthyans, two clades of non-brachiopoid temnospondyls and giant shastasaurid ichthyosaurs survived into the latest Triassic but not beyond. Non-plesiosaurian sauropterygians also went extinct, but plesiosaurs seem to have suffered little. In summary, the extinctions appear to have been sudden, constrained to the latest Triassic Event Beds, but selective.

Grant Information:
We acknowledge the LWL Museum für Naturkunde, Münster, Germany, for financial support through the Denkmalpflegeprogramm NRW.

Technical Session VI (Thursday, October 10, 2019, 12:00 PM)

A REVIEW OF AFRICAN ELASMOTHERES (MAMMALIA, RHINOCEROTIDAE) AND THEIR ROLE ON EARLY MIOCENE MIGRATION EVENTS INTO EAST AFRICA

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Rhinoceroses first ventured into Africa at the early Miocene. By the beginning of the middle Miocene, all the main clades recorded in Eurasia were already represented across East Africa by a series of endemic species, pointing to a critical period of rhinoceros evolution at a continental level. These include members of the Elasmotheriina, rhinoceroses with a highly hypsodont dentition and a conservative postcranial skeleton. We studied the holotype of *Turkanatherium acutirostratum*, the first elasmothere species reported from the continent. The skull comes from the early Miocene (16.8–17.5 Ma) strata of the Moruorot Hill, Kenya, and is housed at the National Museum of Colombo, Sri Lanka, where has not been accessed by specialists for the last 65 years. Previous studies proposed the presence of a long-lasting lineage of African elasmotheres. Our detailed re-description and revised diagnosis of *T. acutirostratum* not only confirms its elasmothere affinities but also shows that African Elasmotheriina species are related to separate Eurasian clades. The lineage leading to *T. acutirostratum* is part of a distinct early Miocene migration event separated from that of *Ougandatherium napakense*, an earlier elasmothere species found in the early Miocene deposits of Napak (Uganda). However, East African elasmothere postcranial remains poorly known, highlighting the need for their study in order to elucidate the distribution of the group at a continental level. This work highlights the role of Rhinocerotidae in the strong but progressive faunal turnover event taking place in East Africa for much of the Miocene.

Grant Information:
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Technical Session VI (Thursday, October 10, 2019, 10:15 AM)

THINK BIG, EVOLUTIONARY ALLOMETRY AS A MAJOR FACTOR IN RATES OF MORPHOLOGICAL EVOLUTION OF THE PRIMATE BRAIN SHAPE

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Primates constitute one of the most successful and diverse mammalian clades. One key factor in their diversification is the evolution of their peculiar brain morphology, however, the evolutionary and developmental processes determining the relevant shape changes in the primates brain remains largely unknown. In this study we used 3D geometric morphometrics, phylogenetic comparative methods and Bookstein's novel concept of scaling in shape

variation to understand the factors influencing rates, trajectories and scaling of brain shape in a sample of 152 species (147 extant and 5 extinct) including members from each major primate clade (including *Homo sapiens* and the omomyid taxon *Rooneyia*). We found only Hominoidea and Cercopithecinae showed a significant evolutionary allometry after controlling for phylogeny, whereas Strepsirrhini, Colobinae and Platyrrhini did not. However, Hominoidea and Cercopithecinae both showed markedly high rates of morphological evolution, whereas Strepsirrhini and Platyrrhini display a significant slowdown. As a consequence, Hominoidea and Cercopithecinae have different trajectories and magnitudes of shape changes when compared with the remaining clades. Apes, lesser apes and cercopiths tend to have an overall globular brain shape with more developed frontal lobes. Furthermore, there is a large-scale effect (global pattern of variation) of size on brain shape in Hominoidea and Cercopithecinae, whereas size better describes smaller scales of variation (local pattern) in the slowly evolving clades. In conclusion, our results suggest that the evolution of allometry may have favored shape changes at larger scales and promoted the rapid evolution exhibited by Hominoidea and Cercopithecinae. On the other hand, the smaller scale effect of size on brain shape of Strepsirrhini and Platyrrhini might have had a key role in their reduced evolutionary rates.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

COSPLAY FOR SCIENCE: UTILIZING POP CULTURE NARRATIVES AS A MEANS FOR SCIENCE EDUCATION OUTSIDE TRADITIONAL LEARNING CENTERS

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The intersection of popular culture and science is often not considered by the general public, yet narratives produced by popular culture have been an incredibly effective avenue when introducing scientific concepts into general knowledge. Multimedia franchises like the Jurassic Park series, Walking With Dinosaurs, and Arc: Survival Evolved have exposed audiences to palatable paleontological concepts and have brought dinosaur taxa into common vernacular. While not often accurate in portrayals, the scientific concepts introduced through these narratives can be used as starting points for engagement through informal science education with general audiences fostered by their familiarity. Cosplay for Science is a STEAM-powered science communication initiative created to employ well-known pop culture narratives as a means to make science education concepts more relatable and accessible, entice a broader audience, and allow scientists to be more approachable. Through the use of online media and in-person engagements, such as pop-up museums, Cosplay for Science events aim to highlight how science intersects with pop culture in high-traffic spaces not traditionally used for education. Cosplay for Science members aim to benefit from the familiarity and popularity of pop culture franchises with charismatic creatures such as dinosaurs to develop audience's appreciation for paleontology and natural history institutions, and encourage audiences to think critically about science topics in their everyday lives by utilizing these inherent interests in unique delivery methods. Additionally, through the use of qualitative and quantitative surveys with audiences at our in-person engagements, the Cosplay for Science Initiative looks to study how pop culture influences audiences' perceptions of science and develop best practices for utilizing it in science communication and education.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

A PRACTICAL GUIDE TO START A NEW VERTEBRATE FOSSIL PREPARATION LAB

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After field collections and acquisition of specimens, fossil preparation is the crucial next step in the conservation of fossil dedicated to research, collection, exhibition, and education. Proper and safe fossil preparation requires a well-equipped laboratory that is supplied with a variety of mechanical equipment, hand tools, and chemical supplies. Starting a new fossil preparation lab is a challenging task, especially for institutions in which space is limited, and in developing countries with limited budget and without an experienced preparator. In order to facilitate the difficulties associated with planning to start a new lab, we have developed a practical guide with a categorized list of items.

A list containing about 50 basic items was made with the purpose to start a preparation lab for a museum in China in 2011. Over the years, preparation labs were built at three museums, more items were added as projects in the labs expanded and the list became extensive after several revisions. The current list contains over 180 categorized items. Categories include a general lab environment, tools for work stations, safety equipment, matrix removal, acid preparation, molding/casting, and conservation. This list serves as a useful guide to aide in selecting items to start a new lab based on the type of preparation and conservation work performed according to institutional needs.

It is important for an institution to identify the techniques and materials required to prepare different types of fossil specimens and various modes of preservation so that the lab can be equipped accordingly for the tasks at hand. Different tasks require different supplies. For example, if the majority of lab work focuses on manual and mechanical preparation, then the lab should be equipped with items from the 'lab environment', 'work station', 'safety equipment', and 'matrix removal' categories but leave out items from the 'molding/casting' or 'acid preparation' sections. Subcategories are also useful to guide selecting specialized materials and equipment suited for a particular project, such as macro preparation involving large sauropod elements in coarse sandstone which requires air scribes and a high capacity compressor. Micro preparation of small and delicate specimens require a high-powered binocular stereo microscope and a pin vise fitted with a carbide rod. As a different task is assigned, lab personnel can plan a budget to purchase items from the appropriate category. This guide is a practical reference for starting and expanding a vertebrate fossil preparation lab.

Technical Session XII (Friday, October 11, 2019, 11:00 AM)

LONGEVITY AND GROWTH DYNAMICS OF *TRICERATOPS* AS REVEALED BY FEMORAL HISTOLOGY

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The chasmosaurine ceratopsid *Triceratops* underwent dramatic cranial changes through ontogeny, including reorientation of the postorbital horn cores (from caudally to rostrally curved), flattening of initially delta-shaped frill epiossifications, and expansion and fenestration of the parietal-squamosal frill. Studies of postorbital horn core histology reveal bone remodeling and secondary osteon density is positively correlated with cranial changes, providing a means for determining relative maturity and validation of the hypothesized cranial growth trajectory. Due to aggressive remodeling, postorbital horn cores do not preserve an absolute record of ontogenetic maturity. Here we present the results of the first histologic sampling of six *Triceratops* femora associated with cranial material and correlate ontogenetic skull morphologies with absolute individual ages.

The smallest specimen sampled, MOR 2951, is a juvenile with a basal skull length (BSL) of 58.6 cm, caudally curved postorbital horn cores, and a femoral circumference (FC) of approximately 21 cm. This specimen preserves one cyclical growth mark and was approaching the end of its second year at death. One large subadult specimen, MOR 3027, with a BSL of 110 cm and an FC of approximately 49 cm, preserves at least five annuli and dense remodeling. Variation in the extent of remodeling and relative maturity is noted between the histology of more mature specimens. MOR 2982, a specimen with a BSL of 100 cm, subtriangular epiparietals, and a FC of approximately 43 cm, preserves seven to eight annuli and a distinct external fundamental system (EFS). While MOR 2702, a larger individual with procurved horn cores, a BSL of 121 cm, and a FC of 54 cm, preserves at least 11 annuli and no clear EFS. MOR 10843 is the most ontogenetically mature specimen sampled; it has a procurved postorbital horn core, flattened frill epiossificatons, and the large partial femur has a circumference of approximately 49 cm. The MOR 10843 femur preserves dense secondary remodeling and a thick EFS; many erosion rooms throughout the cortex show remodeling was ongoing at death.

This study confirms the utility of cranial morphological features for determining relative maturity in *Triceratops* and demonstrates that body size does not always correlate with absolute age. *Triceratops* lived for at least 11 years, but determining the extent of its lifespan beyond this point may be complicated by dense bone remodeling. Continued histological sampling of additional specimens will further illuminate growth dynamics in *Triceratops*.

Technical Session IX (Thursday, October 10, 2019, 3:00 PM)

THE FIRST KNOWN FOSSIL OF *UMA* DEMONSTRATES EXAPTATION AND ECOLOGICAL EVOLUTION IN A SPECIALIZED CLADE

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Evidence from the fossil record suggests that extant lizard genera of North America (north of Mexico) evolved during the Miocene. Although fossils of Phrynosomatidae (fence lizards, sand lizards, and horned lizards) were previously described, there are no known fossils of the fringe-toed sand lizards (*Uma*). *Uma* are restricted to sand dunes and other desert environments containing fine-grained sand in the extant biota. I describe the first known fossil of *Uma* and refer that fossil to the panstem lineage of *Uma* with a global apomorphy-based diagnosis. The fossil was found in the Miocene strata of the Dove Spring Formation in southern California, dating to 8.77 Ma. The *Uma* fossil is a premaxilla and partially preserves the shape of the shovel-shaped snout of extant *Uma* species, which is used to accelerate sand burial by extant *Uma*. I estimated new divergence times for *Uma* and related phrynosomatid lizards using molecular data and five fossil calibrations, including the new fossil. The new divergence times provide a temporal context for the evolution of *Uma* and for the divergence of *Uma scoparia* from the *Uma notata* complex. The crown clade of *Uma* evolved in the early to middle Miocene, and the west clade of *Uma* evolved in the late Miocene to middle Pliocene. The paleoenvironment of the Dove Spring Formation was semiarid and contained ephemeral streams, but there is no evidence of sand dune deposits in the formation or of fine-grained sand in the strata containing the locality from which the *Uma* fossil was found. In their early history, *Uma* were not restricted to fine-grained sandy habitats but already displayed one of the morphological correlates of living in sand. I recommend exercising caution when using environmental tolerances and morphological features of extant taxa to hypothesize paleoecological reconstructions.

Grant Information:
Geological Society of America (GSA) student grant
Jackson School of Geosciences, University of Texas at Austin

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

INNER EAR ORIENTATION REFLECTS HEAD POSTURE IN THE WOOLLY RHINO (PERISSODACTYLA: RHINOCEROTIDAE)

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During the Pleistocene a climatic fluctuation occurred between colder glacial and warmer interglacial periods in Eurasia. Each period showed distinct floral and faunal elements adapted to the particular climatic conditions. Beside the woolly mammoth, the woolly rhinoceros (*Coelodonta antiquitatis*) was an important member of the Pleistocene herbivore megafauna. Both taxa were adapted to the cold temperatures of the glacial periods. Mummies from Siberia and Ukraine provide an exceptional insight in the paleobiology of the woolly rhino, much better than reconstructions from solely fossil bones. Stomach content and anteriorly abraded nasal horns show feeding preferences on low vegetation. The nasal horns were abraded because they were used to remove the snow cover from low growing plants on the ground. This specific feeding habit targeting low vegetation is also expressed in the natural head posture. The woolly rhino like the modern grazing white rhino from the African continent shows a downward oriented head posture. This is reflected by the backward inclined occipital crest of the skull, which is seen in both the woolly rhino and the extant white rhino.
In this study different skulls of the woolly rhino from different German localities were scanned using micro-computed tomography to reveal the orientation of the bony labyrinth inside the petrosal bone. The endocast of the inner ear was reconstructed digitally to make the position of the semicircular canals visible. As a premise, it is assumed that the lateral semicircular canal is oriented horizontally in the habitual head posture of mammals. The reconstructed lateral semicircular canals of both petrosals of each skull were aligned to a horizontal plane to calculate the habitual head posture using the orientation of the inner ear within the skull. As a result, the skulls of the woolly rhino show a downgrade head posture. This approach was initially tested using extant rhino skulls, resulting in a downgrade head posture for the grazing white rhino. Thus, beside the shape of the occipital region of the skull, the orientation of the inner ear can be used to reconstruct the habitual head posture (and therefore feeding preferences) in fossil (and extant) rhinos.

Grant Information:
This work received support from the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) under grant number SCHE 1882/1-1.

Technical Session XIX (Saturday, October 12, 2019, 3:15 PM)

ANGOLA AND ITS ROLE IN THE PALEOBIOGEOGRAPHY OF GONDWANA

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Tectonic rifting of Africa from South America began by 131 Ma. The rifting of Africa and South America allowed communication of flood plain and terrestrial biota, including fish, crocodylians, and piscivorous dinosaurs between what is now Africa and South America during the Early Cretaceous. Marine flooding and more open ocean conditions were initiated in the central South Atlantic by the late Aptian (113 Ma), interrupting the terrestrial biome. With the opening of the Equatorial Atlantic Gateway by 90 Ma (Turonian), bottom water flowed north to cool global oceans. Mosasaurs entered the central South Atlantic from the northern Tethyan Biogeographic Province and plesiosaurs entered from the southern Weddellian Province.
Our excavations in Angola, ongoing for almost 15 years now, have documented these developments, and show that coastal upwelling traced along the southwestern continental margin as Africa drifted north during the Late Cretaceous and Cenozoic. The Cretaceous rich upwelling ecosystem along what is now Angola gave way, following the Cretaceous-Paleogene extinction event, to a Cenozoic upwelling system increasingly centered on modern day Namibia, which became fully established, apparently with the parameters now observed, in the Late Miocene around 10 Ma. Marine turtles are the only amniotes to inhabit both the Cretaceous and Cenozoic phases of this upwelling ecosystem.
Northward drift of Africa that shifted the position of upwelling along the African coast concomitantly also shifted the position of the associated hyperarid coastal desert that now is the refugium for the enigmatic gnetalian plant Welwitschia. The paleogeographic position of southern Africa since the Miocene established the modern environmental conditions of the Namibian Desert and Benguela Current, and induced development of the hyperdiverse Cape Flora and related biological hotspots in southern Africa.

Technical Session VIII (Thursday, October 10, 2019, 2:45 PM)

NEW INSIGHTS INTO FEEDING PERFORMANCE OF THE VIRGINIA OPOSSUM (*DIDELPHIS VIRGINIANA*) AND IMPLICATIONS FOR THE EVOLUTION OF MAMMALIAFORM MASTICATION

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Fundamental transformations of feeding system, especially jaws and teeth, occurred in early evolution of mammals. Feeding behavior and masticatory function correlate with occlusal patterns. By applying 3D analytical methods and kinematic simulations of the feeding function in modern mammals, we aim to shed light on the masticatory behaviors in early fossil mammals and their relatives. We seek to understand the evolutionary transition of the feeding system by combining classic tooth wear analysis and X-ray Reconstruction of Moving Morphology (XROMM). XROMM visualizes *in vivo* skeletal movements of a feeding animal by aligning CT-based 3D models of the bones with kinematic data of the same individual from biplanar x-ray videofluoroscopy. This creates highly accurate animations of the jaws moving in 3D space. Feeding bouts of *Didelphis virginiana* (n=2, male and female) were recorded during a three month period. Animals were provided a range of food items ranging in material properties with added controlled abrasives (pumice consisting of amorphous aluminum silicate was added to simulate grit). Changes in the tooth wear pattern were recorded by casting the cheek teeth of each animal in regular intervals (every two weeks). Preliminary results show strong dependency in chewing behavior based on food properties. While soft food was directly triggering cyclical chewing movements, hard to brittle food required initial food break down reflected by short intervals of fast opening and closing of the lower jaw without direct tooth contact prior to the cyclical chewing. Food of intermediate hardness required longer periods of cyclical processing compared to the other two types of food. We recorded independent movement of each hemimandible including rotation along the long axis and jaw, which is made possible by the highly mobile symphysis. The movements recorded for *Didelphis virginiana* revealed that differences in food hardness appeared to be correlated with

differences in biting and masticatory behavior. This new observation can be useful for understanding the dietary differences within mammaliaforms. The mammal molar wear patterns are distinct and directly related to food mastication, the chewing movements calculated from occlusal fingerprint analyses of a variety of mammaliaforms can now be tested by XROMM examination of extant mammals.

Grant Information:
JAS was supported by a two year DAAD (German Academic Exchange Service, Project 57073880) scholarship during the research.

Technical Session VII (Thursday, October 10, 2019, 8:00 AM)

BACK TO THE SEA – ADAPTATIONS OF THE TYMPANIC SYSTEM IN THALATTOSUCHIAN CROCODYLOMORPHS

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Cranial sensory organs are a powerful ecological proxy, and give unique insights into ancient animal behaviour and lifestyles. One of those sensory organs is the otic region, comprising the inner and middle ear, as well as the tympanic air space. The inner ear includes the membranous and the bony labyrinth, and besides its involvement in hearing, it is also involved in for equilibrium and head stabilisation. Such sensory organs also played a key role in major evolutionary and environmental transitions within vertebrates. We here study one group, thalattosuchian crocodylomorphs, that underwent a major transition, evolving from terrestrial ancestors into pelagic marine species during the Jurassic. Their osteological changes are well known, such as their development of paddle-shaped limbs, loss of osteoderms, and a vertically orientated tail fluke. However, little is known about how their neurosensory systems changed during that transition.
Using µCT scans we digitally segmented the endosseous labyrinth of a broad sample of taxa including eleven extant species, six thalattosuchians, *Eopneumatosuchus colberti*, and two non-crocodyliform crocodylomorphs.
Basal thalattosuchians, such as the basal metriorhynchoid *Pelagosaurus typus* and teleosaurids, have 'M'-shaped semi-circular canals and reduced canal curvature. The 'M'-shaped canals hint that thalattosuchians retained the basal crocodylomorph condition, as this shape is present in *E. colberti* and non-crocodyliform crocodylomorphs, but absent in extant crocodylians or derived metriorhynchids. The metriorhynchids '*Metriorhynchus' brachyrhynchus*, *Cricosaurus schroederi* and *Cricosaurus araucanensis* however, have dorsoventrally shortened anterior and posterior semicircular canals as well as increased canal diameters. Furthermore, they have a shortened cochlear duct possibly related to reduced role for hearing of airborne sound. This difference may be explained by the different lifestyles of these animals: semi-aquatic in basal thalattosuchians, and pelagic marine in derived metriorhynchids. This parallels the trends seen in marine turtles and sauropterygians, suggesting a common pathway for pelagic reptiles to adapt to marine life and a strong correlation between aquatic lifestyle and semicircular canal morphology.

Grant Information:
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Technical Session V (Wednesday, October 9, 2019, 2:30 PM)

MEDICAL CT REVEALS THE OLDEST, SMALLEST, AND PHYLOGENETICALLY MOST BASAL PELAGORNITHID (AVES: ODONTOPTERYGIFORMES), FROM THE EARLY PALEOCENE OF NEW ZEALAND.

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Although huge advances have been made in the last 20 years in the use of computed tomography (CT) in paleontology, the majority of recent studies use specialist micro-CT (µCT) technology. Here we show how the use of advanced medical CT using dual energy can (in some cases) allow the characterisation and description of fossils better than using specialist µCT. In this study we scanned and segmented a partial skeleton of a small-sized pelagornithid bird from the early Paleocene of New Zealand. The new taxon investigated was in a pyrite-rich glauconitic greensand that did not allow successful imaging using µCT. By using a medical Siemens Dual Energy CTSOMATOM Definition scanner a high quality scan free of metallic x-ray artefacts was produced. Thus we were able to describe and characterise the oldest record of the Pelagornithidae globally, the smallest known species, and the first pre-Eocene pelagornithid from the Southern Hemisphere. The skull of the new species exhibits the characteristic pelagornithid morphology, but the postcranial skeleton distinctly differs from other pelagornithids and various plesiomorphic features indicate that it is the earliest-diverging representative of the Pelagornithidae. The much stouter humerus suggests that the new species was less adapted to sustained soaring than previously known pelagornithids. Pseudoteeth therefore evolved before pelagornithids became highly specialized gliders. The new species furthermore suggests that pelagornithids evolved in the Southern Hemisphere and documents a very early radiation of neornithine seabirds, which may have been triggered by changes in marine ecosystems at the end of the Mesozoic.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

NORTHERNMOST RECORD OF LANCIAN (LATEST CRETACEOUS) MAMMALS

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Mammals of Late Cretaceous (Aquilan–Lancian) age are well known from western Canada, and provide an important record of mammalian evolution throughout a substantial part of the Late Cretaceous. When placed in the larger context of vertebrate faunas, they provide a better understanding of how vertebrate communities responded to a dynamic period in Earth history. We report here on a new locality in western Alberta, 80 km north of the hamlet of Grande Cache, that preserves the remains of mammals and other vertebrates. The locality occurs at a cutbank of the Kakwa River, where rocks of the Upper Cretaceous Coalspur Formation are exposed. Exposed bedrock consists of ripple-laminated and cross-bedded fine-grained sandstones, organic rich mudstones, shales, and sub-bituminous coals containing thin bentonites, as well as pockets of fossil mollusks, coalified wood, and leaf fragments, all suggestive of deposition in an ancient alluvial wetland. The vertebrate fauna is dominated by scales, teeth, and bones of bony fish, but also includes rare lizard and theropod dinosaur teeth, as well as those of several mammalian taxa. Two multituberculates have been identified (*Mesodma* cf. *M. hensleighi*, and a probable cimolomyid), as well as three marsupials (*Protolambda* cf. *P. florencae*, *Pediomys* cf. *P. elegans*, and a new pediomyid), and one eutherian (*Gypsonictops* cf. *G. illuminatus*). Although presently small, the mammalian fauna is nonetheless most consistent with those from Lancian localities at more southern latitudes in the North American Western Interior. A palynomorph sample from immediately above the vertebrate horizon preserves an assemblage that is likely correlative with the *Triprojectus quadricretaeus–Bratzevaea amurensis* Biozone immediately preceding the K-Pg boundary, a result that is congruent with the mammalian evidence. The new locality occurs some 280 km north of the KUA-1 locality in south central Alberta, and at nearly 55 degrees latitude—with a projected paleolatitude of approximately 62 degrees—documents the northernmost occurrence of Lancian mammals to date. Given the paucity of Lancian faunas in western Canada, the new locality is a welcome addition to the record of Late Cretaceous mammals. Its high latitude and stratigraphic proximity to the K-Pg boundary offer a unique perspective on mammalian and other vertebrate assemblages just prior to the end-Cretaceous extinction event.

Technical Session IV (Wednesday, October 9, 2019, 3:30 PM)

COMPLEXITY OF THE LOWER MOLAR ROW IS EXPLAINED BY THE INHIBITORY CASCADE MODEL AND DIET WITHIN EUARCHONTA

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The inhibitory cascade model (ICM) postulates that molar morphogenesis in mammals follows a ratcheting pattern, with the development of M1 inhibiting

that of M2, and that of M2 inhibiting M3. It is currently unknown if the development of molar complexity in euarchontans follows the ICM, and how inhibition affects euarchontans with different diets. The ICM predicts that M3/M1 complexity regressed on that of M2/M1 should result in a linear regression with a slope of 2.0 and an intercept of -1.0. Previous work has shown that high molar complexity provides a functional advantage for folivores and insectivores; such taxa are predicted to show a linear increase in complexity moving distally among molars as inhibition should be weak. Frugivores are predicted to show the opposite pattern, with a decrease in complexity moving distally, as high complexity is not as necessary to process less mechanically challenging food.
We measured Orientation Patch Count Rotated and surface area of the lower M1, M2, and M3 from micro-CT data for a sample of frugivores (e.g., *Macaca fascicularis*, *Cheirogaleus major*, *Cebus capucinus*, *Ateles geoffroyi*), insectivores (e.g., *Ptilocercus lowii*, *Carlito syrichta*), and folivores (e.g., *Galeopterus variegatus*, *Propithecus verreauxi*, *Alouatta palliata*). We used reduced major axis (RMA) regression to test if molar complexity follows the predictions of the ICM.
The slope and intercept predicted by the model lie within the 95% confidence interval of the RMA analysis, and the relationship between M3/M1 and M2/M1 complexity is significant ($p = 0.006$). Moreover, patterns differ based on diet. The frugivores show high inhibition of complexity in the molar row, while the folivores and insectivores show low inhibition and a linear increase in complexity from M1 to M3. These patterns are independent of molar size, as mean M3 surface area is lowest in the molar row for each dietary guild.
The development of molar complexity is in part controlled by the sonic hedgehog pathway, which affects the cascading pattern of molar size. This pathway, as well as others, may provide a mechanism for the selection of molar complexity within different dietary guilds. Our findings suggest a simple rule of inhibitory dynamics may control the evolution/ development of molar complexity in Euarchonta, where selection needs only act upon the complexity of M1 to change that of distal molars. This model may therefore provide a framework to understand fundamental shifts in molar morphology in euarchontan evolution, which may be more broadly applicable in Mammalia.

Grant Information:
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Technical Session VII (Thursday, October 10, 2019, 9:30 AM)

AN AGILE UNARMORED NOTOSUCHIAN FROM CENOMANIAN-AGE ROCKS IN NIGER INITIATE THE PARTITIONING OF THE GONDWANAN PLEXUS OF *ARARIPESUCHUS* SPECIES

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A new slender-limbed notosuchian is described from Cenomanian-age rocks in Niger. The single, and only known, adult specimen preserves in articulation the cranium and lower jaw, the axial column to the mid dorsal vertebrae, and the pectoral girdle and most of the forelimb. More posterior portions of the axial column including sacral and caudal vertebrae and portions of the the pelvic girdle and both hind limbs suggest that the skeleton was very complete and articulated when originally buried. However, not a single osteoderm is preserved, and the cranium, furthermore, lacks the pitted texturing that characterizes nearly all other crocodylomorphs. The new taxon is allied with *Araripesuchus tsangatsangana* from Madagascar, and has the same paleogeographic link to Madagascar as its contemporary, the fanged *Kaproscuhus*. The Malagasy araripesuchid, furthermore, also shows little evidence of dorsal osteoderms, despite the recovery of multiple, semi-articulated specimens from a single locality as well as the presence *in* the same formation of *Simosuchus* with its extraordinary osteoderm sheathing. We reconstruct the new species as one of the most erect, long-limbed notosuchians of all, a striking departure from the previous reconstruction of *A. tsangatsangana* as semi-erect with a full compliment of parasagittal dorsal osteoderms. The new species, as well as additional remains of the older *A. wegneri* from Niger, provide new evidence to tease apart the paraphyletic assemblage of Gondwanan species currently assigned to *Araripesuchus*.

Technical Session VII (Thursday, October 10, 2019, 10:15 AM)

LARGE NUTRIENT FORAMINA IN FOSSIL FEMORA INDICATE INTENSE LOCOMOTOR AND METABOLIC ACTIVITY IN TRIASSIC ARCHOSAUROMORPHS AND THE PSEUDOSUCHIAN LINEAGE

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The size of the principal nutrient foramen on long bones can indicate the size of the nutrient artery and hence an index of blood flow rate (Qi) to the bone shaft. Because blood flow is essential for bone remodelling to repair micro-fractures caused by locomotion, the foramen size and Qi are functionally related to the level of locomotion. In extant mammals, for example, Qi increases with body mass with an exponent of 0.86, which is almost indistinguishable from the exponent (0.87) for exercise-induced maximum aerobic metabolic rate. Extant non-avian reptiles, which generally do not remodel their long bones, have Qi values about 10 times lower than mammals, and considering their low blood pressure, bone perfusion is about 50 times lower. Extant bipedal cursorial birds have Qi values that also scale with body mass to the 0.89 power, but are almost twice the values for cursorial quadrupedal mammals, because bipeds place about twice the stress on their femora, compared to quadrupeds. These results for living animals show how the size of the nutrient foramen relates to intensity of locomotion.
Nutrient foramina on well-preserved fossil femora can be photographed, measured and compared to data from living species. We searched world collections and sampled about 200 fossil femora with preserved foramina. The present study is based on 34 specimens of Triassic, non-archosaurian archosauromorphs and pseudosuchians, dating from 250 Mya to 48 Mya. The Qi values for these animals are not significantly different from extant mammals and birds, and reveal a similar scaling exponent of 0.90. They are significantly above the Qi data for extant non-avian reptiles, which are ectothermic and rely extensively on anaerobic metabolism during brief bouts of intense activity. These results support the hypothesis that the crocodylian lineage of archosaurs were originally highly active animals, relying on aerobic metabolism for sustained locomotion. They required high rates of blood flow to all parts of the body, including the bones. These results complement the cardiovascular evidence of a previously enigmatic, 4-chambered heart in extant ectothermic crocodiles. A completely divided heart is essential for high aerobic metabolic rates in birds and mammals to separate systemic and pulmonary blood pressures and pump oxygenated blood at high rates to the tissues. As a result, this evidence bolsters the idea that the heart morphology in extant crocodiles is a retention of an ancestral trait that no longer functions to support endothermy.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

RECORDS OF VERTEBRATE REMAINS FROM THE LATE TRIASSIC TIKI FORMATION, MADHYA PRADESH, INDIA: IMPLICATIONS ON GONDWANA PALEOBIOGEOGRAPHY

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The Tiki Formation is well known for its rich vertebrate fossils of Late Triassic (Carnian) age. The sanstone, siltstone and mudstone sequence of Tiki Formation, representing as a significant lithostratigraphic unit of the South Rewa Gondwana Basin of India, is equally important for paleobiogeographic reconstruction of Supercontinent Pangea. The recent field work carried out at Tiki Formation during 2016-2018 could recovered certain mega-vertebrate remains comprising of rhynchosaurid *Paradapedon*, phytosaurid *Parasuchus*, rauisuchuid *Tikisuchus,* etc.; numerous microvertebrates represented by advanced cynodont *Rewaconodon*, the fish remains of elasmobranch sharks such as *Xenacanthus* xenacanthids *Mooreodontus indicus and Mooreodontus jaini* and *Hybodus* hybodonts *Lonchidon estesi, L. incumbens, Lissodus duffini and Parvodus tikiensis* as well as dipnonian fish *Ceratodus* sp;

reptilian fossil of Sphenodontidae (Rhynchocephalia), basal mammaliforms such as *Gondwanadon, Tikitherium*; remains of Anurans, Eodiscoglossus sp. and unidentified teeth and scale of actinopterigian fishes, etc. The majority of the microfossils of the lower Tiki section are suggesting of the fluvio-lacustrine condition in which the terrestrial and fluvio-lacustrian fauna are part of higher-level food chain system. These diverse fauna are also corroborating well with the global increase in biodiversity during the Late Triassic time. The present study also gives the global paleobiogeographic scenario of Late Triassic time which is well supported by closely correlatable Late Triassic taxa in different continents which might have served a relatively rapid intercontinent passage of the vertebrate community extending across the ancient Supercontinent, Pangea.

Grant Information:
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Technical Session XVIII (Saturday, October 12, 2019, 3:15 PM)

HIGH LOCOMOTOR DIVERSITY IN EARLY PALEOGENE MAMMALS PROVIDES ECOMORPHOLOGICAL INSIGHT INTO EVOLUTION FOLLOWING THE END-CRETACEOUS MASS EXTINCTION.

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The Paleogene followed a catastrophic mass extinction and the abolition of complex ecosystems dominated by non-avian dinosaurs and heralded the Age of Mammals. The Paleogene mammal fauna is perceived from two standpoints: on the one hand, it is a classic adaptive radiation marked by the proliferation of eutherian mammals, more ‘advanced’ than their Mesozoic ancestors; on the other, Paleogene taxa are considered ‘archaic’ compared with their extant relations. Seldom are Paleogene taxa considered for their own objective merit. Here, we investigate the locomotor behaviors of Paleogene mammals using a suite of multivariate and statistical analyses.
We compiled a dataset of 29 tarsal measurements for 36 Paleogene taxa alongside a sample of 69 extant therian mammals of known locomotor mode and five Mesozoic cladotherians. Functional indices of the skeleton show Paleogene taxa to be significantly more robust than extant and Mesozoic species. A linear discriminant analysis classified the locomotor mode of 88.41% of extant species correctly. All Mesozoic taxa were classified as arboreal and a plurality of the Paleogene species (16/36) were classified as semi-fossorial. Principal Components Analysis show Paleogene taxa to exhibit a range of body sizes and morphologies related to a variety of locomotor behaviors. Statistical tests of morphospace separation demonstrate that Paleogene taxa are significantly separated from the extant and Mesozoic ones. Sum of range disparity metrics show that Paleogene taxa occupy a smaller area of morphospace compared to extant species. However, when accounting for sample size, a permutation test finds that the difference is not statistically significant. When morphospace occupation is quantified using sum of variance disparity to describe dissimilarity within groups relative to their mean, Paleogene taxa exhibit greater disparity than both the extant and Mesozoic mammals, although it is non-significant.
Our results show that Paleogene mammals are significantly different from extant mammals in their tarsal morphology and locomotor behavior, thus indicating ecomorphological diversity that is not directly comparable to extant mammals. Far from being a generalized ancestral stock for extant mammal orders, Paleogene mammals were experimenting with their own unique robust anatomies and locomotor behaviors combining a basic placental bauplan with numerous inimitable specializations in their anatomy that exemplify the ability of mammals to adapt and evolve following catastrophic environmental upheaval.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

THE BODY SIZE OF MEGATOOTHED SHARK, *OTODUS MEGALODON* (LAMNIFORMES: OTODONTIDAE), REVISITED

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Otodus megalodon (Lamniformes: Otodontidae) is a late Neogene shark often regarded as the largest marine macropredator to have ever lived. Its estimated total lengths (TL) in scientific literature using the extant white shark, *Carcharodon carcharias*, as a model have ranged up to ca. 30 m, although a commonly cited maximum TL in recent scientific literature is 18 m. I re-examined the previously published quantitative relationships between TL (in cm) and crown height (CH: in mm) of each anterior tooth in *C. carcharias*. I attained a linear regression equation combining the upper first and second anterior teeth (TL=11.788·CH+2.143; r^2=0.983) and another combining the lower first and second anterior teeth (TL=14.060·CH–3.914; r^2=0.930). My study suggests that either of the upper anterior teeth or both combined would yield similar TL estimations, but estimations based on lower anterior teeth are rather variable. Thus, the use of upper anterior teeth is much preferred over lower anterior teeth when estimating TL, not only for *O. megalodon*, but also extinct *Carcharodon*, such as *C. hastalis*, *C. hubbelli*, and fossil *C. carcharias*. An upper tooth of *O. megalodon* with the tallest CH (120 mm) that I am aware of in museums is NSM PV-19896 (National Museum of Nature and Science, Japan), although its total tooth height (TH: 149 mm) is smaller than FMNH PF 11306 (Field Museum of Natural History, U.S.A. ; 117 mm CH), a tooth of *O. megalodon* with the tallest TH in museum collections (162 mm TH; previously reported erroneously as "PF 1168" and "168 mm"). If the 120-mm CH of NSM PV-19896 and the above equation based on upper anterior teeth are used, the estimated TL is 1,417 cm TL. If the 162-mm TH of FMNH PF 11306 is applied to a previously published TH-TL linear function, it yields 1,533 cm TL. Anecdotal accounts indicate that teeth of *O. megalodon* may reach up to ca. 20 cm TH and 15 cm CH, that would yield ca. 18 m TL. However, at present, the verifiable maximum TL estimates of *O. megalodon* (i.e., scientifically repeatable and justifiable account based on museum specimens) are 14.2–15.3 m TL. Regardless, individuals of *O. megalodon* exceeding 15 m TL were likely exceptionally rare.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

CHALLENGES IN THE FIELD: COLLECTING WET VERTEBRATE FOSSILS WITH THE APPLICATION OF ACRYSOL WS24, ACRYLOID B72, AND CYANOACRYLATE CONSOLIDANTS

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Recent field excavations of wet vertebrate fossils (dinosaur, turtle, fish) in groundwater saturated, clay-rich sediments from the Chronister Dinosaur Site in southeastern Missouri, U.S.A. , presented unique excavation challenges, but provided great opportunities to apply various consolidation methods in wet sediment conditions. Originally discovered in 1942, the first fossils recorded from this site belong to the iguanodontian *Hypsibema missouriense*. Since its initial discovery, the site was purchased for science by Bruce Stinchcombe and has been periodically excavated with efforts led by Guy and Doris Darrough. A large greenhouse currently protects the site from collecting rainwater and against vandalism. Over the past three years, field crews from the Field Museum of Natural History have carried out systematic paleontological excavations with assistance from the Darroughs and other local volunteers.
The fossil elements are preserved in various states, ranging from almost pristine to dorso-ventrally crushed and plastically deformed. Due to the near permanently wet conditions of unlithified sediments, much of the in-situ fossil material is soft and porous, making excavation and collection of the fossils challenging. Separation of matrix from bone in the field was difficult and frequently resulted in the ‘peeling off’ of cortical bone, exposing trabecular bone or the medullary cavity and damaging internal structures. Air drying the fossiliferous clays prior to excavation proved impractical and potentially harmful to the fossils due to formation of large desiccation cracks, necessitating excavation in wet sediments. Applying a variety of consolidants was necessary to protect fragile specimens. The application of 10% Acrysol WS24 (WS24) was preferred over 10% Acryloid B72 (B72) on matrix at the Chronister Site. WS24 penetrated deeper into the matrix and the adjacent bone and solidified harder, providing better stabilization for the fossils. B72 dried quicker, but penetrated poorly, and left a white film on glued surfaces. B72 proved effective in filling porous bones. The use of 50% B72 solutions, typically used as a temporary glue in 'dry' field sites and in the lab, was ineffective for wet specimens. Instead, cyanoacrylate worked well on moist surfaces and nearly disintegrated fossils. When applied one at a time, no negative interaction between the three consolidants was observed. Applying a combination of these types of consolidants has proved to be effective and is necessary when collecting specimens from water saturated sediments.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

DOUBLE-SCANNING AND GAUSSIAN BLURRING IMPROVE QUALITY OF PALEONTOLOGICAL CT DATA: EXPERIMENTS WITH TWO MAMMOTH TUSKS

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High-resolution computed tomography (CT) provides paleontologists access to information about specimens that was unattainable until recently. Because fossils consist primarily of mineralized hard parts of ancient organisms, often in a rock matrix, paleontological scanning requires high X-ray energies, which tend to decrease contrast in the resulting scans. Therefore, reduction in noise and enhancement of features is critical for paleontological CT applications. The simplest means of reducing noise is by averaging data from consecutive slices in a CT image stack. More control of this type of combination is possible with a blur function in three dimensions, which permits different weighting of data averaged from nearby voxels in different dimensions, rather than an unweighted average between consecutive slices. Applying a Gaussian blur to our scans altered the original data, but permitted recovery of information on features that were otherwise easily misidentified, unidentifiable, or unmeasurable. We measured annual increments of tusk dentin on a mammoth from Maly Lyakhovsky Island, in the Siberian Arctic, using the modified data to recognize life history patterns that were indecipherable in the noisier raw data. We attempted a second method of feature enhancement in the tusk of Yuka, a juvenile mammoth from the northern coast of Yakutia. By scanning the same tusk twice and adding the scans together, we were able to suppress some noise and known artifacts of reconstruction without losing resolution or otherwise compromising the data, revealing measurable growth features within the tusk that were obscured by noise and artifacts in the unmodified data. This methodology may further enhance features by combining scans taken at different X-ray energies to distinguish nearly identically radiodense materials from one another based on differential absorption of radiation related to density and atomic number. Controlled 3-dimensional blurs and double-scanning have merit beyond the realm of Quaternary mammoth tusks, and may be instrumental in clarifying features of older fossils with more extensive diagenetic alteration.

Technical Session XV (Saturday, October 12, 2019, 9:30 AM)

VERTEBRATE PALEONTOLOGY OF THE LOWER TRIASSIC FREMOUW FORMATION IN THE SHACKLETON GLACIER AREA (ANTARCTICA)

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Rocks of the Transantarctic Mountains exposed in the area of the Shackleton Glacier were first investigated by vertebrate paleontologists during the 1970–1971 austral summer. Tetrapod fossils (e.g., *Lystrosaurus*, *Procolophon*, and *Thrinaxodon*) collected from the lower member of the Fremouw Formation were a critical link to coeval assemblages from the Karoo Basin of South Africa and elsewhere and provided compelling evidence that Antarctica once formed part of Pangea. Historic localities such as Halfmoon Bluff, Kitching Ridge, Shenk Peak, and *Thrinaxodon* Col provided the bulk of the geological and paleontological information about the Lower Triassic of Antarctica, but have received little attention since their initial discovery almost 50 years ago. In 2017, we conducted four weeks of helicopter-assisted fieldwork in the Shackleton Glacier area, which led to more precise geographical and geological data for old quarries as well as the discovery of new fossil localities that yielded well over 200 specimens.

Newly measured stratigraphic sections suggest that vertebrate fossils of the lower Fremouw Formation primarily occur in crevasse splay deposits, characteristic of a meandering fluvial environment. The wackestone subunits contain abundant siliceous root traces and relict ripple cross laminations, suggesting early phases of soil development on the floodplain (i.e., Protosol). Isolated bones often occur in intraformational conglomerates, especially near the base of the formation, interbedded with large channel-fill trough cross-bedded sandstones. Footprints and trackways were rarely encountered in floodplain deposits, but large diameter sand-filled burrow casts (14 cm across) were occasionally locally abundant. Vertebrate fossils include isolated elements and partially articulated individuals preserving remarkable detail. Importantly, we collected the first diagnostic tetrapod material from the middle member of the Fremouw Formation. Although preparation is ongoing, our initial identifications suggest that both the lower and middle members are likely Lower Triassic, indicating broad-scale correlation to the Katberg Formation of South Africa. Interestingly, small temnospondyls are an important component of the middle Fremouw assemblage and likely represent a species allied with *Lapillopsis* from the Lower Triassic Arcadia Formation of Australia.

Grant Information:
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Technical Session XIX (Saturday, October 12, 2019, 1:45 PM)

REPTILE MACROEVOLUTIONARY DYNAMICS ACROSS THE PERMIAN-TRIASSIC MASS EXTINCTION AND THE EMERGENCE OF NEW BODY PLANS

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Mass extinctions are unique periods in the history of life, capable of replacing entire faunas by new emerging evolutionary lineages and resetting ecological niche structure. Importantly, mass extinctions provide natural experiments to understand how fast environmental shifts may cause substantial changes on the diversity of phenotypic traits (morphological disparity) and the speed of evolutionary change, besides indicating how long it takes for lineages to recover from global level climatic disruptions. However, few studies have assessed large-scale dynamics of trait evolution among terrestrial vertebrates, and even fewer among reptiles, during the largest mass extinction in the history of complex life: the Permian-Triassic Mass extinction (PTME). Here, we utilize morphological and molecular data sampled across various families of squamates (lizards and snakes), along with morphological data from several early diverging diapsid reptiles to assess the rates of morphological and molecular evolution in reptiles, with special focus on those parameters across the PTME. We implement relaxed clock Bayesian inference analyses using total evidence dating and corrections for deep root attraction, establishing new and more precise estimates for the origin of the major lineages of diapsid reptiles. Our results indicate a considerable decrease in morphological disparity in the Early Triassic following PTME, but a quick recovery to pre-extinction levels by the Middle Triassic. We also find increasingly high rates of morphological evolution during the Early Triassic, supporting a model of fast adaptive radiation and occupation of new ecological niches following the aftermath of the Permian Mass extinction. Average rates subsequently stabilize during the Middle Triassic, but at relatively high levels, indicating the adaptive radiation event was still ongoing during the Middle Triassic, although some few lineages already reached more neutral levels of evolutionary rates. We also find that the origin of new and extreme body plans is marked by the highest rates of morphological evolution in the history of reptiles. In contrast, molecular rates of evolution present greater stability and more moderate values throughout most of reptile evolution. Our interpretations of the later are limited by the number of sampled loci, but lends support to previous studies indicating that great morphological changes, and possibly the origin of new body plans, are the result of the release of cryptic genetic variation instead of a large number of de novo mutations.

Grant Information:
Alexander Agassiz Postdoctoral Fellowship [to TS]

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

ADDITIONAL FOSSILS REMAINS FROM THE HOMINOID BEARING LATE MIOCENE TAPPAR LOCALITY OF KUTCH, INDIA: IMPLICATION ON PALEOENVIRONMENT

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The Tappar locality of Late Miocene, Kutch, India is well known for its fossil mammalian remains. However, the microfossils are very rare in the area. During the year 2018-2019 field work, various invertebrates, microflora and microfauna were recovered from the Tappar section of Chhasra Formation. We here report a list of invertebrate and micro vertebrate fossils such as gastropods (*Viviparus* indet.), bivalves (*Lamellidens* indet), charophytes (*Chara glubularis* cf. *aspera*, *C. globularis* cf. *globularis*, *C.* sp. indet. and *Nitellopsis (Tectochara) meriani*, teleost fish (cyprinids, bagrids, clariids, silurids and channids), chondrichthyes (*Dasyatis rugosa, Dasyatis probsti*, *Himantura* sp. and *Pristis* sp.) and small colubrine snake (*Chotaophis padhriensis*). The─occurrences of fossil molluscs, charophytes, teleost, chondrichthyes and colubrine snake from the late Miocene deposit of Tappar, Chhasra Formation, Kutch, Gujarat suggests the presence of fresh to slightly brackish water environment under tropical to temperate humid conditions during the Late Miocene (~11-10 Ma). This is also corroborated by a rich mammalian and reptilian fauna comprising elephants, rhinos, giraffids, equuids, suids, crocodiles and turtles found associated with the present species at Tappar.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 9:45 AM)

TROPHIC MORPHOLOGY REVEALS THE ECOLOGICAL DYNAMICS OF EARLY MESOZOIC HERBIVORES.

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Terrestrial ecosystems underwent significant remodelling during the Late Triassic via faunal and floral turnovers that established many of the structural elements found in modern ecosystems. Paleozoic 'holdovers' such as the procolophonid parareptiles and dicynodont therapsids were superseded by new archosauromorph and mammalian clades. Recent stratigraphic revision has highlighted the potential role of the Carnian Pluvial Event (CPE) in spurring this turnover, focusing attention on the environmental changes and functional diversity of Late Triassic ecosystems. In order to investigate the impact of this event I chart the evolution of key herbivorous tetrapod groups through the Triassic and Early Jurassic. Herbivores acutely reflect their environments, often acting as the first animal links in most terrestrial food webs. Consequently, they can act as indicators of wider eco-environmental changes. This study of herbivore macroevolution uses geometric morphometric methods and biomechanical characters derived from the mandibular, feeding morphology of >130 synapsid, saurian, and parareptile genera. Using mandibular ecomorphology as an indicator of dietary ecology, I assess the impacts of ecological and environmental dynamics through this interval. My results show a strong relationship between mandibular form and function within terrestrial herbivores. The clear morpho-functional concurrence allows me to dissect the morpho-functional variation of Triassic herbivores, and identify their different dietary strategies. Multivariate statistical analyses reveal significant differences in jaw morphology that suggest niche partitioning within the herbivore guild. Furthermore, morphospace and functional space occupation through time illustrates how divergent feeding ecologies may have acted in concert with the environmental changes in the Late Triassic to drive faunal evolution and the decline of key clades such as the dicynodonts and gomphodont cynodonts, and even the success of the archosaurs, particularly dinosaurs through the Triassic-Jurassic boundary. This pattern of niche partitioning and extinction selectivity that suggests intrinsic dissimilarities promoted differential survival, influencing but not driving the Triassic faunal transformation.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

FOSSILS WITH FEATHERS AND PHILOSOPHY OF SCIENCE

SMITH, Adam, Clemson University, Clemson, SC, United States of America; HAVSTAD, Joyce C., Oakland University, Rochester, MI, United States of America

The last half century of paleontological and ornithological research has utterly transformed the ways that biologists perceive the evolutionary history of birds. This metamorphosis has been driven, since 1969, by a series of provacative fossil discoveries combined with intense scientific debate over how best to interpret these discoveries. The ideal scenario with regard to the scientific process is one in which evidence accrues, complementary results accumulate, and interpretive scientific agreement forms. But this has not entirely happened in the debate over avian origins: the accumulation of scientific evidence and analyses has had some effect, but not a conclusive one, in terms of resolving the question of avian origins. Although the majority of biologists have come to accept that birds are dinosaurs, there is lingering and, in some quarters, strident opposition to this view. In order to both understand the ongoing disagreement about avian origins and generate a prediction about the future of the debate, here we use a revised model of scientific practice to assess the current and historical state of play surrounding the topic of bird evolutionary origins. Many scientists are familiar with the meta-scientific scholars Sir Karl Popper and Thomas Kuhn, and these are the primary figures that have been appealed to thus far, in previous attempts to assess the dispute. However, we demonstrate that a variation of Imre Lakatos's model of progressive versus degenerative research programmes provides a novel and productive assessment of the debate. We conclude that a refurbished Lakatosian account both explains the intractability of the dispute and predicts a likely outcome for the debate about avian origins. In short, we offer a meta-scientific tool for rationally assessing competing theories—one that allows researchers involved in seemingly intractable scientific disputes to advance their debates.

Grant Information:
J.C. Meeker Postdoctoral Fellowship (FMNH)
Conceptual Foundations of Science Project (FMNH)
University Research Committee Faculty Research Fellowship (Oakland University)

Technical Session XI (Friday, October 11, 2019, 8:30 AM)

A TAPHONOMIC ANALYSIS OF A LATE PLEISTOCENE FOSSIL ASSEMBLAGE FROM NGALAU GUPIN, SUMATRA.

SMITH, Holly E., Griffith University, Brisbane, Australia; PRICE, Gilbert, University of Queensland, Brisbane, Australia; RIZAL, Yan, Institut Teknologi Bandung, Bandung, Indonesia; ZAIM, Jahdi, Institut Teknologi Bandung, Bandung, Indonesia; PUSPANINGRUM, Mika, Institut Teknologi Bandung, Bandung, Indonesia; ASWAN, -, Institut Teknologi Bandung, Bandung, Indonesia; TRIHASCARYO, Agus, Institut Teknologi Bandung, Bandung, Indonesia; STEWART, Mathew, University of New South Wales, Sydney, Australia; LOUYS, Julien, Griffith University, Brisbane, Australia

Our study highlights the potential for analyses of breccia deposits in anthropological and paleontological studies in the caves of Southeast Asia in the future. Furthermore, our spatial distribution data uncovers evidence of multiple taphonomic agents that could offer a contemporary method of analysis in complex depositional cave environments that has removed all other indication of this activity. We present a taphonomic analysis of fossil material excavated from Ngalau Gupin, a cave located approximately 27.5 km southeast of the village of Sawahlunto in the Padang Highlands of western Sumatra, Indonesia. Extraction of fossils took place from two discrete cemented breccias, NG-A and NG-B, as well as from the unconsolidated cave floor. The cave breccia found in the cave preserved numerous fossil bones and teeth cemented on the cave walls (NISP = 931). The dense nature of the breccia in Ngalau Gupin has preserved tooth crowns of tiny (<1kg) to very large (>180kg) species characteristic of the Late Pleistocene, including *Panthera tigris*, *Pongo pygmeaus*, *Hexaprotodon* and *Hystrix cristata*. In total, 21 species were identified, with over 1400 fossils catalogued in total.
Tomographic imaging is used as a macro-taphonomic approach to determine the alteration processes of the vertebrate bearing breccia deposits from Gnalau Gupin during burial or post-deposition. One block sample was taken from both site NG-A and NG-B and these consolidated samples have been scanned in a neutron imaging station. Examination of the neutron scan images combined with evidence from the faunal analysis indicates that the vertebrate-bearing breccias are heavily altered from their original composition by multiple taphonomic agents. This evidence is critical in evaluating the paleoenvironment and the agents responsible for site formation events. This study highlights the potential of tomographic imaging of incorporated fossils

and clasts within a cave breccia matrix to interpret taphonomic characteristics and infer the complex taphonomic history of incorporated faunal assemblages. These data could strengthen our understanding of the ancient rainforest migrations and occupation by hominids and associated paleofauna.

Technical Session I (Wednesday, October 9, 2019, 9:15 AM)

ENDOCRANIAL MORPHOLOGY AND ENCEPHALIZATION IN THE PROTOCETID CETACEAN *GEORGIACETUS VOGTLENSIS*

SMITH, Kathlyn, Georgia Southern University, Statesboro, GA, United States of America; GEISLER, Jonathan, NYIT College of Osteopathic Medicine, Old Westbury, NY, United States of America; PATEL, Darshini, NYIT College of Osteopathic Medicine, Old Westbury, NY, United States of America

Endocranial morphology provides insight into the biology and behavior of extinct vertebrates. Previous studies have documented drastic changes to the endocranial region of cetaceans, including an increase in encephalization and a reduction or loss of the olfactory tract. Here we investigate this region in the protocetid archaeocete *Georgiacetus vogtlensis* (Mammalia: Cetacea) to provide insight into the evolution of archaeocetes.
A digital endocast of the *Georgiacetus* holotype (GSM 350) was created using computed tomography. The endocast does not preserve subtleties of its external surface, but its overall shape reflects the shape of adnexia, including a posterior rete mirabile. The presence of a rete mirabile is suggested by the fact that the posterior cranial fossa is much wider and dorsoventrally taller than the middle cranial fossa, whereas in extant mammals the cerebellum is either smaller or subequal to the cerebral hemispheres. There is no trace of a falx cerebri; instead, a comparable position is marked by a narrow and tall cast of the dorsal sagittal sinus. Posterior to this sinus is a triangular depression for a median tentorial projection, the only clear demarcation between the middle and posterior cranial fossae. Posterior to this depression the cast of the rete mirabile forms the highest point of the endocast, as in basilosaurids but unlike in *Indocetus* and *Remingtonocetus*. A cross section through the anterior of the endocast is trefoil in shape, with a median dorsal portion corresponding to the olfactory tract and bilateral ventral portions to neurovascular structures. This portion of the endocast is quite large and tubular, as in basilosaurids but unlike the narrow morphology seen in *Remingtonocetus*.
The encephalization quotient (EQ) of *Georgiacetus* was calculated using the equation EQ = brain mass/0.12*body mass$^{0.67}$, a brain mass of 451 g (endocranial volume less retial volume, converted to mass) and a body mass of 672 kg (calculated using a regression equation from a previous study that predicts body mass based on skeletal length for modern cetaceans). The resulting EQ of 0.47 is subject to some uncertainty, but is higher than reported for *Dalanistes*, slightly lower than reported for most basilosaurid archaeocetes, and substantially lower than reported for nearly all modern cetaceans. This supports previous studies that show increased encephalization, a common characteristic of modern cetaceans, did not evolve in archaeocetes.

Technical Session V (Wednesday, October 9, 2019, 3:45 PM)

PHYLOGENETIC RELATIONSHIPS OF SULIDAE (AVES: SULIFORMES) INFERRED FROM EXTERNAL MORPHOLOGICAL CHARACTERS AND CONGRUENCE BETWEEN MORPHOLOGICAL AND MOLECULAR DATASETS

SMITH, Nathan, Natural History Museum of Los Angeles County, Los Angeles, CA, United States of America; WATKINS, Jalesa, Howard University, Washington, DC, United States of America; JAY, Judith, Howard University, Washington, DC, United States of America

Sulidae are a group of seabirds comprised of ten species of gannets and boobies. They were historically classified within the polyphyletic avian order Pelecaniformes, a group notable for long-standing conflicts between molecular and morphological estimates of relationships. Diverse phylogenetic datasets focused on sulid relationships exist for DNA, osteological, and behavioral characters. However, no external morphological (e.g., plumage traits) dataset exists, and no attempt has been made to analyze the varying levels of congruence of these disparate datasets. We present a new dataset of 24 external morphological characters collected for Sulidae and outgroups. The dataset was analyzed using maximum parsimony to infer evolutionary relationships within Sulidae. Our results exhibit some congruence with previous analyses (e.g., monophyly of Sulidae, *Morus*, and a *Sula neubouxii* + *Sula variegata* clade), but differ primarily in: 1) failing to recover *Sula* monophyly; and 2) the position of *Papasula*. The latter result confirms that independent forms of character data (nuclear genes, mitochondrial genes, osteology, external morphology) all differ in the placement of this enigmatic species. Trees inferred from osteological, behavioral, and external morphological datasets show variable congruence and conflict with the molecular topology, cautioning against simplistic arguments regarding "molecules vs. morphology" debates in phylogenetics. Additionally, statistical tests reveal that osteological, behavioral, and external morphological datasets all possess significant phylogenetic signal on the molecular tree, and also do not differ significantly from each other in measures of homoplasy or retained synapomorphy. These results lay the groundwork for more rigorous total evidence analyses of sulid phylogeny incorporating disparate data, and also suggest that the relationships of extinct sulids can be robustly resolved within such a framework. Future work requires a two-fold approach of rigorously assessing hypotheses of primary homology in avian morphological characters, and testing hypotheses of convergence using modern phylogenetic comparative methods.

Grant Information:
NSF OPP-1341475 (NDS); NSF DEB-0808250 (NDS)

Technical Session VI (Thursday, October 10, 2019, 11:00 AM)

WEEKLY-SCALE OXYGEN ISOTOPE MEASUREMENTS IN PRIMATE TEETH REVEAL ANCIENT ENVIRONMENTAL VARIATION

SMITH, Tanya M., Griffith University, Nathan, Australia; GREEN, Daniel R., Forsyth Institute, Cambridge, MA, United States of America; WILLIAMS, Ian S., The Australian National University, Canberra, Australia

Oxygen isotopes in tooth enamel vary with temperature, precipitation, and evaporation cycles during an organism's development, aiding reconstructions of past environments. Enamel is typically sampled by micro-drilling to recover oxygen inputs from food and water consumed during tooth formation. This method has poor spatial resolution, yielding samples that integrate long formation times of unknown chronological age, and therefore limiting the recovery of seasonal environmental patterns from teeth.
To address this dilemma we employ a Sensitive High Resolution Ion Microprobe (SHRIMP SI) to measure oxygen isotope compositions ($\delta^{18}O$) from tooth enamel on a spatial scale of 15 µm, which can be related to daily increments and birth lines to determine formation times and calendar ages. $\delta^{18}O$ values of sheep enamel measured by SHRIMP SI are nearly identical to those from silver phosphate microprecipitation, confirming the fidelity of this approach for enamel bioapatite oxygen recovery. Here we analyze teeth from wild orangutans (*Pongo* sp.) collected over a century ago, and two fossil orangutan teeth from Lida Ajer, Sumatra – the site that yielded the oldest insular Southeast Asian human remains; 63-73 ka. Molars were sectioned and sampled sequentially along the enamel-dentine junction on a spatial scale corresponding to a near-weekly timeframe using secondary-ion mass spectrometry. Standardized $\delta^{18}O$ values were related to temporal records of formation over 3-4 years per tooth.
Oxygen isotope values in wild-shot Bornean and Sumatran orangutan first molars ranged from 11.3 to 19.9 ‰, and 13.4 to 20.4 ‰, respectively. Concurrently forming left and right molars from the same fossil orangutan ranged from 15.4 to 20.1 ‰ and 15.1 to 19.9 ‰, supporting the biogenic fidelity of this paleoclimate record. All teeth showed isotopic variation on a circannual basis, particularly after the animals ceased feeding exclusively on mother's milk.
Enamel is the most chemically resilient tissue in the body, and the recovery of similar $\delta^{18}O$ values from these unburied and fossilized orangutan molars confirms the usefulness of teeth for probing ancient climates. We have demonstrated here and in other studies that isotope variation in fossilised mammalian tooth enamel formed over multiple years is substantial, even in equatorial regions. Future research on slow-growing primate teeth may help to establish conclusively whether environmental variation was a significant force in the evolution and dispersal of the human genus (*Homo*) and our own species 300,000 years ago.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

PALEOCENE AND EARLY EOCENE BIRD ASSEMBLAGES FROM THE SOUTHERN NORTH SEA BASIN

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Numerous bird bones from the Paleocene and early Eocene of the Belgian and Paris basins have been collected by amateur paleontologists. Four bones from the early-middle Selandian of Maret, Belgium are among the earliest

Cenozoic avian remains from Europe and include the oldest temporally well constrained records of the Gastornithidae, as well as tentative records of the paleognathous Lithornithidae and the Ralloidea. Another assemblage from the middle Thanetian of Templeuve, France contains multiple bones of the Lithornithidae as well as a record of the Pelagornithidae. Specimens from the latest Thanetian of Rivecourt-Petit Pâtis, France are tentatively assigned to the Ralloidea and Leptosomiformes. An assemblage of 54 bones from the middle Ypresian of Egem, Belgium represents at least 20 species in more than 11 higher-level taxa. Well-identifiable specimens are assigned to the Odontopterygiformes, Galliformes, Messelornithidae, Apodiformes, Halcyornithidae, Leptosomiformes, and Coraciiformes. Further specimens are tentatively referred to the phaethontiform Prophaethontidae and to the Accipitridae, Masillaraptoridae, and Alcediniformes.
These three-dimensionally preserved fossils provide new data on the osteology of taxa that are otherwise mainly known from compression fossils with crushed bones. They also further knowledge of the composition of early Paleogene avifaunas of the North Sea Basin. Paleocene avifaunas of Europe and North America appear to have had different compositions and only a few taxa, such as the paleognathous Lithornithidae, are known from both continents. This suggests that the very similar early Eocene avifaunas of Europe and North America are the result of early Cenozoic dispersal events. The well-represented small galliform species from Egem most closely resembles *Argillipes aurorum*, an ignored galliform species from the London Clay. The tentatively identified fossils of Accipitridae and Alcediniformes would represent the earliest fossil records of these clades. The birds from Egem include few seabirds (Odontopterygiformes, cf. Prophaethontidae) and is dominated by terrestrial species (Galliformes, Messelornithidae). Arboreal birds (Halcyornithidae, Leptosomiformes, cf. Alcediniformes, Coraciiformes) are less abundant and aerial insectivores (Apodiformes) very scarce, which either indicates a taphonomic bias in the composition of the avifauna or particular paleoenvironmental characteristics of the nearshore habitats in that area of the southern North Sea Basin.

Grant Information:
Funded by Belgian Science Policy Office (project BR/121/A3/PalEurAfrica).

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

SMALL CARNIVORE COPROLITES FROM THE LATE TRIASSIC OF SOUTHERN BRAZIL: PALEOBIOLOGICAL IMPLICATIONS

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A remarkable fauna is recorded in early Norian beds (ca. 225.42±0.37Ma) from the municipality of Faxinal do Soturno, State of Rio Grande do Sul, Brazil. This is mainly composed by small-sized vertebrates (maximum body length around 200-250 mm), such as probainognathian cynodonts, rhynchocephalians, non-rhynchocephalian lepidosauromorphs and procolophonians. The only relatively large animal found there is the saurischian *Guaibasaurus* (ca. 2m). The fossils occur in massive sandy lenses interpreted as a fluvial/deltaic system. In this same level, more than 80 elliptical coprolites, resembling rodentian feces, were found. They exhibit a whitish color and range from 7 to 10mm long and 3 to 5mm in diameter. Eight isolated coprolites were analyzed chemically and by microscopy. The x-ray diffractometry indicated quartz, plagioclase, smectite and apatite with major pick, consistent with carnivore coprolitic materials. Thin section analyses showed a massive coprofabric bearing sand (quartz) grains and bone remains. Micro-CT images were obtained from a sandy block with seven "in situ" coprolites. Inside each one, a dense amount of millimetric bone elements was revealed compound about 40-70% of the total volume. All bones are disarticulated. Some are complete, but the most part fragmented. Few signs of chemical corrosion (pits) are present. Among the identifiable elements are indeterminate long bones, ribs, phalanx, and parts of neural arches of the rhynchocephalian *Clevosaurus brasiliensis.* Although it is difficult to assign these coprolites unequivocally to a specific producer, their measurements are in accordance with the sizes of the aforementioned small tetrapods. The evidences point out to a strict carnivore producer with some ability of chewing bone and with fast digestion, which refers to a more mammalian physiology than a reptilian one. The sand inside the coprolites is suggestive of soil ingestion during feeding to obtain nutrients, as commonly practiced by current fossorial animals, or just accidental ingestion. Therefore, we defend the probainognathian cynodonts may be the potential candidates. This is corroborated by their sectorial postcanine teeth with a more effective occlusion, enabling chewing movements, and features suggestive of fossoriality, like a robust humerus and hypertrophied rodent-like lower incisors (e.g., Irajatherium, Riograndia). This unprecedented Triassic record constitutes a rich ichnologic data source that contributes for a better understanding of the initial steps of the mammalian paleobiology.

Grant Information:
CNPq - 312387/2016-4 (MBS)

Technical Session XIII (Friday, October 11, 2019, 1:45 PM)

A SMALL DIAPSID FROM THE LOWER KEUPER OF GERMANY AND THE ORIGIN OF AQUATIC REPTILES

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The Middle Triassic was a time of major changes in terrestrial tetrapod faunas, but the fossil record of this interval is largely obscure. This is unfortunate, since many modern groups originated or diversified during this time. However, recent excavations in the upper Middle Triassic of Germany have revealed several new taxa, most of which are much smaller than those found in other tetrapod-bearing basins of similar age. Here, we report a new taxon from the Vellberg limestone quarry comprised of skull bones distinct from other diapsids from this locality. It is diagnosed by a long maxilla with a far posteriorly reaching tooth row; a long and stout ventral process of the postfrontal; exclusion of the postorbital from the lower temporal fenestra due to a contact between the anteroventral process of the squamosal and the dorsal process of the jugal; and a tall quadrate + quadratojugal complex. Some anatomical aspects of the new taxon are similar to stem diapsids such as *Elachistosuchus huenei* from similar deposits of Northern Germany and of uncertain phylogenetic affinity. A phylogenetic analysis retrieved both taxa in an "ichthyosauromorph" clade, included in an almost exclusively aquatic group. The new taxon, *Hupehsuchus*, and *Elachistosuchus* appear as successive sister-taxa to Ichthyopterygia. It is interesting to note that many of the autapomorphic characters of the new taxon pertain to elements related to the lower temporal fenestra. In particular, the contact between the jugal and squamosal is unusual, but is also found in sauropterygians, saurosphargids, *Hupehsuchus*, and *Wumengosaurus*, as well as in rhynchocephalians. Derived ichthyosaurs show the typical jugal-quadratojugal contact, but via an unusual dorsal contact between the two. The jugal–squamosal contact may thus represent a transitional state to the anatomy observed in later ichthyosaurs, reinforcing the interpretation of the 'ventral cheek embayment' of basal 'euryapsids' as a ventrally open lower temporal fenestra. Thus, the new taxon has implications for the origin of secondarily aquatic groups, and therefore also paleobiogeographic significance. The appearance of placodontians has been traced to central Europe, but ichthyopterygians are believed to have originated in the Eastern Tethys. The new taxon indicates that the earliest evolutionary history of these groups may have occurred in the Western Tethys, associated with the Germanic Basin. This new material emphasizes the importance of sampling small-bodied taxa in the understanding of reptile evolution.

Grant Information:
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Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

UNUSUAL TOOTH REPLACEMENT IN A NEW CENOMANIAN IGUANODONTIAN FROM THE MUSSENTUCHIT MEMBER OF THE CEDAR MOUNTAIN FORMATION

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A partial skeleton including both dentaries and multiple isolated teeth of an early diverging iguanodontian (NCSM 29373) was excavated from the Cenomanian-aged Mussentuchit Member of the Cedar Mountain Formation in Emery County, Utah during the 2014-2016 field seasons. Due to the presence of jaw sections with unerupted teeth, we were able to calculate tooth replacement rates of NCSM 29373 by counting incremental von Ebner lines – dentine growth lines homologous to the lines in extant amniote teeth that represent daily dentine deposition. To avoid damaging the intact dentary, we made thin sections of a complete isolated tooth and using light microscopy calculated the mean width of von Ebner lines across several increments where they were preserved – 17 μm (n=11, range = 13.4-23.2 μm). A reconstructed crown height of 6719 μm, yields an estimated tooth formation time of 395 days. Enamel thickness was determined to be greatest at the central ridge on the labial side of the tooth – 159 μm compared to 88 μm in between the ridges.

Micro CT scan of the dentary revealed two teeth in each alveolus - one functional tooth and one replacement tooth. Using this data we determined crown height in two successive teeth (7.07 mm for the functional tooth and 3.53 mm for replacement tooth) and derived formation time – specifically, 416 days for the functional tooth and 208 days for the replacement tooth and an estimated tooth replacement rate of 208 days.
Tooth replacement rate in the Mussentuchit iguanodontian (NCSM 29373) is 2-4 times slower than calculated for hadrosaurs with specialized tooth batteries (e.g., *Edmontosaurus* and *Prosaurolophus* average 50 and 81 days respectively). In fact, although slightly faster, tooth replacement rate in NCSM 29373 is most comparable to that of theropods, perhaps reflecting a plesiomorphic condition – a slower rate is expected for early-diverging ornithopods not yet exhibiting a sophisticated tooth battery. Alternatively slower tooth formation times and replacement rates may be a dietary specialization of NCSM 29373; further data among non-hadrosaurian ornithopods is necessary to test amongst these competing hypotheses.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

PALEOMETRY: MOLECULAR AND ELEMENTAL CHARACTERIZATION OF THE SLOTH *CATONYX CUVIERI* (MAMMALIA, XENARTHRA, MYLODONTIDAE) FROM THE PLEISTOCENE-HOLOCENE OF PARAGUAY.

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In this work we present the results of the first paleometry studies using X-ray fluorescence (XRF) techniques, X-ray photoelectron spectroscopy (XPS), Fourier transform infrared (FTIR) and Raman spectroscopy, applied to the characterization of a specimen of *Catonyx cuvieri* (Lund 1839) extracted from the caves of Cerro Riso in the district of San Lázaro, Department of Concepción, Paraguay. The specimen is deposited in the Laboratorio de Paleontología collection of the Facultad de Ciencias Exactas y Naturales (FACEN), Universidad Nacional de Asunción (UNA), Paraguay.
A total of 10 bone samples corresponding mostly to fragments of ribs were subjected to non-destructive analysis. These were selected because they did not suffer alterations in their surface as product of the processes of preservation (bonding, consolidation) to which this type of remains are usually subjected for their preservation in collections.
The chemical characterization was performed by means of Fourier Transform Infrared (FTIR) and Raman spectroscopy with 785nm laser excitation source, identifying the functional groups (PO4)-3 and the presence of organic groups assigned to Amide I and II respectively. The elementary identification was performed by X-ray fluorescence spectrometry (XRF) with Silver target (Ag) and SDD detector of the majority elements. In addition to an analysis by X-ray photoelectron spectroscopy (XPS)with dual source of Aluminum (Al,) for light elements and the determination of the proportion of Ca / P in the bone samples through the analysis of Ca 2p and P 1s. The C 1s to corroborate the presence of organic material in the analyzed samples.
Differences of the data obtained with the XRF and XPS will be established, being a central point of discussion the difference in the ratio of Ca / P obtained in both techniques.
The results obtained were compared with hydroxyapatite (main mineral material in bones) synthesized in the laboratory, showing differences in the (PO4) -3 P v3 bands due to the presence of amorphous and / or crystalline calcium phosphate material in the samples. The main objective of this work is to know the processes, molecular and structural changes caused by the incorporation of elements in the structures of bio-apatites in the processes of diagenesis.

Grant Information:
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INV15-120 Técnicas Nucleares Analíticas aplicadas al Patrimonio Cultural del Paraguay
14-INV-200 Cuaternario del Paraguay

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

RECONSTRUCTING COMPLEX PATTERNS OF ENAMEL ON A TOOTH WITH COMPUTATIONAL SIMULATIONS

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Teeth of most mammals are covered by a layer of highly mineralized enamel that cannot be remodeled or repaired. Several mammalian lineages have evolved thick enamel, associated with diverse dietary adaptations. Consequently, differences in enamel thickness among species have been used to examine functional properties of teeth. The thickness of the enamel layer, however, is rarely completely uniform over the crown. Since the enamel surface is not a simple extrapolation of the dentine surface, it is difficult to reconstruct the surface based on the dentine. Variable enamel thickness implies that the process of enamel matrix secretion itself plays a role in dietary adaptations. Nevertheless, it remains to be explained how the distribution of enamel on the tooth crown is developmentally regulated. Here we use molars of extant suids (*Sus domesticus*, *Phacochoerus africanus*) and primates (*Homo sapiens, Gorilla gorilla, Pongo pygmaeus*) with a computational model to explore which kind of mechanisms could underlie the complex patterns of enamel distribution. Starting from tomography-imaged teeth from which enamel has been digitally removed, enamel secretion is computationally simulated. We show how using a diffusion-limited secretion of enamel matrix, it is possible to reconstruct the enamel distribution on the tooth. Moreover, diffusion limited secretion of the enamel matrix can substantially increase the complexity of the tooth surface. These simulations provide a simple principle that accounts for the complex patterns of enamel distribution found in many taxa, and suggest a framework to classify teeth and taxa based on the mode of enamel formation.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A LARGE PTEROSAUR HUMERUS FROM BONE CABIN QUARRY, MORRISON FORMATION, COLORADO

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Bone Cabin Quarry is a historic Morrison Formation quarry in southeastern Wyoming. Here we describe a large pterosaur humerus from this locality (EDP-SM 2017.02.003) housed at the Stewart Museum in Eccles Dinosaur Park. Its stratigraphic position places it among the oldest pterosaurs in the Morrison Formation. The bone is three-dimensionally preserved, although slightly crushed, and is the largest definitively Jurassic pterosaur humerus recorded in the literature. Proximodistal length is 110.5 mm, and the diaphysis measures 16 mm at its median point. The deltopectoral crest is tongue-shaped with a semi-rounded distal end and is inclined proximally. The distal half of the humerus is bowed anteriorly. The ectepicondyle is more expanded than the entepicondyle, and the radial condyle is visible as an elongated lozenge-shape that angles diagonally toward the ulnar condyle.
In order to determine the wingspan of the pterosaur that possessed this humerus, wingspans from various rhamphorhynchid pterosaurs were graphed using a previously published dataset. Deriving a regression equation from this data and substituting in the proximodistal length yields a result of 2067.6 ± 169.7 mm. Previously, the largest definitively Jurassic humerus in the literature measured 100 mm and had an estimated wingspan of 1.6-3.2 m, although there is a 112 mm long humerus from Thailand (PRC 64) that may be from an uppermost Jurassic deposit.
Most rhamphorhynchid humeri to which this specimen could be compared are not three-dimensionally preserved, so it is difficult to assign it to a specific clade within Rhamphorhynchidae. Nevertheless, the humerus is most morphologically similar to those seen in Dorygnathus and to PRC 64, the putatively Jurassic humerus from Thailand that was considered an azhdarchoid but we interpret to be a rhamphorhynchid. The Bone Cabin humerus differs from Dorygnathus humeri in size and in the morphology of the distal condyles. It is similar in size to PRC 64, although the distal condyles in PRC 64 are not well-preserved.
Also found in Bone Cabin Quarry was the holotype rostrum of Harpactognathus gentryii, a rhamphorhynchid. By extrapolating total skull length, the wingspan was estimated to be approximately 2.5 m. Given the wingspan estimate for the humerus is similar, it is possible that the two bones belong to the same species. Regardless, the discovery of this Bone Cabin humerus provides more evidence for surprisingly large pterosaurs (~2-2.5 m wingspans) in the Jurassic of North America.

Grant Information:
Expenses were funded by the Department of Earth and Biological Sciences at Loma Linda University.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

CONSTRAINTS AND ADAPTATIONS IN CROCODILIAN SKULL FORM AND FUNCTION

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Crocodilians, one of only two living groups of archosaurs, display a diverse range of skull morphologies. A classic hypothesis states that crocodilian skull shape is responsive to selective feeding strategy; yet extant crocodilians possess platyrostral (broad and flat) snouts, thought to be sub-optimal for feeding due to the conflicting demands of feeding optimization and hydrodynamic constraints. In contrast, numerous Mesozoic crocodilians possessed oreinirostral (dome-shaped) skulls. Some of these forms were terrestrial and hence free from the aforementioned constraints. This study aims to review the role of functional controls that determine skull shape in crocodilians and seeks to assess the differences in the feeding mechanics between the terrestrial extinct taxa and the semiaquatic extant taxa. This was carried out using beam analysis and finite element analysis (FEA) for evaluating resistance to feeding-induced loads in the Mesozoic taxa *Baurusuchus salgadoensis*, *Montealtosuchus arrudacamposi* and *Caipirasuchus paulistanus*, which have oreinirostral skulls, compared to the extant *Alligator mississippiensis, Crocodylus niloticus, Paleosuchus palpebrosus* and *Gavialis gangeticus,* with platyrostral skulls. Adductor muscles were digitally reconstructed in *Baurusuchus* and scaled in other taxa to assess myological variations, estimate bite forces and muscle efficiency. The results show that oreinirostral morphologies are comparatively better-suited for resisting force as lower stresses were observed under various biting scenarios. Conversely, bite forces are independent of rostral shape and instead scale positively with body size. The oreinirostral taxa, however, show increased mechanical advantages compared to their platyrostral counterparts, due to the differences in the musculoskeletal architecture. Overall, fossil taxa with oreinirostral morphologies show skull structures that are better optimized for feeding in the absence of hydrodynamic constraints. These observations are expected to serve as models to explore further the biomechanics of other tetrapods with homologous morphologies.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

CRANIOFACIAL ONTOGENY IN PACHYCEPHALOSAURUS WYOMINGENSIS

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Pachycephalosaurus wyomingensis was the largest of the pachycephalosaurid dinosaurs. It lived in the Maastrichtian age of the late Cretaceous period in North America, and its fossils have been found in Wyoming, South Dakota, and Montana. The goal of this study was to recover the ontogeny of the craniofacial skeleton of *P. wyomingensis* through quantitative cladistic analysis. A previous hypothesis of ontogeny divides the growth series of *P. wyomingensis* into juvenile (2 specimens), subadult (10 specimens), and adult (7 specimens), which is a low resolution hypothesis because multiple specimens are included in each group. A cladistic analysis provides a high resolution analysis that has the potential to recover the relative maturity of each specimen relative to each other. A hypothetical embryo was used as an outgroup. Nine cranial characters were independently coded, including four binary growth characters and five multistate growth characters. An exhaustive search recovered five trees, with a CI of 1.00, an HI of 0.00, an RI of 1.00, an RC of 1.00, and a tree length of 14 steps. The growth stages (based on one of the 5 most parsimonious trees) are defined by, Stage 1 (UCMP 130049) is not supported by an optimized character; Stage 2 (UCMP 134979, TCNI 2004.17.1), a frontoparietal (fp) dome zone 2 that is reduced, a fp zone 3 that is moderately thinning; Stage 3, a dorsal temporal fenestra that is closed, a fp dome that is significantly inflated, a fp dome that is moderately long. There are two groups beyond this stage, Group 1(fully domed *Pachycephalosaurus*) and Group 2 (Stygimorph). Group 1, Stage 1 (UCMP 556078), a middle anterior node that is absent; Stage 2 (VRD 13), a horn/node profile that is blunt; Stage 3 (AMNH FARB 1696), a fp dome length that is long. Group 2, Stage 1 (MOR 453), a reversal in fp dome zone 2 from reduced to moderate; Stage 2 (UCMP 128383, MPM 8111), a reversal in the fp dome inflation from significant to moderate inflation. Growth rank data are normally distributed under a Shapiro-Wilk test ($p = 0.933$). The splitting in the tree is evidence of sexual dimorphism in *P. wyomingensis*. It is unclear which group represents which sex.

Technical Session XI (Friday, October 11, 2019, 9:15 AM)

LATE HOLOCENE FAUNAL DYNAMICS IN A NORTHERN ROCKY MOUNTAIN FOREST COMMUNITY

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Anticipating how species and ecosystems will respond to climate change is critically important to conservation of biodiversity and functioning ecosystem processes. Identifying how species in a community have responded in the past can be accomplished by evaluating the fossil record, and by comparing paleoecological trends to modern abundance and diversity. Detailed paleoecological records from Quaternary deposits have long been used to characterize century-to-millennial scales of ecological dynamics, but few Quaternary localities have sampled the small mammal community of forested ecosystems. Here, we document changes in small mammal diversity in Waterfall Locality, a fossil packrat midden assemblage from northeastern Yellowstone National Park. Skeletal specimens at Waterfall Locality are the product of packrats (*Neotoma cinerea*) concentrating carnivore scats and pellets of avian predators. AMS radiocarbon dates on 8 bone and 13 charcoal samples suggest that the site spans ~4500-200 calendar YBP, and so this site contributes to our understanding of pre-industrial variation in the Yellowstone region by providing faunal data for a period of recent climate change, most notably the Medieval Climatic Anomaly.
We trace relative abundance and community evenness of 28 small mammal taxa from the genera Mustela, Erethizon, Ochotona, Lepus, Marmota, Tamiasciurus, Spermophilus, Phenacomys, Microtus, Sylvilagus, Zapus, Sorex, Thomomys, Neotoma, Glaucomys, Tamias, Peromyscus, and Clethrionomys. We find no significant correlations among abundances of different taxa, indicating that species are responding individualistically to their environment. Using Probability of Intraspecific Encounter (PIE), we found no significant changes in evenness through time. However, Constrained Hierarchical Cluster Analysis (CONISS) reveals periods of relatively stable taxonomic composition from ~4500-2300 calendar YBP and ~2300-2100 calendar YBP, followed by repeated, rapid (on the scale of 100 years or less) compositional reorganization from ~1800-200 calendar YBP. Preliminary data comparing the proportion of nocturnal versus diurnal taxa suggests that vectors of bone accumulation (i.e., which predators are responsible for the assemblage) have changed little over the course of the last ~4500 years.

Technical Session XX (Saturday, October 12, 2019, 3:30 PM)

GEOMETRIC MORPHOMETRIC AND FINITE ELEMENT ANALYSIS OF THE MEKOSUCHINE CROCODILE FORELIMB AS AN ASSESSMENT OF LOCOMOTION

STEIN, Michael D., University of New South Wales, Sydney, Australia; WILSON, Laura A., University of New South Wales, Sydney, Australia; HAND, Suzanne J., University of New South Wales, Sydney, Australia; ARCHER, Michael, University of New South Wales, Sydney, Australia

The focus of evolutionary biomechanics is to relate form to evolutionary function in the context of physical restraint. A morphological shift in the fossil record would therefore indicate a concomitant shift in ecological condition. Mekosuchine crocodiles (Crocodylidae, Mekosuchinae) of Oligo-Miocene Australia display departures from the typical eusuchian body-plan both in the cranium and postcranium. Results from previous qualitative studies suggest these crocodiles had a more terrestrial habitus compared with modern crocodylians, yet the full capacity of mekosuchine locomotion remains to be tested. We apply a quantitative approach to mekosuchine biomechanics using both geomorphic morphometric and finite element methods, to examine the unusual morphology of the mekosuchine humerus observed in specimens available from Queensland and the Northern Territory and estimate the locomotory stresses engendered by it. The results indicate differences in the geometry of the diaphysis between modern freshwater crocodiles and mekosuchines along with different patterns of structural stresses between models that simulate sprawling and high-walk gaits. Our results lend quantitative support to the terrestrial habitus hypothesis and suggest behavioural adaptations for burrowing in late Plio–Pleistocene mekosuchines.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

LATE OLIGOCENE MACROSCELIDEANS FROM THE NSUNGWE FORMATION, RUKWA RIFT BASIN, TANZANIA

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Among the least sampled intervals in vertebrate evolutionary history is the late Oligocene of continental Africa. The Nsungwe Formation in the Rukwa Rift Basin of Tanzania has revealed a rich faunal assemblage with key first and last appearances in the Cenozoic record including the earliest fossil evidence for the divergence of cercopithecoids and hominoids discovered alongside late-surviving parapithecid primates. Age constraint for the Nsungwe Formation leverages high-precision U-Pb and Ar/Ar geochronology of intercalated volcanic tuffs. Multiple localities sample differing depositional environments and preserve a range of vertebrate fossils including articulated anurans, associated crocodylians, isolated lizard, snake, turtle and fish remains, as well as a diversity of invertebrate fossils. Non-primate mammals include numerous rodents, as well as evidence of hyracoids, anthracotheres and a hyaneodont. Here we report on novel macroscelideans recovered from localities in the Songwe Member of the Nsungwe Formation, documenting a glimpse into African mammalian evolutionary history at the Paleogene-Neogene boundary.

Grant Information:
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Technical Session II (Wednesday, October 9, 2019, 8:30 AM)

PALEOENVIRONMENTAL ASSOCIATIONS AND VERTEBRATE ICHNOLOGY OF A DIVERSE, MULTI-LAYERED, DINOSAUR TRACK ASSEMBLAGE FROM THE UPPER CRETACEOUS CANTWELL FORMATION (MAASTRICHTIAN), DENALI NATIONAL PARK AND PRESERVE, ALASKA

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Denali National Park and Preserve (DENA) in south-central Alaska has recently been recognized as a major high latitude dinosaur track-bearing locality. An abundant and taxonomically diverse array of ichnofossils are preserved in the Upper Cretaceous Cantwell Formation in DENA. However, ichnological and paleoenvironmental studies are still in their infancy, due in part to the remote nature of the mountainous exposures and substantial tectonic deformation that limits our understanding of the stratigraphic relationships within the formation. Here we present data on the largest known single *in situ* track assemblage currently known in DENA and all of Alaska, a football field-sized outcrop of nearly-vertically inclined, fossiliferous rock exposed as a series of north-facing flatirons. This site, known as the Coliseum, is composed of 65+ meters of vertical section, with laterally extensive mudstones, fine- to medium-grained sandstones, carbonate-siliciclastics, and bentonite. Facies analysis of the fossiliferous horizons reveal organically rich, repetitive fining upward successions of varying thickness commonly exhibiting small asymmetric ripples suggesting the tracks were formed subaerially on top of shallow water crevasse splays within an alluvial floodplain. U-Pb dating of zircons collected from a bentonite at the site return an age of 69.4±0.9 Ma, adding important new data to understanding the temporal constraints of the formation and their stratigraphic relationships to other dinosaur sites in Alaska, including the penecontemporaneous Prince Creek Formation in northern Alaska. Trace fossils at the Coliseum include true tracks, undertracks, natural casts, and trackways that vary in their preservation from eroded, trampled surfaces to skin impressions. The tracks were documented via handheld and UAV-assisted photogrammetry, enabling a large-scale 3-dimensional mapping of the Coliseum, including inaccessible surfaces. Large-bodied ornithopod tracks (*Hadrosauropodus*) dominate the assemblage, along with those of ceratopsids. A variety of non-avian theropod (including probable tyrannosaurid) and avian tracks are also preserved. The extensive trace fossil record of the Cantwell Formation provides important complimentary data to the body fossil record preserved in the Prince Creek Formation, allowing better understanding of the taxonomic composition and paleoecology of Late Cretaceous Arctic ecosystems.

Grant Information:
This work was funded by the National Park Service through an award to P. Druckenmiller

Technical Session V (Wednesday, October 9, 2019, 3:30 PM)

AVIAN EVOLUTION NEAR THE TIBETAN PLATEAU AND EVIDENCE FOR CENTRAL ASIAN ARIDITY IN THE LATE MIOCENE BASED ON THE FIRST FOSSIL SKELETON OF A SANDGROUSE (AVES: PTEROCLIDAE) FROM THE LINXIA BASIN IN WESTERN CHINA

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Adding to the rapidly growing avian fauna of vultures, falcons, pheasants, and ostrich from the Liushu Formation (7.25- 11.1 Ma), is a partial skeleton of a sandgrouse (Columbiformes) that is the most complete fossil of the group known, the oldest record of the group in Asia, and fills a significant temporal gap in their Neogene history. The specimen includes articulated and associated elements of the wing, shoulder girdle, vertebrae, and hind limb. The skeleton preserves a notarium of four fused vertebrae that is present also in pteroclids and columbids. The fossil's coracoids have short shafts unlike that of stem pteroclids and columbids. The dorsal supracondylar tubercle on the humerus is elongate and differs from that of columbids. The radiale has a much less distinct groove for m. ulnometacarpalis ventralis than the condition in the sandgrouse genus *Syrrhaptes*. The furcula has a unique elongate (caudodorsally directed) articulation with the coracoid that may be an autapomorphy of this extinct species. Despite occurring within the extant geographic range of the Asian endemic *Syrrhaptes*, it appears that the fossil is a member of the crown pteroclid clade, and also outside of crown *Syrrhaptes*. This pteroclid skeleton was found associated with the foot of an ergilornithine gruoid and mammalian remains, and the majority of the sandgrouse skeleton is adjacent to and in contact with a horned bovid skull roof. The mixture of articulated, semicomplete individuals, and broken, unassociated vertebrate remains in otherwise structureless fine-grained sediments parallels that seen at other localities in the Liushu Formation. That taphonomy potentially suggests flood plain deposition during a flash flood event (possibly related to the seasonal Asian monsoon).
Males of extant sandgrouse are known for their unusual use of modified breast feathers for absorbing water from permanent water bodies and transporting it long distances to supply their young. Extant and fossil sandgrouse are known from arid habitats across Eurasia and Africa. The interpretation of the Linxia Basin deposits at the northeastern edge of the Qinghai-Tibetan Plateau has been as an arid savannah habitat occupied by a diverse *Hipparion* fauna. The occurrence of a sandgrouse within this environmental setting reinforces the hypothesis of drying and increased aridity in Central Asia associated coincidentally with the rise of the plateau. Even though fossil fish are unknown in the formation, the discovery of this sandgrouse points to the past presence of permanent water bodies in the area.

Grant Information:
National Natural Science Foundation of China #NSFC41772013

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

PRACTICES FOR NATURAL HISTORY MUSEUM PROGRAMS TO CLOSE THE DISABILITY ENGAGEMENT GAP FOR PEOPLE WITH THE AUTISM SPECTRUM DISORDER

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Many of the first contacts with paleontology by the public are with science presented in a museum setting. However, crowded, loud, and sensory dense natural history museums and exhibits can create an engagement gap with respect to people with the Autism Spectrum Disorder (ASD) because they are less likely to visit a museum or visit less frequently. This gap can be bridged by both easily implemented and more costly modifications that will create a warm, comfortable, and welcoming environment for the ASD population. Even the simplest changes to exhibit and other public spaces, such as reducing light levels, reducing or eliminating sounds, and restricting crowd sizes, all contribute to the creation of a beneficial sensory environment. Avoidance of extensive amounts of bright white and red colors in public areas (and in staff clothing) can help to reduce their triggering effects. Programs should provide

sensory rooms or spaces that serve as a quiet, calm retreat. One key component is providing adequate information prior to any visit, including a sensory map of the museum (along with well marked access to toilets and sensory room), times when the museum is not crowded, and a social story about visiting the museum and its exhibits (highlighting any potentially stressful parts of the exhibits or events). Optimal programs for those with ASD can provide exclusive (at least partial) museum access by opening early or later than normal hours (an hour or two) for a limited number of pre-registered families with members with ASD. The exclusivity of a autism event allows families to be comfortable in an understanding environment free from judgment, and free to explore at their own pace, participating in the direction of their interests. In addition, (weighted) sensory backpacks can be provided to visiting families (when requested), and they should include a variety of items such as noise cancelling/reduction headphones, squishy toys, fidget spinners, and other items to relieve stress. Do not set low expectations for visitors with ASD. Only adjust the setting and the approach, not the scientific content or activities. People with ASD are active contributors, not just observers. Make programs for ASD (and other non-physical disabilities) integral to education programs with associated training across the staff, and thus not reliant on a single person or position. While outside funding may help initiate ASD programs in a museum, they should not be considered as separate from the normal education budget and operations of a museum.

Technical Session IV (Wednesday, October 9, 2019, 3:00 PM)

IMMUNOHISTOCHEMICAL INSIGHTS INTO DISTRIBUTION AND OSTEOLOGICAL CORRELATES OF PERIODONTAL LIGAMENT INNERVATION IN *DIDELPHIS VIRGINIANA*

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The periodontal ligament (PDL) around tooth roots is a multimodal sensory system in mammals. It anchors the teeth to the alveolar sockets by a network of unmineralized collagen fibers, and nerve fibers in PDL form a sensory complex that transduces and integrates sensations of pressure, vibration, and pain from the teeth to the brain. New model systems can inform functional studies of the evolution of the PDL. Metatherians such as *Didelphis virginiana* are sistergroup to eutherians and can be phylogenetically informative for interpreting the ancestral characters of basal mammals. We identified and mapped individual nerve locations and types around the roots of lower m1 of *Didelphis* using immunofluorescence. Blood vessels, nerves, as well as glial and glial-related cells surrounding neurons were immunolabeled with S100, two neurofilament motor proteins (SMI 312 and NF-M), and protein gene product 9.5 (PGP 9.5). The labeled structures were imaged with a confocal microscope. To quantify the orientation and organization of PDL collagens sections were stained with Picrosirius Red (PSR) and imaged with circular polarizing microscopy. Collagen orientations were measured using direction image analysis with OrientationJ package in Fiji.
RESULTS: SMI 312 was found to be the most effective neuronal marker. S-100, NF-M, and SMI 312 showed neurons running dorsoventrally in neurovascular bundles parallel to both the alveolar socket and tooth root. Nerves enter the PDL both through the root apex PDL space and laterally through the alveolar bone. Nerves are more numerous and diffuse within the PDL at the apex of the root. PSR revealed that the collagen fibers attaching to the lower two thirds of the root radiate upwards and outwards from the tooth root to the alveolus. In the upper one third, close to the crown, collagen fibers radiate both upwards and downwards as they run from the root to the alveolus.
We identified several possible osteological correlates of PDL innervation, which can be mapped to basal mammaliaforms in early mammal evolution: (1) The inter-radicular PDL: blood vessels enter the inter-radicular PDL all along its length, but nerves appear to only enter the inter-radicular PDL near the root apex. (2) Longitudinal grooves in the alveolar wall are associated with neurovascular bundles.

Technical Session XIII (Friday, October 11, 2019, 2:00 PM)

AN EXCEPTIONALLY PRESERVED SMALL ARBOREAL REPTILE FROM THE UPPER PERMIAN USILI FORMATION OF TANZANIA

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The Permo-Triassic mass extinction is recognized to have massively reorganized terrestrial tetrapod communities from the synapsid-dominated ecosystems of the late Permian to communities with more reptile diversity in the Early and Middle Triassic. Additionally, evidence of body size changes across this boundary indicate that most early reptiles were small until after the extinction, when they were able to expand into the vacated large-bodied niches. The Ruhuhu Basin of Tanzania documents the latter part of this transition well, with early members of several archosaurian clades present in the Middle Triassic Manda Beds. However, only large pareiasaur parareptiles and a single specimen of the possible early archosauromorph *Aenigmastropheus parrintoni* are known from the upper Permian Usili Formation, despite decades of collecting that have yielded 24 species of synapsids ranging from tiny *Kawingasaurus* to hippo-sized *Rhachiocephalus*. Here we report a recently discovered, unique reptile from the Usili Formation that possibly represents the oldest diapsid from Tanzania. CT data reveal densely packed and well-ossified, though apparently unduplicated, bony elements, indicating that the specimen represents the remains of a single individual. The taphonomic mode of these articulated skeletal elements in our specimen suggests preservation within a coprolite. This small specimen (estimated humeral length = 21 mm) includes articulated forelimbs and hindlimbs with a humerus with both ent- and ectepicondylar foramina and a distinct capitellum, elongated metapodials and phalanges, and curved and tapered unguals, suggesting an arboreal lifestyle. The combination of elongated caudal vertebrae and morphology of the pes and the manus suggest that this amniote is likely a diapsid reptile; however, most character states that diagnosis this clade lie in the skull, which was not found in this specimen. Additionally, the articulated caudal vertebrae have elongated centra distinct from those of anomodont synapsids, such as the possibly arboreal *Suminia* from the late Permian of Russia, further corroborating our identification and indicating an arboreal ecology for at least some small reptiles in the late Permian.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

UNIVERSITY OUTREACH SERVING RURAL COMMUNITIES: WEST VIRGINIA SCIENCE ADVENTURES K-12 STEM SUMMER CAMPS

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Recent studies have shown that as little as 5% of an individual's lifetime science education comes from a formal classroom setting. Outside of school, science is learned from a variety of informal education venues including museums, science centers, and zoos. Informal education has been shown to promote STEM learning, inform career choice, and encourage diversity. However, in rural areas access to informal education is limited. In such cases it is possible for universities to develop programming, such as science festivals and summer camps, to fill this void matching opportunities typically only found in urban areas.
For the last 7 years West Virginia Science Adventures at Marshall University has offered 9 weeks of STEM summer camps serving approximately 400 K-12 students annually. These week-long camps span many fields including paleontology, geology, astronomy, biology, coding, chemistry, physics, engineering, and math and focus on hands-on, making, and activity-based learning. The goals of these camps are both science enrichment and working towards science inclusion and diversity. It is especially important to make these camps accessible to all members of the community regardless of socioeconomic status. This programming has moved beyond financially self-sustaining, so we are able to provide approximately 35% of our campers with full scholarships based on demonstrated financial need. Earlier camp years

were biased toward boys (typically in the 65% range), with grades 6-8 being the most challenging ages to recruit girls. However targeted marketing and diversifying camp themes have now succeeded in establishing an even distribution of boys and girls across our age groups.
Our camps are mostly designed and staffed by MS graduate students, giving them a chance for both summer support and outreach experience. Providing university sponsored camps on campus has two further goals. First, children are exposed to exciting hands-on science with actual scientists, while at the same time demystifying college and STEM by exposing children at an early age to campuses and research labs. This place bound experience is especially valuable for potential first-generation college students.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

THE SKULL OF A YOUNG JUVENILE ELASMOSAUR FROM THE CAMPANIAN BEARPAW FORMATION OF SASKATCHEWAN, CANADA

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The Campanian-aged Bearpaw Formation of Alberta, Saskatchewan, and Montana represents one of the final transgressions of the Western Interior Sea across central North America during the Late Cretaceous. This inland seaway was inhabited by various marine reptiles including sea turtles, mosasaurs, and both polycotylid and elasmosaurid plesiosaurs. A new Bearpaw site in southwestern Saskatchewan differs from other outcroppings in that fossils including mollusks, arthropods, echinoderms, and vertebrates are preserved in phosphatic concretions. A very small (~13 cm long) elasmosaur skull was discovered inside one such concretion. In addition to the small size, the extremely poorly ossified cranial bones support the interpretation of the specimen as a young juvenile. The preservation of some of the vertebrate material recovered from various concretions at this site, including some regions of the juvenile elasmosaur skull, is atypically glassy and brittle. Therefore, the concretion containing the skull was scanned using micro-computed tomography. These scans reveal that the nearly complete cranium is preserved in three dimensions with little deformation.
Preservation of skull elements differs based on developmental origin, with endochondral bones being better ossified and the dermal bones exhibiting the glassy appearance. This difference is particularly apparent in the micro-CT scans, where the dermal elements are difficult to resolve from the matrix of the nodule. Little is known about the timing of ossification in developing plesiosaur skulls, but it is possible that the difference in levels of ossification between the endochondral and dermal bones may indicate that this individual died shortly before or shortly after parturition. If so, this specimen provides a unique opportunity to explore the developmental relationships between the chondrocranium and dermatocranium in plesiosaurs.

Technical Session XII (Friday, October 11, 2019, 10:15 AM)

WHY DID SOME QUADRUPEDAL DINOSAURS HAVE SMALL FRONT FEET?

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Some quadrupedal animals have a manus and pes of notably different size, i.e., they exhibit strong heteropody. This is particularly common within the dinosaur fossil record in both skeletons and trackways. Previous hypotheses as to why this might arise have focused on equalization of underfoot pressures relating to centre of mass (CM) position, but this reasoning remains untested. We used 3D models of extant taxa to explore the relationship between manus and pes size, and centre of mass position. Since most dinosaur remains are limited to skeletons, we first set out to understand the relationship between foot surface area of soft and skeletal tissue. 2D alpha shapes of feet derived from CT scans of 29 extant species (mammals, reptiles, birds and amphibians) were used to examine the relationship between skeletal and skin foot surface area, and whether it is possible to predict *in vivo* foot contact area from fossil foot remains. Underfoot soft tissue area was found to be ~1.67 times that of skeletal surface area. When manus and pes were analysed separately, this number was ~2 times for manus and ~1.6 times for pes, with a high degree of predictability.
3D models of complete skeletons from 57 extant, quadrupedal animals (mammals, crocodiles, and lepidosaurs), were collated. CM positions for each were calculated using convex hulls, and autopodial bone measurements were taken to determine foot area. CM ranged from 0.6 to 67% gleno-acetabular distance in front of the hip, with most animals clustered around a CM of ~50-65%. Heteropody index (manus size as a percentage of pes size) ranged from 21-188, with most animals between 70 and 120 (manus is 0.7 to 1.2 times pes size). These two variables were not correlated. Extreme heteropody was particularly common in semi-aquatic species. When split into subgroups based on morphology, phylogeny, and ecology, semi-aquatic animals were the only group to show a strong correlation, with higher heteropody index associated with more anterior centre of mass, and greater weight support on the forefeet. It appears there is no ubiquitous functional explanation for extreme heteropody, except in animals with morphologies that counter selective pressures to equalise foot size, such as advantageous large hindfeet in swimming animals. We posit that extreme heteropody in some sauropod and ornithopod dinosaurs may not have been a function of using foot surface area to equalise pressure. It may instead be the result of phylogenetic inertia from their bipedal ancestors, or different foot postures and weight support strategies in their manus and pes.

Technical Session XIX (Saturday, October 12, 2019, 2:30 PM)

THE UPPER CRETACEOUS WAPITI FORMATION OF NORTHERN ALBERTA, CANADA AS A UNIQUE WINDOW INTO THE CONTINENTAL VERTEBRATE FAUNA OF BOREAL LARAMIDIA DURING BEARPAW TIMES

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The Campanian to early Maastrichtian Wapiti Formation (WF) of northern Alberta has received increasing attention from paleontologists since the 1980s. This has resulted in an improving picture of a succession of faunas situated well north (at paleolatitude ~60° N) of the classic sites of southern Alberta and the western United States, extending knowledge of the Campanian biogeography of Laramidia. Especially important in this respect is Unit 3 of the WF, which formed during a part of the Campanian (~73-74 Ma) when terrestrial deposition in southern Alberta was interrupted by the marine Bearpaw Formation. Unit 3 is clearly terrestrial, and preserves a unique record of land life in boreal Laramidia from this time.
Unit 3 includes the Pipestone Creek Bonebed, source of the otherwise unknown dinosaurs *Pachyrhinosaurus lakustai* and *Boreonykus certekorum*. Two other sites, Kleskun Hill (KH) and the recently discovered DC Bonebed (DCB), preserve small, disarticulated bones and teeth. A sample of over 200 vertebrate specimens from the DCB includes many elements that are common in the pre-Bearpaw Dinosaur Park Formation (DPF) of southern Alberta, such as champsosaurs, trionychid turtles, and baenid turtles including *Plesiobaena antiqua*.
However, the DCB assemblage differs from that of the DPF in that acipenserid fish, chelydrid turtle and thescelosaurid ornithischian elements are relatively abundant, while crocodylians are known from only one tooth. A caenagnathid mandible from the DCB resembles *Chirostenotes* from the DPF, but is very small. This bone may be juvenile, but the DCB champsosaurs are also small, and large turtles such as *Adocus* are absent. A juvenile lambeosaurine found near the DCB is comparable to *Corythosaurus*, but may be a new taxon given its trident-like nasal. Similarly, the KH fauna resembles that of the DPF but shows a few novelties, notably the presence of abundant troodontid teeth and the unique lizard *Kleskunsaurus*.
The Unit 3 fauna differs in detail but not in general composition from slightly older, more southerly Campanian ones, given the few known distinctive species and high abundances of some groups. However, the fact that Unit 3 coincides with a gap in the southern Alberta terrestrial record implies that some oddities of the Unit 3 fauna may result from sampling of an otherwise poorly represented time. The near-absence of crocodylians and the small size of the turtles and champsosaurs are perhaps most likely to reflect a true latitudinal signal, given latitudinal constraints on the size and distribution of ectotherms today.

Grant Information:
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Technical Session XV (Saturday, October 12, 2019, 9:45 AM)

A NEW PRIMITIVE CASEASAURIAN SYNAPSID FROM THE EARLY PERMIAN OF CENTRAL GERMANY AND ITS IMPLICATIONS FOR THE EVOLUTION OF DENTITIONS, DIETS, AND HERBIVORY OF CASEIDS

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A new basal pelycosaurian-grade synapsid, family Caseidae, is described on the basis of four partial to nearly complete mostly articulated skeletons from the Bromacker locality, in the Lower Permian Tambach Formation, lowermost formational unit of the Upper Rotliegend Group or Series, near the village of Tambach-Dietharz in the mid-region of the Thuringian Forest, central Germany. Based on its highly diverse vertebrate assemblage the age of the Bromacker locality is judged middle Early Permian Artinskian. The specimens comprising the new caseid present nearly complete knowledge of its skeletal morphology. It is the first caseid to be reported from Germany and can be distinguished readily from all other caseids based on a substantial list of autapomorphic and plesiomorphic characters. Of the four new caseid specimens, the smallest, a juvenile, and the largest, an adult, are nearly complete, articulated, and possess cranial material: in the juvenile a small partially articulated portion of the skull, and in the adult an essentially complete but crushed skull. The two specimens can be distinguished from one another by features attributed to different ontogenetic stages of development, including degree of ossification, differences in the proportional dimensions of pre-and post-orbital elements, and marginal dentitions. Notably, the lattermost difference is interpreted as evidence of a deciduous dentition. Extremely small tubular teeth in the juvenile suggestive of an insectivorous diet are replaced in the adult by much larger, narrowly triangular, slightly recurved, and distally pointed teeth suggestive of an omnivorous diet. Although the presumably insectivorous teeth of the juvenile lack the crowns,they are otherwise very similar to those reported in the oldest known caseid, the Late Pennsylvanian holotypic juvenile specimen *Eocasea martini*, which were argued as evidence of a non-herbivorous diet. The dentition in *E. martini*has been argued as further evidence that herbivory evolved within Caseidae. Cladistic analysis suggests *E. martini* as the most basal member of the monophyletic Caseidae and the later occurring middle Early Permian and the new German caseid as the sister taxon of the remaining late Early and Middle Permian members of the clade. This series of relationships, as well as the ontogenetic trajectory seen in the new German caseid's dentition, both parallel a proposed chronology of evolutionary changes in the dentitions and associated diets of caseids.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

THE PATTERNS PROJECT - PHYLOGENY-DRIVEN, ANATOMICAL TAXON TRANSFORMATION AS EDUCATION RESOURCE FOR NATURAL SCIENCES: USING DIGITAL MORPHING ANIMATION TO INTERPOLATE STRUCTURES AND ENHANCE EDUCATION AND OUTREACH IN VERTEBRATE PALEONTOLOGY

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The PATTERNS Project was initially envisioned as a means to bring virtual reality projects to children by appealing to them with a medium similar to video games and hand-held device apps. When phylogenetic hypotheses are incorporated into the outreach resources, they provide a natural way to bring evolutionary theory, earth history, and deep time into educational tools. Successful integration into such materials demands increasingly visual interactive components. This facilitates their incorporation into stationary presentations such as museum displays, but also mobile devices. A visually enhanced phylogeny becomes: (1) a tool with which students, scientists, and artists can observe the morphological transformations necessary between known, described taxa; and (2) a hypothesis generator for possible, plausible intermediate taxa within a phylogeny. This is achieved by utilizing the ability of computer modeling and animation software to morph from one predefined shape to another. To this end, a demonstration of the strategy was undertaken using a basal diadectomorph tetrapod, *Limnoscelis*, and two well-known pelycosaurian-grade sphenacodontid synapsids: the "sail-less" *Sphenacodon*, and the iconic sail-backed *Dimetrodon*. Using software packages generally employed in the visual effects and computer animation industries, digital sculptures of each were generated based on accepted body proportions of complete skeletons, and conservative estimates of surface shapes of their bodies. This example allows users to track the relatively subtle differences in head shape and dentition between the basal diadectomorph and synapsid. It also allows users to monitor the much more dramatic change accompanying the development of a sail within sphenacodonts. This system is being developed primarily to demonstrate relationships to users; however, it can also generate hypotheses of intermediates between known forms. Focusing on a gap between modeled taxa, interpolation techniques demonstrate the range of morphological possibilities between taxa and can be predict them in a visually dynamic way. The system correctly generated the body form for *Ctenospondylus*, a form considered intermediate in vertebral morphology between *Sphenacodon*and *Dimetrodon*. Teaching and education are often relegated to trickle down recipients of scientific research. Inverting this relationship, we see in the PATTERNS system an education and outreach tool that becomes a hypothesis generator for paleontological research.

Technical Session XI (Friday, October 11, 2019, 8:45 AM)

STABLE ISOTOPE TRACKING ON TOOTH ENAMEL OF LARGE MAMMALS IN PENINSULAR THAILAND: IMPLICATIONS FOR THE HYPOTHESIS OF AN EQUATORIAL SAVANNA CORRIDOR DURING THE LATE MIDDLE PLEISTOCENE

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The story of early human migration between mainland and island Southeast Asia is one of the most debated topics in paleontological communities today. The hypothesis of a "savanna corridor" or a band of open vegetation (seasonal forests and grasslands), stretching from mainland Southeast Asia to Java at several periods of lowering sea level and exposed land bridges though the Pleistocene glacials, has therefore been proposed to explain the facilitated migration route into Indonesian islands for early humans and associated large mammals. To test this scenario, multi-proxy evidence for the Pleistocene climatic and environmental changes in Sundaland has mostly been investigated for the central and southern portions, but rarely for the northern part (Thai-Malay Peninsula) of the Sundaic subregion.
For the past three decades, stable isotope analyses have become commonplace in paleoecological investigations. This method allows us to explore the diets and habitats of ancient animals and to reconstruct environmental and climatic conditions in the past. Here we reconstructed the Pleistocene vegetation and environments in Peninsular Thailand, using a stable carbon isotope analysis of mammalian tooth enamel from two newly excavated caves: Yai Ruak (Krabi Province) and Tham Phedan (Nakhon Si Thammarat Province). The ages of these contemporaneous faunas from both fossil sites are tentatively attributed to the late Middle Pleistocene based on the presence of an extinct subspecies of spotted hyaena *Crocuta crocuta ultima* that is recognized as being a key biochronological index in Southeast Asia. Our stable carbon isotope results indicate a variety of habitat types ranging from closed C_3 to open C_4 environments. Unlike the present-day ecosystem, a forest-grassland mosaic (more open vegetation) was dominant in this region, thus confirming the existence of the hypothesized savanna corridor in Peninsular Thailand during the late Middle Pleistocene.
However, the connection of similar open vegetation types between northern (Thai-Malay Peninsula) and southern (Java) parts of the equatorial Sundaland remains ambiguous due to the scarcity of proxy data that are submerged under the sea. In future work, further investigations into the Pleistocene environmental and climatic conditions in equatorial Southeast Asia in order to identify such a continuous/discontinuous savanna corridor is critically helpful to better understand the early human migration route to the islands as well as the complex biogeographic patterns of past and extant mammals in this region.

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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A THEROPOD REMAIN FROM THE UPPER CRETACEOUS YEZO GROUP, HABOROGAWA FORMATION IN ASHIBETSU CITY, HOKKAIDO PREFECTURE, JAPAN

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Dinosaur records from Japan have been increased in last three decades, but many of these fossils have been recovered from the Lower Cretaceous deposits. Recently, dinosaur remains from the Late Cretaceous have been discovered from the northernmost (Hokkaido) and southernmost (Kyushu) main islands of the country. Hokkaido exposes the Upper Cretaceous Yezo Group, which consists mainly of marine sediments and occasionally yields vertebrate fossils such as plesiosaurs, mosasaurs, marine turtles, and dinosaurs. Dinosaur remains from the group include a nodosaurid from the Hikagenosawa Formation (Cenomanian), a maniraptoran from the Osoushinai Formation (early Campanian), and two hadrosaurids from the Hakobuchi Formation (Maastrichtian) and from an unidentified locality of the Yezo Group.

In 2016, an isolated centrum, 89 mm long, was newly discovered from a sandstone layer of the Haborogawa Formation (Coniacian to early Campanian), which underlies the Hakobuchi Formation. The stratigraphic position of the dinosaur-bearing horizon suggests that it is dated as the late Coniacian in age. The spool-shaped centrum has paired triangular chevron facets and a dense cancellous bone and thin cortical bone with a large internal cavity at the mid-length of the centrum based on transverse CT images, indicating that it is a caudal vertebra of a theropod dinosaur. It preserves the base of a transverse process and has a low height-length ratio (0.63), suggesting that it is a mid-caudal centrum near the antero-posterior caudal transition point. This centrum also shows similarities with tyrannosauroids: height-length ratio less than 1, round edges of intervertebral articular surfaces, and amphicoelous centrum with deeper concavity of anterior surface than posterior one. The size of the centrum is comparable to "medium-sized" tyrannosauroids such as *Timurlengia* from Turonian of Uzbekistan.

This centrum is the first dinosaur remain from the Coniacian Haborogawa Formation and the fifth from Hokkaido, filling the temporal gap of dinosaur records in this region and suggesting continuous existence of dinosaurs along the coast of the northern Far East during the Late Cretaceous. It also supports the previous hypothesis that the early Late Cretaceous may have been an important time for a body size transition from small (Late Jurassic to Early Cretaceous) to large (late Late Cretaceous) sized tyrannosauroids.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

THE FIRST COMPREHENSIVE RECORD OF ELASMOBRANCHS FROM THE MID-PALEOCENE BOONGEROODA GREENSAND MEMBER OF WESTERN AUSTRALIA

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The first comprehensive record of elasmobranchs from the mid-Paleocene (upper Selandian–Thanetian) Boongerooda Greensand Member of Western Australia was compiled through bulk sampling and identification of isolated elasmobranch teeth. Four teeth potentially belonging to two new genera (Hexanchidae gen. indet.) and two new species (*Galeorhinus* n. sp., and one *Scyliorhinus* n. sp) were identified, all left in open nomenclature. A large number of isolated teeth from *Weltonia* sp*, Striatolamia* sp*., Isurolamna inflata, Foumtizia* sp*., F. abdouni, Galeorhinus mesetaensis, Paleogaleus larachei, Triakis antunesi* and *Torpedo dormaalensis* were also identified. These taxa have been described from Paleocene (Thanetian) deposits in Europe, North America and North Africa, indicating that they were cosmopolitan. The presence of one tooth with affinities to *Torpedo dormaalensis* is the second pre–Miocene report of this species worldwide.

The majority of teeth found in the Boongerooda Greensand Member are poorly preserved (rounded or splintered) with less than 3% of the elasmobranch teeth found completely intact. The presence of poorly preserved elasmobranch teeth throughout the Boongerooda Greensand Member suggest the depositional environment was in shallow water or an open marine environment above storm wave base. Analysis of planktic foraminiferal species from the Boongerooda Greensand Member indicates a tropical warm temperate depositional setting with a depth of 50–100 m. While the presence of Hexanchidae is normally an indicator of a deep-water (200 m) environment, their presence in the shallow (50–100 m) Boongerooda Greensand Member suggests that they are not an explicit indicator of deeper water environments. The presence of deeper water hexanchids into shallow water environments was not restricted to Australia, having also been recorded in Paleocene deposits in Europe and New Zealand. The movement of taxa from areas such as Northern Africa into Europe and Australia may also be the result of an ecological change brought about by the K/T boundary extinction event, such as an increase of vacant ecological niches.

Technical Session XIII (Friday, October 11, 2019, 3:45 PM)

LIMB MORPHOLOGY OF THE LATE TRIASSIC STEM TURTLE *PROTEROCHERSIS POREBENSIS* (PROTEROCHERSIDAE)

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Thus far, the limbs of only two Triassic testudinatan taxa – *Proganochelys quenstedti* and *Paleochersis talampayensis* – were described in detail. Recently, however, the Norian locality of Poręba (Poland) yielded numerous limb and girdle bones of varied sizes (and thus, probably, varied ontogenetic stages) of the older and less derived turtle, *Proterochersis porebensis*. The material gathered thus far includes epiplastra (clavicles) and entoplastra (interclavicles), a scapulocoracoid, an isolated scapula, humeri, ulnae, a partial radius, pelves, femora, and fibulae. No autopodial elements were identified yet. Since proterochersids represent the earliest branch of true turtles (Testudinata), the morphology of their appendicular skeleton is of special interest.

Unlike *Prog. quenstedti* and *Pa. talampayensis*, in *Prot. porebensis* the relatively long dorsal processes of epiplastra did not form strong connections with the carapace. The lack of a stable connection in the anterior part of the shell was compensated by a very strong connection of the sacrum and pelvis with the posterior part of the shell. The scapulocoracoid of *Prot. porebensis* is generally similar to that of the remaining Triassic turtles in its triradiate shape and enclosed coracoid foramen. The humerus of the largest specimen of *Prot. porebensis* differs from the described humeri of the remaining species in a more anterior direction of the proximal head and slightly wider and more distinct shoulder. This is less pronounced in smaller specimens. The gathered sample of humeri shows that the ectepicondylar foramen in younger individuals is open in form of a groove and became enclosed by bone later in ontogeny. The ulnae exhibit proportionally shallow sigmoid notch and small olecranon process, but this may be related to their relatively small size of the gathered specimens. The articular surface of the femoral head of small individuals lacks fine details and is rounded, while in larger specimens it becomes triangular in dorsal view, in contrast to more rectangular in *Prog. quenstedti* and *Pa. talampayensis*. In later stages of ontogeny the femora start to gain robustness proportionally faster than length.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

AN EARLY LATE TRIASSIC RHYNCHOCEPHALIAN FROM NORTHERN PANGEA SUGGESTS RELIC NATURE OF SOME BRITISH RHAETIAN VERTEBRATE ASSEMBLAGES

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Current understanding of early phylogeny of lizards and rhynchocephalians suffers from paucity of their Triassic fossils. The known Carnian rhynchocephalians are already fully acrodont and have the lower temporal fenestrae closed. *Diphydontosaurus* and *Planocephalosaurus*, less derived in this respect, are of 15-20 Ma later, late Norian-Rhaetian age. This paradox may express a relic character of some Rhaetian vertebrate assemblages or have resulted from a reversal of evolution. Two rhynchocephalian skulls from the mid-late Carnian Wozniki locality in Poland may help in solving the problem. Both specimens are incomplete but complementary to each other. The enlarged posteriormost tooth on the dentary, incomplete lower temporal bar, fused frontals, two enlarged tooth rows on the palatine and other features suggest that the new material belongs to *Planocephalosaurus*. Maximum Parsimony and Chronophyletic analyses support monophyly of the genus. The new species is the oldest member of the lineage filling the long temporal gap in the early evolution of rhynchocephalians. Few morphological differences between Carnian and Rhaetian members of *Planocephalosaurus* suggest that the primitive aspects of its osteology were conserved for most of the Late Triassic (237-201 Ma). This suggests that the Rhaetian vertebrate assemblages from the British Isles are to some degree relic.

Grant Information:
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Romer Prize Session (Thursday, October 10, 2019, 11:45 AM)

LOOSENING THE MACROEVOLUTIONARY RATCHET: DOES DIETARY PLASTICITY ALTER MORPHOLOGICAL INSIGHTS INTO CANID EVOLUTION?

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The macroevolutionary ratchet, exemplified by the canid family (Mammalia: Carnivora), is a pervasive pattern of iterative clade replacement whereby increasingly specialized species are eventually driven to extinction and replaced by younger, more generalized species. However, specialization and its link to extinction has traditionally been inferred from morphological traits alone (e.g., body mass, molar surface area) rather than from direct dietary reconstruction. While a species' morphology reflects its overall dietary capability, individuals frequently forage in ways that morphology cannot predict. Thus it is the dietary plasticity of populations, which isn't captured by morphology, that truly defines a species' dietary specialization. I tested the association between dietary specialization and lineage extinction by quantifying the dietary niche of 9 extinct species (representing the Hespercyoninae, Borophaginae, and Caninae subfamilies) over the past 33.3 million years of Canidae evolution using Dental Microwear Texture Analysis (DMTA). DMTA quantifies microscopic wear patterns on tooth enamel that capture a comprehensive picture of dietary resource use. Species' dietary specialization was calculated using multi-dimensional Bayesian ellipsoid volumes of DMTA parameter space and correlated with their duration as estimated using PyRate. I found dietary specialization as inferred from DMTA to be a better predictor of species duration than all considered measures of morphology, including the commonly used metric of body mass ($\Delta AICc > 2$). DMTA data also suggested hypercarnivory is positively linked to body mass, consistent with metabolic scaling theory. Counter to expectations, I observed a positive correlation between specialization and lineage duration ($p < 0.05$; $_{adj}R^2 = 0.38$), that specialization was lowest for canids of intermediate body mass, and that specialization was not correlated with traditionally-used dietary categories (i.e., hypo-, meso-, or hypercarnivory). My results therefore run counter to the macroevolutionary ratchet hypothesis, suggesting that overspecialization in diet alone was not enough to drive iterative extinctions in canids. Instead, I suggest that dietary specialization offers selective advantages during times of fluctuating prey abundance that facilitated the coexistence of a diverse canid assemblage in the Tertiary.

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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

FOSSIL BIRD BONES FROM THE SUBANTARCTIC AUCKLAND ISLANDS

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Thousands of Holocene fossil bones were collected between 1963 and 2018 from dune deposits on the uninhabited subantarctic Auckland Islands, south of New Zealand. The island group has a rich seabird fauna and a distinctive land bird fauna with many endemic taxa. However, between 1840 and 2000 at least four extinctions occurred due to predation by introduced mammals and human hunting (a duck *Mergus australis*; two petrels *Pelagodroma marina* and *Pelecanoides georgicus*; and a plover *Thinornis novaeseelandiae*). The fossil fauna is dominated by small seabirds still found at the island group (diving petrels *Pelecanoides* spp. and prions *Pachyptila* spp.) but a wide range of other taxa have also been found, including nearly all species that breed at the island group today. Several vagrant seabird taxa were found, including king penguin *Aptenodyptes patagonicus* and Kerguelen petrel *Lugensa brevirostris*. Additionally, fossils have revealed one previously unknown extinct species (a raven *Corvus* sp.) and that some taxa used to be more widespread, e.g., the Auckland Island rail *Lewinia muelleri* formerly lived on Enderby Island. This information on prehistoric distributions will assist the management of the avifauna of the Auckland Islands which is currently the subject of a major ecological restoration programme.

Romer Prize Session (Thursday, October 10, 2019, 9:30 AM)

STRONTIUM ISOTOPES: A NEW TOOL FOR EXPLORING MIGRATORY BEHAVIOURS IN ORNITHISCHIAN DINOSAURS

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When studying the paleoecology of long extinct animals, interpretations are made based on highly incomplete data preserved in the fossil record. With no possibility of observing these organisms living in their natural habitats, interpretations rely on body fossils, trace fossils, the rock record, and observations of similar living taxa. In order to model past behaviours, novel approaches to cut through the gaps inherent to the fossil record must be developed. Migration is one such behaviour which has a large impact on how animals utilize the resources in their environment and significantly impacts the ecology of that environment. Paleontological migration studies primarily rely on geographic fossil distributions, limited trackway evidence, paleo-environmental interpretations, and biomechanical reconstructions, and while these techniques allow for judging if migration is plausible or likely, they are generally unable to definitively show or quantify this behaviour.
In this study, a procedure is developed to estimate the actual range and maximum migration distances carried out by large herbivorous dinosaurs using strontium isotopes preserved in tooth enamel. Enamel is known to be the most resistant tissue in the vertebrate skeleton to diagenetic alteration, making an ideal source for original biological information. As strontium enters the body through diet without fractionating, the environmental signal of strontium isotopes is directly preserved in the hard tissues of vertebrates. Since large herbivorous dinosaurs such as hadrosaurs and ceratopsians had relatively rapid tooth replacement rates and complex dental batteries with multiple generations of teeth present, they have the potential to record changes in the environmental strontium isotopic signature resulting from movements from one locality to the next. Comparing these results to localized environmental values (determined from co-occurring enamel samples of non-migratory taxa such as freshwater fish) allows for estimations of migratory behaviour and distances in these dinosaurs. Using this method, Alberta hadrosaurs are estimated to range less than 100km in an east-west orientation. This method is also currently being applied to approximate the migratory range of a ceratopsian herd from Southern Alberta. The results of this study show this technique to be a potentially powerful tool for studying migratory behaviour in fossil taxa, opening up a new avenue through which we can achieve greater ecological understanding of paleoenvironments.

Grant Information:
Jurassic Foundation Grant
Dinosaur Research Institute Grant

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

MYSTERIOUS METOPOSAURIDS – PALEOHISTOLOGY HELPS TO UNDERSTAND INTERSPECIFIC VARIETY AMONG LATE TRIASSIC AMPHIBIANS

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Temnospondyli is a large clade of extinct amphibians, with cosmopolitan distribution and wide time occurrence (from Carboniferous to Cretaceous). Metoposauridae is a group restricted only to the Late Triassic but commonly known worldwide (Poland, German, Portugal, Morocco, and India). It makes metoposaurids the excellent case taxon to find out histologically how the growth pattern varies in one taxon but from different geographical localities and finally to check if and how the local conditions did influence the growth. The analyzed material includes *Metoposaurus krasiejowensis* from polish locality Krasiejów, *Dutuitosaurus ouazzoui* from Morocco and *Panthasaurus maleriensis* from India. The paleohistological analysis was conducted on long bones (21 humeri and 24 femora) using standard petrographic thin sections.
On the histological level, all taxa represent common pattern independent of the locality with the dominance of parallel-fibred bone mixed with lamellar bone and similar organization of the vascular canals. The most important differences between localities are observable in the origination of the growth marks (thickness of the zones and annuli and presence of the Line of Arrested Growth). In *Metoposaurus krasiejowensis* two growth systems has been observed (H1 represents an alternating growth; H2 represents a rapid growth) which are not connected to the size and individual age of the bone. The typical LAGs are not observed there. *Dutuitosaurus* shows both histological patterns first with thick zones, thin annuli, and annual LAGs and the second with rapidly growing zones. *Panthasaurus maleriensis* represents both histotypes of *M. krasiejowensis* but as an age-dependent system (small bones - rapid growth, larger bones - alternating growth).
For *Metoposaurus* and *Dutuitosaurus* the expressed pattern is strictly related to the local climate. The lack of typical, annual LAGs in both histotypes of

Metoposaurus inform that the local conditions were milder in Krasiejów, and even during a dry season, slow growth was possible. *Dutuitosaus* had to face very dry conditions and was forced to annual aestivations, expressed as regular LAGs. *Panthasaurus* after the juvenile phase of the fast growth shows the alternation, which could mirror the change of the ecological niche by an adult. However, currently the explanation of this phenomenon is not possible and other methods, e.g., geochemistry, need to be applied.

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Technical Session XIV (Friday, October 11, 2019, 4:00 PM)

RECRUITMENT OF CROWN-CLADE PENGUINS INTO NEW ZEALAND

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Around one quarter of the world's approximately 360 extant seabird species breed in New Zealand today. Resolving the timing and geographic origins of the New Zealand seabird fauna has been hindered by a generally sparse fossil record for most seabird lineages. Penguins (Aves: Sphenisciformes) are the exception, and a well-preserved group of Pliocene penguin fossils from New Zealand provide some of the first insights into a long history for crown seabird genera in the region. We have discovered an extinct species within the crested penguin genus *Eudyptes* from Late Pliocene sediments (ca. 3 Ma) in the North Island of New Zealand. Several endemic species within *Eudyptes* live in the region today which raises the possibility that New Zealand has been continually inhabited by this genus for at least the last several million years. The Pliocene *Eudyptes* is represented by bones from several individuals and is principally distinguishable from extant congenerics by cranial morphology. The Pliocene species has a more-slender bill compared with extant crested penguins. Using phylogenetic analysis of variance we find that krill are an important source of food for living penguins that have relatively deep mandibles, which includes most extant *Eudyptes*. Ancestral state reconstruction methods suggest that that the mandible deepened during the crown radiation of *Eudyptes* which may reflect a change in diet over time for this group. The discovery of the Pliocene *Eudyptes* species sheds new light on similarly-aged penguin material from New Zealand. Ancestral area estimates across a phylogeny inferred with Bayesian methods indicate that *Eudyptes* and the closely related yellow-eyed penguins (*Megadyptes*) have lived in the New Zealand region since at least the Early Pliocene.

Grant Information:
Massey University Research Fund
Massey University Innovation and Excellence Grant

Romer Prize Session (Thursday, October 10, 2019, 10:30 AM)

ONE SKINK, TWO SKINK, BIG SKINK, BLUE SKINK: MIOCENE ORIGINS AND PLIO-PLEISTOCENE GIGANTISM IN THE AUSTRALASIAN GENUS *TILIQUA* (SQUAMATA: SCINCIDAE)

THORN, Kailah M., Flinders University, Aberfoyle Park, Australia

The social lizards of the Egerniinae repeatedly evolved large body sizes; one species now the world's largest living skink. Nowhere is this trend towards gigantism more apparent than within the charismatic blue-tongue lizards of the genus *Tiliqua*. I examine how and when this group managed to grow so large, how their body shapes became so diverse and I explore how a pygmy species appeared amongst giants. Discrete and continuous morphological characters, combined with molecular data, were analysed with both parsimony and tip-dated Bayesian methods. Three fossil *Tiliqua* species were added to these analyses, *Tiliqua pusilla*, a tiny middle-Miocene taxon; *Tiliqua wilkinsonorum*, a large Pliocene taxon; and *Tiliqua frangens,* an extinct Pleistocene 'megafauna' shingleback. The resulting tip-dated total-evidence phylogeny suggests that the most rapid morphological evolution in the Egerniinae, in the Oligo-Miocene, produced the highly distinctive body forms typical of *Tiliqua*, and the clade *Cyclodomorphus*. Within *Tiliqua*, phyletic gigantism began after the middle Miocene, and peaked in the Plio-Pleistocene with two giant taxa. There are also examples of: autapomorphic nanism, which produced the endangered pygmy *Tiliqua adelaidensis*, sister taxon to one of the largest extant egerniines, *T. rugosa;* and phyletic nanism, a trend in decreasing body size which produced the clade inclusive of the small *Cyclodomorphus branchialis*. Knowledge of how and when these body size changes occurred would not have been possible without a total-evidence phylogeny of this group. This investigation has uncovered another exception to Cope's rule that bodies grow larger through evolutionary time, and highlighted the morphological diversity of Australia's previously underrepresented fossil herpetofauna.

Grant Information:
Supported by an Australian Government Research Training Program Scholarship

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

SAUROPOD DINOSAUR TRACKS AND ASSOCIATED SEDIMENTARY STRUCTURES IN THE BROOME SANDSTONE (CRETACEOUS) OF WESTERN AUSTRALIA.

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Since the early 1990s ongoing research has revealed the existence of many and varied dinosaur tracks in coastal exposures of the Broome Sandstone (Lower Cretaceous, Valanginian?) of the Dampier Peninsula, in the Kimberley region of Western Australia. This ichnofauna constitutes practically the entire record of dinosaurs in the western half of the Australian continent and is distinctly more ancient than the better-known Cretaceous dinosaur faunas of eastern Australia (Queensland, Victoria). The dinosaurian ichnofauna includes evidence of theropods, ornithopods and thyreophorans ('stegosaurs'?), but is overwhelmingly dominated by the tracks of sauropods. While the exact identity of these sauropod track-makers cannot be established with certainty, they seem most likely to have been brachiosaurs and titanosaurs – or, at least, titanosaur relatives such as *Diamantinasaurus*, *Wintonotitan* and, perhaps, the still-enigmatic *Austrosaurus*. Most of their tracks are exposed in the form of transmitted reliefs ('undertracks') and, in places, these are so densely concentrated as to deform the substrate into discrete basins and troughs which are sometimes large enough (>30 metres diameter) to be mistaken for minor tectonic features. These gigantic basin-like structures clearly qualify as some of the largest dinosaurian fossils on Earth, and on the basis of their seemingly unique properties they are designated Foulkesian basins – to mark their discovery by the late Paul Foulkes, an amateur naturalist who imagined them to be dinosaurian wallows or 'rolling-over areas'. Good examples are found in the region of James Price Point (Walmadany), on the western coast of the Dampier peninsula, north of Broome.
Unfortunately the existence of these structures may have been called into doubt by reports that failed to detect them (or, at least, failed to mention them) and, in some instances, claimed that the sauropod tracks were merely erosional features (potholes) or fossil traces of rays or turtles. Here it will be reiterated that all adequately preserved examples exhibit the diagnostic morphological features of sauropod tracks. Moreover a previously unexplored body of evidence will confirm the existence of Foulkesian basins in the region of James Price Point.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

CRANIAL MORPHOLOGY OF *HSIANGOLESTES* (MAMMALIA: INSECTIVORA) AND *NARANIUS* (MAMMALIA, CIMOLESTA) AND PHYLOGENY OF BASAL INSECTIVORES

TING, Suyin, Louisiana State Univ, Baton Rouge, LA, United States of America; WANG, Xiaoming, Natural History Museum of Los Angeles County, Los Angeles, CA, United States of America; MENG, Jin, American Museum of Natural History, New York, NY, United States of America

Recent studies of *Hsiangolestes youngi* and a new species of *Naranius,* based on complete and partial skulls and mandibles, provide detailed information on their cranial morphology and shed new light on their phylogenetic position and the relationships of early insectivores. New materials of these taxa were discovered from the Early Eocene Lingcha Formation, Hengyang Basin, China, where the negative excursion in $\delta^{13}C$ values marking the Paleocene-Eocene boundary was recognized. Specimens were collected from the sediments about 15m above the Paleocene-Eocene boundary. These fossils were involved in the faunal transition and exchange in response to the global climate warming.
We coded 290 dental and cranial characters and selected 36 species for the phylogenetic analysis. *Hsiangolestes youngi* is a taxon endemic to Asia. It is a genus initially placed in the family Didymoconidae, order Insectivora, later grouped under order Cimolesta, and then referred to family Micropternodontidae, order Lipotyphla. Our study shows that *Hsiangolestes youngi* is closely related to *Sinosinopa sinensis*, *Sarcodon pygmaeus*, and *Prosarcodon lonanensis*, for which we suggest creation of family

Sarcodontidae, Insectivora incertae sedis. Given the only known cranial character, lack of a large contribution to the orbital wall of the maxilla, of *Hsiangolestes youngi*, we suggest excluding Sarcodontidae from Lipotyphla. The taxa in Sarcodontidae previously assigned to Micropternodontidae are mainly based on large hypocone and expanded hypocone-shelf of upper molars; however, these characters in sarcodontids differ from those of the latter. Family Micropternodontidae may better be restricted to *Micropternodus borealis* and its North American allies.
The type species of *Naranius*, *N. infrequens*, is from Early Eocene Bumban Member of Naran Bulak Formation, Tsagan-Khushu, Nemegt Basin, Mongolia, and was a genus in the family Paleoryctidae, order Proteutheria, and later assigned to the family Cimolestidae, order Cimolesta. The new species differs slightly from the type species in the cranial morphology. Our study indicates that *Naranius* is well clustered with *Cimolestes*. The only known species of *Naranius* outside of Asia, *N. americanus* from Tuscahoma Formation, Lauderdale County, Mississippi, United States, is represented by two isolated molars. Its dental similarities to the molars of *Naranius* are mainly primitive characters, and the classification is uncertain.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

AN EARLY-DIVERGING CROCODYLOMORPH FROM THE EARLY NORIAN (LATE TRIASSIC) OF DOCKUM GROUP, TEXAS

TO, Khanh H., Virginia Tech, Blacksburg, OK, United States of America; NESBITT, Sterling J., Virginia Tech, Seattle, WA, United States of America; STOCKER, Michelle R., Virginia Polytechnic Institute and State University, Blacksburg, VA, United States of America

Archosaurs, after first diversifying by the Early Triassic, continued their diversification into the Late Triassic, specifically the late Carnian to early Norian. Within this radiation, the coeval diversification of dinosaurs and crocodylomorphs (pseudosuchian clade more closely related to crown Crocodylia than to aetosaurs, rauisuchids, poposauroids, phytosaurs, and ornithosuchids) appeared in the fossil record. However, the precise timing of this diversification, order of anatomical transformations, and biogeographic patterns of early crocodylomorphs are poorly understood. The oldest forms (231-227 Ma) are from higher latitudes (*Trialestes* from Argentina), whereas the fossil record in low latitudes (e.g., *Dromicosuchus* and CM 73372 from North Carolina and New Mexico, respectively) lies in younger strata (early and late Norian, respectively). Thus, the Carnian and earliest Norian record remains unclear. However, the Otis Chalk localities in the Dockum Group of Texas host one of best known early Norian terrestrial faunal assemblages, including early diverging forms of temnospondyls, dinosaurs, phytosaurs, and crocodylomorphs. Here we describe the first early-diverging crocodylomorph from the Otis Chalk localities, represented by TMM 31100-1494, a nearly complete right ilium. This ilium has a concave ventral acetabulum edge, a supra-acetabulum buttress, and a hypothesized long anterior process, bracketing the specimen as an early-diverging crocodylomorph similar to CM 73372. The presence of this taxon in the Otis Chalk localities fills in both a chronological and geographical gap for early-diverging Crocodylomorpha. The Otis Chalk localities were biochronologically constrained to be 8-11 million years older than those of *Dromicosuchus* and *Hesperosuchus* but still younger than the *Trialestes* localities. Geographically, this specimen connects the known range of the clade from southern high latitudes (*Trialestes*) to the low latitudes and suggests that crocodylomorphs were widespread across what is now North America early in their history. The Otis Chalk crocodylomorph adds to the wide array of early-diverging crocodylomorphs present in the Late Triassic and shows that early members of this clade diversified across a wide range of paleolatitudes.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

REFINED AGE AND GEOLOGICAL CONTEXT OF TWO OF AUSTRALIA'S MOST IMPORTANT JURASSIC VERTEBRATE TAXA (*RHOETOSAURUS BROWNEI* AND *SIDEROPS KEHLI*), SURAT BASIN, QUEENSLAND

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The current Jurassic vertebrate fossil record in Australia is extremely sparse, with only two temnospondyl amphibians and two dinosaur taxa identified to date. Remains of several freshwater plesiosaurs have also been uncovered; however, these are still unnamed. Of the identified taxa, the spectacular and extremely well-preserved giant amphibian, *Siderops kehli*, and the only known pre-Cretaceous sauropod in Australia, *Rhoetosaurus brownei*, are perhaps the most important. The age of both specimens, and the stratigraphic context of *Rhoetosaurus brownei,* are weakly constrained and imprecisely defined, which limits our understanding of their evolutionary relationships within a broader Gondwanan context. To clarify and contextualise the evolutionary relationships and ages of these two iconic Jurassic taxa, we used U-Pb detrital zircon geochronology to date the sandstone matrix from around the bones of these historic Queensland Museum specimens. A robust maximum depositional age for *Siderops kehli* was calculated at 176.6 Ma ± 2.0 Ma, indicating that it is no older than late Toarcian, which refines existing biostratigraphic estimates. The *Rhoetosaurus brownei* maximum depositional age was determined at 162.6 ± 1.1 Ma, no older than early Oxfordian, demonstrating that the fossils are much younger than expected, and confirms a Walloon Coal Measures stratigraphic origin.

Grant Information:
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Technical Session III (Wednesday, October 9, 2019, 2:00 PM)

CARNIVOROUS MAMMALS FROM THE MIDDLE EOCENE WASHAKIE FORMATION, WYOMING, U.S.A., AND THEIR DIVERSITY TRAJECTORY IN A POST-WARMING WORLD

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The middle Eocene Washakie Formation of southwestern Wyoming, U.S.A., provides a rare window into the faunal transition within a single depositional basin over the period of gradual cooling that followed the early Eocene warming events. To investigate temporal changes in the mammalian carnivore assemblage, we conducted extensive re-examination of previously-reported materials and identification of newly-cataloged specimens. As a result, we now recognize a minimum of 28 species of mesonychians, oxyaenodontans, hyaenodontans, and carnivoramorphans, more than doubling the previous taxic count. This diverse array of carnivores includes up to ten possibly new taxa. The result of our cladistic analysis of early Carnivoramorpha, incorporating new data from the Washakie fossils, suggests a clade of derived non-carnivoran carnivoraforms in the late Bridgerian to early Uintan of the central Rocky Mountain region exhibiting clear variations in body size and dental adaptation. We also observe coupled trends of body-size increase and modifications toward more sectorial teeth in several distantly-related lineages spanning a wide range of body size. Model-based Bayesian analysis of diversity dynamics accounting for imperfect detection of taxa revealed a high probability of substantial loss of carnivore species between the late Bridgerian and early Uintan, coinciding with disappearance from the basin of formerly common mammals such as the hyopsodontid *Hyopsodus* and the adapiform primate *Notharctus*. These observations are consistent with a major biomic transition in the region involving opening-up of forests, the macroevolutionary consequences of which warrant further investigation.

Grant Information:
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Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

WALKING WITH DINOSAURS: THE USE OF PALEOICHNOLOGICAL SITES AS TOOLS FOR EDUCATION AND OUTREACH

TORICES, Angelica, Universidad de La Rioja, Logroño, Spain; FERRER VENTURA, Mireia, Universidad de La Rioja, Logroño, Spain; NAVARRO LORBES, Pablo, Universidad de La Rioja, Logroño, Spain; SAN JUAN PALACIOS, Raul, Universidad de La Rioja, Logroño, Spain

La Rioja, Spain, has an extremely rich paleontological heritage. This Spanish province has a fossil record that expands from the Cambrian to the Pleistocene. However, it is La Rioja lower Cretaceous sites, famous for dinosaur footprints, the ones that are more known to the general public. There are around 150 paleontological sites and more than 10000 dinosaur footprints studied. This extraordinary fossil record has been used for the development of a summer course program at University of La Rioja that has been active since 1980 till 2014 under the supervision of Dr. Felix Perez Lorente. More than

2000 students worked in this summer course that allowed them experience paleontological fieldwork for the first time in many occasions.
The summer course was not opened for three years until 2017 and has gained popularity in this last two years that has been reinstated. The course is opened to undergraduate and graduate students from all disciplines, so it is not limited to geology and biology students. During the course, students learn techniques in restoration and preservation of paleoichnological sites, not only in theory, but applying those techniques directly to the sites under supervision. Also, they have the opportunity to learn the application of new technologies, as photogrammetry, that are used nowadays in paleoichnological studies and conservation. Students are, also, given research projects to develop at the site and are encouraged to present the results at young researchers' conferences and seminars. They also have the opportunity to attend to an employment workshop so they can learn all the options paleontology has to offer.
Paleontological sites are chosen, not only because of their scientific value, but also for the outreach potential they have. The sites are always very near to towns and in touristic routes so we can combine paleontological outreach with fieldwork. In this way we can communicate directly with the visitors and complement the work done at the local paleontological centers to promote the paleontological heritage in the region.
Associated to the summer course we organize a series of conferences, open to the public, so we can show new paleontological discoveries and invite national and international researchers to share their work.
Therefore, this summer course at University of La Rioja is not only a good opportunity for undergraduate and graduate students to gain experience at fieldwork and research but also an opportunity to promote paleontology as a useful tool for outreach and economic development of the region through tourism.

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 9:30 AM)

FOSSIL EVIDENCE FOR A MIOCENE TURNOVER IN AUSTRALIAN BANDICOOT DIVERSITY AND A PLIOCENE ORIGIN FOR THE MODERN GENERA

TRAVOUILLON, Kenny, Western Australian Museum, Welshpool, WA, Australia; MYERS, Troy, University of New South Wales, Bowral, Australia; BLACK, Karen H., University of New South Wales, Sydney, Australia; GUROVICH, Yamila, University of New South Wales, Sydney, Australia; BECK, Robin, University of Salford, Salford, United Kingdom; LOUYS, Julien, Griffith University, West End, Australia; PRICE, Gilbert, The University of Queensland, Redbank Plains, Australia; ARCHER, Michael, University of New South Wales, Maroubra, Australia; HAND, Suzanne J., University of New South Wales, Sydney, Australia; MUIRHEAD, Jeanette, University of New South Wales, Sydney, Australia

The middle Miocene climate oscillation (MMCO) is a major climatic event that led to the extinction of many vertebrate lineages and diversification of many others. The fossil record of Peramelemorphia, an order of marsupials that includes bandicoots and bilbies, is best represented in Miocene deposits of the Riversleigh World Heritage Area, northwestern Queensland. Prior to the MMCO, peramelemorphians were highly diverse, occupying niches (medium-sized carnivore and small insectivore) that are today occupied by dasyuromorphians. After the MMCO, several peramelemorphian genera disappeared, vacating some of these niches. We present here a new synthesis of the diversity of peramelemorphians before the MMCO, including recognition of a new genus and species that exhibits features (enlarged lower canine with thickened bone around it on the dentary, and significant size reduction of the premolars) that are unlike those of any previously known peramelemorphian. These unique features may relate to some specific resource or challenge present in Miocene rainforests that did not survive the post-oscillation contraction of these previously widespread closed forests. We compare the diversity of pre-, to post-middle Miocene and Pliocene of peramelemorphians. We also present a new phylogenetic overview, including the new genus and species that incorporates both molecular and morphological data. Our results suggest that modern peramelemorphians underwent an adaptive radiation triggered by the extinction of medium-sized peramelemorphian carnivores and small peramelemorphian insectivores and speciation of the medium-sized omnivores, caused by long term climate change.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

TAPHONOMIC ANALYSIS OF AUSTRALIAN OWL PELLET ASSEMBLAGES AS ANALOGUES FOR QUATERNARY DEPOSITS AT NARACOORTE CAVES, SOUTH AUSTRALIA

TRELOAR, Jessie-Briar, The University of Adelaide, Adelaide, Australia; REED, Elizabeth H., The University of Adelaide, Naracoorte, Australia

Quaternary vertebrate fossil assemblages from caves are a crucial resource of paleoecological information, particularly for small mammals which often are the most abundant vertebrates represented in these deposits. The World Heritage listed Naracoorte Caves in South Australia have multiple finely resolved deposits that span a near continuous record of the last 500,000 years. Naracoorte's small mammal assemblages are diverse, abundant and contemporaneous in deposits with megafauna, other vertebrates, plants remains and paleoclimate proxies. Small mammal paleoecological data can be used to help answer crucial questions about past environments and provide insight into vertebrate community responses to change over key periods such as the megafauna extinction window.
The major accumulator of small mammal remains in caves is generally considered to be via regurgitated remains in owl pellets; however, other potential modes of accumulation for small mammals may contribute remains. Taphonomic biases in these cases are not fully understood and lead to misleading paleoecological interpretations. We investigated the modern taphonomic signatures of small mammal bones from the pellets of five Australian owl species and developed a categorical system for the modifications (breakage type, corrosion and size) produced by each owl species. The modern analogue examples were compared with Quaternary fossils from two Naracoorte cave deposits to assess the proportion of small mammal remains that were deposited via owl pellets (and which owl species was responsible), and the proportion that accumulated via other modes such as pitfall entrapment.
As small mammal remains are important paleoecological indicators it is crucial that biases are fully understood and considered when making paleoecological interpretations. Our study provides a taphonomic model to facilitate thorough analysis of small mammal paleoecology at the Naracoorte Caves. These data will allow for a greater understanding of how small mammal remains are deposited in cave systems in Australia and as these systems are similar in other continents this study will have applications to small mammal paleoecology elsewhere.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 8:45 AM)

EXCEPTIONAL 3D PRESERVATION OF SOFT TISSUES AND ORGANS IN THE VERTEBRATE FAUNA FROM THE LATE DEVONIAN GOGO FORMATION

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The Gogo Formation has long been recognized for the exceptional 3D preservation of original bone in a diverse vertebrate and invertebrate fauna that once inhabited the Frasnian reef environment. Fossils were first collected in the late 1960s; however, it was not until 2000 that the first soft tissues were recognized. The first soft tissues recovered from vertebrates were small patches of muscle in placoderms (basal jawed vertebrates) which had been removed from carbonate nodules by acetic acid. Recent collecting has shown soft tissue in varying amounts and preservation styles in all taxa from the Gogo Formation.
To date the most extensive amounts of vertebrate soft tissue have been recovered from placoderms where large blocks of muscles allow for the complete musculature of the neck and body to be determined. Metamerically segmented body musculature has also been recovered from a sole acanthodian specimen, a yet to be described chondrichthyan and actinopterygians. The extensive amount of muscle present from multiple taxa has enabled the evolutionary history of the vertebrate musculature to be determined.
In addition to muscle preservation several taxa preserve organs, including the heart and liver, and the skin with its lateral line is preserved in the chondrichthyan. Soft tissue preservation also confirms the earliest evidence of live birth by the presence of a mineralized umbilical cord in a ptyctodont placoderm, the embryo still within the abdominal cavity of the adult. The presence of the umbilical cord indicates that these fishes were viviparous.
Soft tissue is not particularly decay resistant. The preservation of soft tissue in the Gogo Formation appears to be the result of the combination of bacterial sulfate reduction and rapid burial in a low oxygen environment. Mineralization was rapid enough for high fidelity preservation of some of the muscle fibres, and some organic molecular breakdown products within the fish scales. These discoveries represent the oldest 3D preservation of vertebrate muscle and organs known to date.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

NEW SKELETAL MATERIAL SHEDS LIGHT ON THE EVOLUTION AND PALEOBIOLOGY OF KOALAS

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Koalas (Marsupialia; Phascolarctidae) are a temporally and spatially widespread family represented by a single extant species, Australia's largest arboreal folivore *Phascolarctos cinereus*. In contrast to the modern lack of diversity, fossil phascolarctids are speciose, with 17 species from 10 genera described from the last ~26 Ma. Previous paleobiological interpretations have been limited by a lack of postcranial material. Inferences based on craniodental material inferred that phascolarctids have occupied a sedentary, arboreal specialist niche throughout their evolutionary history. Here, we describe the limbs and tail of the first near-complete skeleton of an Oligo-Miocene (24 - 26 Ma) phascolarctid—*Madakoala devisi*—from the Namba Formation, Lake Frome Basin, South Australia. Our dental analysis indicates that diagnostic characters of *Madakoala wellsi* reflect ontogenetic, rather than taxonomic, differences from *M. devisi* and thus *M. wellsi* should be considered a junior synonym. To elucidate the functional capabilities of the taxon, we compare the skeletal morphology with extant marsupial species using convergent eco-morphological models. An analysis of post-cranial characters reveals that *M. devisi* was a highly mobile arboreal specialist with an elongate, semi-prehensile tail, similar in ecological niche and locomotory style to the extant possum, *Pseudocheirus peregrinus*. This novel interpretation differs markedly from previous inferences and demonstrates that the evolutionary history of phascolarctids is more complex than has previously been thought.

Grant Information:
Funding provided by project: T.H. Worthy, A. Camens. Expanding the vertebrate fossil record of the Frome Basin, South Australia. Sir Mark Mitchell Research Foundation, 2016.

Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 9:00 AM)

HOWE QUARRY (UPPER JURASSIC MORRISON FORMATION, WESTERN U.S.A.), A HOT SPOT FOR SAUROPOD SOFT TISSUE

TSCHOPP, Emanuel, American Museum of Natural History, New York, NY, United States of America; WIEMANN, Jasmina, Yale University, New Haven, CT, United States of America; DELA PIERRE, Francesco, Universita di Torino, Turin, Italy; CAVAGNA, Simona, Universita di Torino, Turin, Italy; NORELL, Mark A., American Museum of Natural History, New York, NY, United States of America

Sauropod soft tissue reports are restricted to a few occurrences of skin impressions associated with skeletal material and/or footprints, and a single occurrence of possible cartilage preservation. Here, we present numerous new soft tissue samples from Howe Quarry, a site from the Upper Jurassic Morrison Formation. Howe Quarry is among the few localities from where sauropod skin impressions in association with skeletal remains have been reported in the past. The skin impressions have two different morphologies, one forming relatively large hexagons, and a second one being composed of small, irregularly shaped bumps. These skin impressions are always covered with a dark layer. Additionally, pneumatic cavities within cervical vertebrae of diplodocid sauropods are lined with a reddish layer. We analyzed the micromorphology and chemical composition of these layers with a series of methodologies, including scanning electron microscopy (SEM), environmental SEM, energy dispersive x-ray spectroscopy (EDS), fluorescence microscopy, ultraviolet photography, decalcification, and raman spectroscopy (RS). The micromorphology of the dark layer on the skin impressions shows mostly smooth surfaces, but with areas marked by structures that have been interpreted as both bacterial mats and melanosomes in the past. EDS analysis shows high amounts of carbon and oxygen, confirming the organic origin of this layer. Skin samples react strongly to UV light and fluorescence microscopy, with a distinct reaction from adhesives, plaster, sediment, and bone. RS reveals the typical signal of eumelanin, indicating that some of the structures seen under the SEM might represent melanosomes. Decalcification of the reddish layer lining the pneumatic chamber resulted in the recovery of fragments of a membrane, likely representing the membrane of the air sac that occupied the pneumatic chamber. RS of these samples show a distinctive signal that is different from both the adjacent bone and sediment, and also lacks the eumelanin peak seen in the skin samples. Hence, Howe Quarry is not only an important site for its 20-25 partly articulated individual skeletons of sauropod dinosaurs, but also preserves an array of soft tissue that will help us understand the paleobiology of these animals in more detail.

Grant Information:
Division of Paleontology and Theodore Roosevelt Memorial Fund, American Museum of Natural History
Train2Move Marie Curie Actions COFUND

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A NEW ORNITHOMIMID (THEROPODA, ORNITHOMIMOSAURIA) FROM THE UPPER CRETACEOUS NEMEGT FORMATION OF BUGIIN TSAV, MONGOLIA

TSOGTBAATAR, Chinzorig, Institute of Paleontology and Geology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia; KOBAYASHI, Yoshitsugu, Hokkaido Univ, Hokkaido, Japan

The Upper Cretaceous Nemegt Formation (upper Campanian-lower Maastrichtian) of the Nemegt Basin of Mongolia is one of the most fossiliferous terrestrial rock units in Asia. Skeletal remains of ornithomimid dinosaurs are relatively abundant among other dinosaurs in this formation. The first ornithomimid, which is composed of three nearly complete skeletons, collected by the Polish-Mongolian Paleontological Expedition and Mongolian Paleontological Expedition between 1965 and 1967 from this formation is *Gallimimus bullatus*. Since then, two more definitive ornithomimosaurs, *Anserimimus planinychus* and *Deinocheirus mirificus*, have been described from the same formation so far.
In the summer of 1995, the Japan-Mongolian Paleontological Expedition found a nearly complete articulated ornithomimid skeleton with a skull from the formation at Bugiin Tsav locality, in the northwestern part of the Nemegt Basin of the Gobi Desert. Here we describe a complete skeleton of an ornithomimid specimen, which provides a great deal of anatomical information and disparities of ornithomimosaurs and helps us to understand interrelationships within ornithomimosaurs.
This new specimen shows the following unique features: sharply recurved ungual I and straight unguals II and III, hump-like tubercle on the dorsal margin of manual ungual I, reduced distal condyles of metacarpal I, pronounced anterior extension of pubic boot, and anteroposteriorly flat articular surfaces of anterior caudals. Our phylogenetic analysis suggests that it belongs to derived ornithomimosaurs and forms a monophyly with *Anserimimus, Qiupalong henanensis*, and the North American taxa. This suggests that it is a new taxon and is the fourth definitive ornithomimosaur from the Nemegt Formation of Mongolia, demonstrating greater diversification in the latest Cretaceous in Asia than previously thought.
Differences in hand structure of this new taxon may show difference in its function from the other Nemegt ornithomimosaurs. The Nemegt ornithomimosaurs reveal wide variations in hand morphology, demonstrating these ornithomimosaurs could have co-existed by having niche partitioning.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

NEW SPECIMENS OF *NYANZACHOERUS* (MAMMALIA, ARTIODACTYLA, SUIDAE, TETRACONODONTINAE) FROM THE UPPER MIOCENE NAKALI FORMATION, KENYA

TSUBAMOTO, Takehisa, Ehime University, Matsuyama, Japan; KUNIMATSU, Yutaka, Ryukoku University, Kyoto, Japan; MANTHI, Fredrick K., National Museums of Kenya, Nairobi, Kenya; NAKATSUKASA, Masato, Kyoto University, Kyoto, Japan

The upper Miocene Nakali Formation (*ca.* 10 Ma) of central Kenya is one of the important localities of vertebrate fossils particularly in anthropology and primatology because the formation yields several taxa of monkeys and apes. Since 2002, a joint research team from Kyoto University of Japan and National Museums of Kenya has been conducting paleontological field research in the Nakali Formation and has collected many fossil specimens of mammals.
Here, we report new gnathodental specimens of *Nyanzachoerus* (Mammalia, Artiodactyla, Suidae, Tetraconodontinae) from the Nakali Formation. The Nakali *Nyanzachoerus* is characterized by a lower crown and relatively weaker furrows of the molars and proportionally larger P3–P4 compared to M3 among the species of the genus, implying that it is morphologically most primitive among the genus and is assigned to a new species of the genus. It shows close morphological similarities of the dentition with a Pliocene Asian tetraconodontine genus *Sivachoerus*, implying a possible closer phyletic relationship of *Sivachoerus prior* with the Nakali *Nyanzachoerus* rather than with *Nyanzachoerus tulotos* or *Nyanzachoerus devauxi*. This phyletic relationship implies a possibility that *S. prior* diverged from a stock of the

Nakali *Nyanzachoerus* during the early late Miocene (Tortonian) in East Africa and then the lineage moved from East Africa to Asia. It stressed that there seem to be a problem of paraphyly of the genus *Nyanzachoerus*.

Grant Information:
JSPS KAKENHI Grant Numbers 25257408 and 16H02757 (to M. Nakatsukasa) and 16K07534 (to T. Tsubamoto).

Technical Session VII (Thursday, October 10, 2019, 8:30 AM)

ECOMORPHOLOGICAL AND ALLOMETRIC SIGNATURES IN ENDOCRANIAL SHAPE IN CROCODYLIANS

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It is well established that ecological transitions are often associated with morphological transformations. The degree to which brain morphology keeps pace with other morphological changes is, however, less well established. Extinct crocodylomorphs exhibit an impressive range of ecologies, spanning fully marine taxa to small herbivores and terrestrial predators across a wide body-size spectrum. This past ecological diversity stands in contrast to modern crocodylians, which are largely semiaquatic ambush predators. Nevertheless, extant forms do show variation in their habitat preferences. Alligators and caimans are saltwater intolerant with dwarf caimans (*Paleosuchus*) inhabiting fast-flowing forested cold-water rivers. Some crocodylids show preference to freshwater systems (*Crocodylus johnstoni*), whereas others (*C. porosus*) prefer coastal saltier waters, while still others prefer rainforest river systems (*Mecistops* and *Osteolaemus*) like their cousins the dwarf caiman or are extreme piscivores like *Gavialis*.
To explore how ecological preferences may be reflected in brain morphology, we used a high-density 3D morphometric approach on cranial endocasts of a broad sample of extant and extinct crocodylians. Endocranial shape broadly exhibits phylogenetic clustering where major clades occupy different, but overlapping regions of the morphospace. Combined with a time-calibrated phylogeny, we performed a suite of comparative phylogenetic analyses. Results indicate that allometry accounts for nearly a third of the endocranial shape variation after correcting for phylogenetic structure. Notably, habitat preference was associated with over half of the total variation in endocranial shape, particularly an enlarged medulla in more salt-tolerant taxa. This brain region is responsible for homeostatic functioning and may have been selected for in marine and marine-tolerant species. Our work indicates that ecomorphological changes extend to brain morphology, especially in regions relevant to functional demands of the environment. Stated another way, neuroanatomical shape has the potential to infer the ecological preferences of extinct vertebrates.

Grant Information:
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Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

PALEONTOLOGICAL INVESTIGATION OF A MIDDLE PLEISTOCENE VERTEBRATE FOSSIL ASSEMBLAGE FROM SPECIMEN CAVE, NARACOORTE, SOUTH AUSTRALIA

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The Naracoorte Caves World Heritage Area (NCWHA), located in southeast South Australia, is one of the world's only fossil localities that preserves a near-continuous fossil record of the last 500 kya. Despite decades of paleontological research, there is a paucity of sites that record vertebrate faunas from ~100 ka to ~200 ka years. This study presents the first systematic excavation and paleontological study of Specimen Cave, one of the region's only known fossil-bearing sites dating to this 'gap'. The primary aim of the study was to determine which species were present at the time of deposition and build on the scant existing Specimen Cave faunal list derived from surface collections in 1908. Faunal data from Specimen Cave were compared to similar data from other NCWHA deposits to provide context for the results of this study. Additional aims were to determine the mode of accumulation, paleoenvironment and proximal vegetation. Fossils analysed in this study were collected from Specimen Cave by the author during the first documented excavation of this cave.
The fossil assemblage preserves a rich and diverse vertebrate fauna, similar to other NCWHA deposits. It is dominated by small mammals, particularly rodents, which make up 85% of the identified specimens. This is a common feature of many NCWHA fossil deposits, as well as modern-day Australian animal communities. The high relative abundance of rodents in the deposit is interpreted to accurately represent their dominance in the paleocommunity. The large mammal component of the fauna, which makes up <5% of the identified fauna, is dominated by macropods. An important feature of the large mammal fauna is the presence of 10 megafauna species. The presence of these animals provides the first robust evidence that certain megafauna species persisted in the region between 100 ka and 200 ka years. The mode of accumulation of the deposit was inferred based on specimen density and the body mass and locomotion of the identified species. The most likely mode of accumulation was a pitfall trap, indicated by the presence of large mammals and the high numbers of saltatory species within the large mammal fauna. Analysis of habitat and dietary preferences of the faunal assemblage suggests the proximal environment was most likely open forest or woodland interspersed with grasslands. The large numbers of woodland species and the apparent coexistence of browsing and grazing macropods support this.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

THE DENTITION AND SKELETON OF *MOOREODONTUS*: NEW INSIGHTS INTO THE ORIGIN AND DEVELOPMENT OF THE TRIASSIC XENACANTH SHARKS

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Triassic xenacanths are known from several Australian localities; the first recorded specimens, "*Pleuracanthus*" *parvidens* (ASW Woodward), came from the Middle Triassic Anisian Ashfield Shale (Wianamatta Group), Sydney Basin, New South Wales. The NSW material has been assigned to *Mooreodontus*, a genus based on isolated Upper Triassic (Carnian) teeth from England. Despite long-standing discussion about generic assignment of xenacanths based on dental features, the Australian articulated material has never been studied in detail. We review the holotype of *M. parvidens* and describe additional new Anisian material from Picton (*M. parvidens*) and Somersby (juvenile/subadult individuals probably a new species).
Mooreodontus has distinct features: 1) lacks a dorsal fin spine in contrast to other xenacanth taxa from the stem *Diplodoselache* to derived *Triodus* and *Xenacanthus* where the spine is present and develops early in ontogeny; 2) a prominent squamation, a shared feature with *Diplodoselache*, *Lebachacanthus* and *Triodus*; 3) a single dorsal fin, starting behind the pectoral girdle, extends along the complete body in contrast to other xenacanths where a caudal fin is quite distinct from an elongated dorsal fin; 4) two anal fins are located in a posteriormost relative position at the level of the caudal vertebrae. Consequently, *Mooreodontus* differs from *Triodus* and *Xenacanthus,* where the anal fins are located close to the pelvic fins and the caudal fin is very well developed approaching a diphycercal morphology; 5) Heterodonty. The individual dental variation includes teeth with the diagnostic features of *Mooreodontus* (i.e., a drop-shaped, lingually pointed bases) and with a rounded lingual margin, which might also be attributed to the genera *Triodus, Xenacanthus and Tikiodontus*.
In conclusion, *Mooreodontus* is a specialised derived xenacanth with several dermal and endoskeletal features that distinguish it from the Carboniferous to Permian xenacanths *Triodus* and *Xenacanthus*. The mosaic of dental features shown by the articulated specimens explains the wide morphological variability already seen in isolated Triassic teeth and the difficulties to distinguish the genera. Future detailed studies of the dentition of articulated Australian material will improve knowledge of the possible diagnostic dental features and allow a more appropriate taxonomic asssignment of isolated teeth from Paleozoic localities (e.g., Corumbataí Fm. at the Paraná Basin, Brazil) where *Mooreodontus* appears to be present together with other xenacanths.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

"BONE HUNTERS" PROJECT – AUSTRALASIAN WOMEN IN VERTEBRATE PALEONTOLOGY

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Women have been pioneers in vertebrate paleontology since the early 19th century to the present day, with an increasing presence in the last 50 years. Our research is creating a history that highlights the important roles and challenges they have overcome to gain degrees and employment. We are delving into their lives and examining work done. Women 'bone hunters' were scarcer in 19th to early 20thcentury Australasia but as in other continents were often 'hidden', as illustrators (Hobson) or unpaid research assistants (Longman). Gaining training and professional employment came slowly, firstly because PhDs were unobtainable until post-WWII and there were few universities or museums with suitable mentors. Professor Dorothy Hill was one who published on vertebrate remains, especially from Queensland and despite this being outside her main research interests. In Australia, much work has been done by incoming researchers from elsewhere, some of whom came to stay – Vickers-Rich (ex U.S.A.), Howie-Warren, Turner (ex U.K.) (all long-standing SVP members) – and these in turn paved the way for later home-grown women to pursue careers in paleontology. Others changed direction: Joan Wiffen in New Zealand was a teacher until retirement allowed her to pursue 'bone hunting'; Mary Wade moved across country when she gained a full-time museum job in Queensland took on the mantle and went on to augment the VP collections and bring to light highly important sites and taxa, including the iconic Lark Quarry Winton dinosaur footprints, work done in conjunction with RA Thulborn of the University of Queensland. Rare VP meetings, such as at IGC 1976, occurred before 1987 when the Conference on Australian Vertebrate Evolution Paleontology and Systematics (CAVEPS) series of symposia began in Brisbane. Funding is elusive and so amateurs, fostered in the late 20th century by Frank Holmes' Fossil Collectors' Association of Australasia, and volunteers have significantly contributed to VP work. A definitive and on-going list of women in VP, both past and present (>1700 strong and counting!), has been developed in the last 18 months; biographic chronologies are being prepared that will be submitted online. Our on-line database of Women in Vertebrate Paleontology (see Research Gate project www.researchgate.net) is available for review, revision and updates. NB. we need your help in our search for names, photos and contributions of women VPs that have collected, taught or pursued research in our discipline.

Grant Information:
Turner acknowledges a Facebook Personal Fundraiser that has supported work this year – thanks to all who contributed.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

GEOCHEMICAL TAPHONOMY OF *TYRANNOSAURUS REX* MOR 1125, THE FIRST CRETACEOUS FOSSIL TO YIELD ENDOGENOUS PROTEIN SEQUENCES

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In 2005, demineralization of a fragment of the femur of *Tyrannosaurus rex* specimen MOR 1125 revealed a new mode of soft tissue preservation which captivated the public and scientific community alike: bone cells and pliable tissues. Although similar cells and soft tissues have since been recovered from more than 50 other Mesozoic and Cenozoic bones, the taphonomic and geochemical conditions leading to such remarkable preservation remain unclear. To explore this topic, we used LA-ICPMS to examine the trace element composition and geochemical history of acclaimed specimen MOR 1125. Our analyses revealed this specimen to exhibit modest rare earth element (REE) uptake compared to most other Cretaceous bones tested to date, but with surface concentrations of light REE comparable to those of other bones previously analyzed from the Hell Creek Formation. Although REE concentrations steeply decrease with cortical depth, indicative of a single phase of simple diffusive uptake, considerable heavy REE (HREE) enrichment was observed within the middle and internal cortices. This combination of elemental signatures is consistent with protracted uptake from relatively HREE-enriched river water and/or diagenetic pore fluids under oxidizing conditions (inferred from the specimen's positive cerium anomaly), which is in turn consistent with recovery of the skeleton from a well-sorted sandstone deposited in an estuarine setting. Relative enrichment in HREE and uranium in the internal cortex also partially reflects changing chemistry of the pore fluid as it percolated through the bone, resulting in fractionation in REE uptake over time. Combining these results with traditional taphonomic data (i.e., minimal weathering and abrasion, disarticulated but closely associated remains) reveals that this specimen underwent skeletonization during prolonged, subaqeous decay in a sandy estuary channel and, following burial, its bones remained exposed to an oxic, potentially brackish water-derived pore fluid through early diagenesis and fossilization; no other interactions with pore fluids during late diagenesis are evident. Our study thus demonstrates the power of trace element analyses to elucidate biomolecular preservation pathways by illuminating the postmortem history of skeletal remains and chemical regime(s) of the depositional environments in which they were interred. The exceptional detail that trace element analyses can provide into fossil diagenesis also makes these methods invaluable toward clarifying molecular preservation mechanisms.

Grant Information:
Rowan University Seed Funding Program

Technical Session XIII (Friday, October 11, 2019, 2:30 PM)

VARIATION IN AUSTRALIAN CRETACEOUS SAUROPTERYGIAN AND ICHTHYOPTERYGIAN POSTCRANIAL MATERIAL

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The lower level taxonomy of Early Cretaceous Australian marine reptile fossils is based mainly on skull morphology, but many specimens lack skulls. This research compared the morphology and morphometrics of vertebrae from previously undescribed and published specimens of Australian plesiosaurs and ichthyosaurs from the Queensland and Richmond museums and from published sources outside Australia. Morphological analysis included variation in size, shape and structure of vertebral elements including centra, zygapophyses, diapophyses and neural spines as possible. Biometric analysis involved measurement of parameters such as height, width, and length of centra, width of zygapophyses, angle between diapophyses and centre of centrum, height of neural spine, height and width of neural canal and distance between the plesiosaur cervical foramen. Vertebral Length Index, Height Index and Breadth Index also were calculated. Patterns of vertebral morphometrics were found to be useful for distinguishing Australian ichthyosaur specimens and morphometric data add a new criterion for evaluating ontogenetic stage. Vertebral data suggest that more than one taxon of Australian ichthyosaur may exist, complicating the status of the only currently recognised species, *Platypterygius australis*. Vertebrae also were found to be useful for distinguishing Australian plesiosaurs with the clearest distinction made at family level where a polycotylid was easily distinguished from all elasmosaurids in all plots. Australian elasmosaurs were distinguished readily from non-Australian elasmosaurs (from literature). However, it is less clear if analysed Australian elasmosaurs represent one or more taxa and further study is required. Regardless, the data suggest that Australian taxa may represent an endemic clade within the elasmosaurs, which is consistent with the restricted intracontinental Eromanga Sea. Patterns in vertebral morphometrics also were found to distinguish juvenile and adult *Styxosaurus*. Hence, it is clear that vertebrae can be useful for taxonomy and assignment of Australian marine reptile remains even where skulls are lacking. However, additional work is required to combine analyses of skulls and associated vertebrae, where possible, and include more specimens to better define intraspecific and ontogenetic variability and test for any sexual dimorphism in both groups.

Preparators' Session (Thursday, October 10, 2019, 2:00 PM)

PREPARATION OF WET VERTEBRATE FOSSILS: DEVISING STRATEGIES TO MITIGATE DAMAGE

VAN BEEK, Constance J., The Field Museum, Chicago, IL, United States of America; SHINYA, Akiko, The Field Museum, Chicago, IL, United States of America

The Field Museum of Natural History has worked in the Chronister Dinosaur Site in southeastern Missouri, U.S.A. for the past three seasons and collected over 80 specimens in 12 plaster field jackets. The quarry is a wet, clay-rich matrix. Preparation of materials from the site has been challenging. The wet specimens are unsafe to prepare due to no separation between clay and fossil. Three different field jackets were opened at different times in order to compare the desiccation process and to determine the best approach to prepare the fossils.

The first field jacket containing a skull and cervical vertebrae was opened immediately after returning from the site to gradually dry the contents under a controlled environment. Matrix and fossil material were still wet. A weekly consolidation with an aqueous glue, 10% Acrysol WS24, was applied; and a large perforated plastic tarp was placed over the jacket over two months. Toilet paper infused with polyethylene glycol (PEG) was used to fill

desiccation cracks for stability. After the clay dried completely, the mechanical preparation began; and the fossil was consolidated with 10% Paraloid B72. The second field jacket containing forelimb elements had a rounded and smooth edge. It was left untouched for about a year, so the contents were allowed to completely dry before opening it. The shrinkage of the clay was apparent with a gap of ¾" away from the jacket walls, but the contents uniformly shrank with only a few cracks. The forelimb elements showed very little distortion, but porous fossils were fragile; so frequent B72 application was required. The third field jacket of about 6 feet in length and a foot in width and depth contained semi-articulated caudal vertebrae. When the jacket was opened after four months, the contents were still moist and unsafe to prepare; so it was left to dry for an additional month. Several large cracks had formed, as the clay was constrained by the shape of the field jacket. The large fissures were filled with PEG, and B72 was used for consolidation of exposed fossil material.
The preparation of three field jackets showed that a gradual drying method with frequent WS24 application was the most effective method. Cracks and fissures could be filled with toilet paper and impregnated with PEG for stabilization. B72 could be used after specimens had totally dried. The rounded edge of the field jacket was advantageous for uniform shrinkage of the wet clay within the jacket, therefore minimizing the formation of desiccation cracks.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

THE EARLY PLEISTOCENE TERRESTRIAL VERTEBRATE FAUNAL SEQUENCE OF JAVA, INDONESIA.

VAN DEN BERGH, Gerrit D., University of Wollongong, Wollongong, Australia; PRASETYO, Unggul W., Museum Geologi Bandung, Bandung, Indonesia; SETIYABUDI, Erick, Museum Geologi Bandung, Bandung, Indonesia; PUSPANINGRUM, Mika R., Bandung Institute of Technology, Bandung, Indonesia; KURNIAWAN, Iwan, Museum Geologi Bandung, Bandung, Indonesia; STOREY, Michael, Natural History Museum of Denmark, Copenhagen, Denmark

The terrestrial vertebrate fauna sequence of the island Java, Indonesia, is comparatively well known, although to date there is no consensus on the absolute dating of the fauna succession. Some of the established fauna units are based on fossil-rich layers or terrace fills, which are thought to represent relatively short periods of time. Examples of these are the Middle Pleistocene fossil assemblage from Trinil, type locality of *Homo erectus*, and the late Middle to Late Pleistocene assemblage from the terrace fill at Ngandong. The oldest fauna that has been recognised on Java is the Early Pleistocene Satir Fauna. The composition of this Fauna is based on contents of five excavations performed during the 1930s by the then Geological Survey of the Dutch East Indies in the basal layers of the Kali Glagah Formation (KGF) near the village Satir in Central Java. The age of the Satir Fauna is estimated to be around 2 Ma. The Satir Fauna has been interpreted as representing insular conditions, based on its limited number of taxa, all pertaining to groups that have been frequently documented from insular conditions (*Hexaprotodon* sp., *Megalochelys atlas*, *Sinomastodon bumiajuensis*, and cervids).
The Satir Fauna is succeeded by the poorly documented Ci Saat composite "Fauna", which is based on scattered finds from the middle and upper fluvial sections of the 575 m thick KGF, mostly collected during 1930s. It is thought that the Ci Saat stage represents the first full land connection with the Asian mainland, based on the occurrence of an increasing number of taxa –including carnivores– and the arrival of *Stegodon* replacing *Sinomastodon*.
Since the establishment of the fossil collections from the 20th century, little systematic fossil collecting has taken place in the region. In order to refine the biostratigraphy of the Early Pleistocene Ci Saat faunal stage of Java, we conducted systematic surveys in the KGF along the Ci Saat River and its tributaries. We performed several test excavations and collected fossils on the surface. Coordinates of all finds were recorded with GPS. Our study focused especially on diagnostic fossils from excavations, and surface-collected fossils from small tributaries with drainage areas limited to exclusively the basal, middle or upper parts of the KGF. $^{39}Ar/^{40}Ar$ dating on hornblendes from pumice clasts from a laharic layer at the boundary between the KGF and the overlying Menger Formation, provided a minimum age of 1.5 Ma for the upper part of the KGF and its fossil content. The results and implications will be discussed during the presentation.

Grant Information:
Financial support for this study was provided by the University of Wollongong and the Geology Museum Bandung

WITHDRAWN

$\Delta^{15}N$ AND $\Delta^{13}C$ STABLE ISOTOPES FROM PRESERVED ORIGINAL TISSUES SHED LIGHT ON EXTINCT ECOSYSTEM TROPHIC LEVELS

VAN DER REEST, Aaron J., University of Alberta, Edmonton, AB, Canada; CURRIE, Philip J., University of Alberta, Edmonton, AB, Canada

Paleo-ecology, community interactions, and niche partitioning have become a focus of study in ancient ecosystems for which data is available. Depositional environments such as those of the Dinosaur Park Formation, Canada, the Jehol biota of the Jiufotang and Yixian Formations, China, and the famous Jurassic beds of Lyme Regis, U.K. , provide opportunities to investigate ancient ecosystems. Classical techniques such as sedimentology, paleobotany, micro-vertebrate assemblages, faunal diversity, tooth mark analysis, *etc*., have been used for decades as indicators of paleo-community structure and niche partitioning. In modern and recently extinct paleo-ecosystems, stable isotopes such as ^{2}H, ^{13}C, ^{15}N, and ^{18}O, can be used to understand paleo-climate, migration patterns, and faunal diet. After an organism consumes food, organic nitrogen is metabolized, enriched, and incorporated into its own tissues such as collagen and blood vessels, thus, these tissues can be used to investigate faunal diet. During metabolism, enrichment of $\delta^{13}C$ and $\delta^{15}N$ occurs, resulting in an increase of approximately 3‰ per trophic level. Although this technique is used frequently in archeological and anthropological studies worldwide, it was believed to be impossible for trophic levels in deep time because original tissues were thought to not preserve. Studies of original tissues preserved in fossil bone, however, indicate otherwise. Late Cretaceous bone from Alberta, Canada, that produced large amounts of tissue structures after dissolution in EDTA were analyzed for $\delta^{13}C$ and $\delta^{15}N$. Results not only support these structures are original organic compounds and not contamination, but also indicate that trophic information can be obtained. Mega-herbivores posses $\delta^{15}N$ ranging from 3-5.5‰ like large extant C3 consumers and carnivorous taxa are typically above 5‰ $\delta^{15}N$. Juvenile *Champsosaurus* specimens at 3.2‰ $\delta^{15}N$, indicate potential insectivorous diet early in ontogeny. This new technique provides the first potentially reliable method to investigate extinct ecosystems and niches from deep time and may reveal the diets of enigmatic animals.

Technical Session III (Wednesday, October 9, 2019, 3:15 PM)

DIET RECONSTRUCTION IN CAVE BEARS FROM MANDIBULAR MORPHOLOGY

VAN HETEREN, Anneke H., Bavarian State Collection of Zoology, München, Germany; FIGUEIRIDO, Borja, Universidad de Málaga, Málaga, Spain

The cave bear (*Ursus spelaeus sensu lato*) is an enigmatic extinct animal that inhabited the European ice-age ecosystems during the Pleistocene. Closely related to the living brown bear (*Ursus arctos*), reconstructions of the cave bear diet have concerned scientists almost since its discovery by Johannes Christian Rosenmüller in 1794. The diet of the cave bear is a controversial topic, as different paleobiological approaches (e.g., dental wear, isotopic biochemistry, skull morphometrics) result in different dietary inferences for the cave bear, ranging from carnivory to pure herbivory. Here, we perform morphometric analyses of the cave bear mandible.
A set of 3D-landmarks were collected from a sample of 103 bear specimens, including 13 specimens of cave bears, and subjected to Procrustes superimposition. To test for the presence of allometry, the Procrustes coordinates were regressed against the log-transformed centroid size. We also computed phylogenetically independent contrasts of mandible shape and size. The axes of maximum shape variance were explored by using a PCA performed on the regression residuals of shape on size pooled-within species using a phylomorphospace approach. Moreover, we reconstructed the evolutionary trajectory of the cave bear mandible from the hypothetical shape of its inferred ancestor.
Our results indicate that the mandible of the cave bear possesses specific traits related to the capability of exerting the high bite force required for feeding on though foods. This is indicative of a highly-herbivorous diet or, at least, more herbivorous than their closest living relative, the brown bear. The cave bear plots away from all other bears in an almost unoccupied region of the morphospace constructed from the first two eigenvectors obtained from PCA, which suggests that they were exploiting vegetal resources not currently exploited by living bears. The mandible shape trajectory followed by the cave bear indicates that its shared traits with the giant panda were not present in the *U. arctos*-*U. maritimus*-*U. spelaeus* common ancestor and, instead, were acquired throughout the evolution of the 'speloid' lineage, as some were already present in the mandible of the more basal *Ursus deningeri* from the middle Pleistocene of Eurasia.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

RESOLVING THE TAXONOMIC VALIDITY OF THE GIANT EXTINCT MARSUPIAL *NOTOTHERIUM* (DIPROTODONTIDAE) AND ITS RELATIONSHIP TO *ZYGOMATURUS*

VAN ZOELEN, Jacob D., Flinders University, Adelaide, Australia; CAMENS, Aaron B., Flinders University, Adelaide, Australia; PRIDEAUX, Gavin J., Flinders University, Adelaide, Australia

The megafaunal herbivores of the family Diprotodontidae were integral members of terrestrial ecosystems in Australia and New Guinea until the last-surviving and largest-ever diprotodontid, *Diprotodon optatum*, became extinct c. 40,000 years ago. Despite their iconic status as the largest-ever marsupials and the frequency with which their remains are encountered, key aspects of their systematics and evolutionary history remain poorly resolved. There is no clearer example of this than the taxonomic confusion surrounding the late Cenozoic genera *Nototherium* Owen, 1845 and *Zygomaturus* Macleay, 1858, which has persisted for more than 160 years. This is attributable to: 1) the highly fragmentary fossil material upon which the original two species of *Nototherium* were founded; 2) the destruction of the lectotype of *N. inerme* during World War II; and 3) marked similarities in the size and shape of the jaws and teeth of species referred to *Nototherium* and *Zygomaturus*. Most recently, this has led to *Nototherium* and its original two species, *N. inerme* and *N. mitchelli*, being relegated to *nomina dubia*. However, re-appraisal of the type material plus new material recently uncovered, including two crania, has shed light on the taxonomy and distinctiveness of *Nototherium* and provided evidence for its validity. Here I reassess the systematics and distribution of *Nototherium* and *Zygomaturus* and provide a preliminary diagnosis of the two most convergent and oft-confused species, *Nototherium inerme/mitchelli* and *Zygomaturus trilobus*.

Grant Information:
Royal Society of South Australia
College of Science and Engineering Flinders University
University of California Museum of Paleontology

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

THE RICH ICHNOLOGIC RECORD OF EGG MOUNTAIN FROM THE TWO MEDICINE FORMATION (UPPER CRETACEOUS) OF MONTANA, U.S.A., PROVIDES INSIGHT INTO THE ENVIRONMENT, SEDIMENTOLOGY AND ECOLOGY OF A DINOSAUR NESTING SITE

VARRICCHIO, David J., Montana State Univ, Bozeman, MT, United States of America; FREIMUTH, William J., Montana State University, Bozeman, MT, United States of America; PANASCÍ, Giulio, Montana State University, Bozeman, MT, United States of America

The Upper Cretaceous Egg Mountain locality is a rich dinosaur nesting site that famously produced the first dinosaur eggs from North America and multiple clutches for the theropod *Troodon formosus*. Recently, the site has produced several well-preserved mammals and lizards. In addition to abundant skeletal and egg remains, several kinds of trace fossils indicate abundant biological activity, representing nesting, dwelling, and feeding behaviors. We report the first comprehensive overview of trace fossils from the site. Reproductive traces of both vertebrates and invertebrates are pervasive. Eggs and eggshell represent five different oviparous vertebrates that bury or partially bury their eggs within the substrate. These include eggs for the dinosaurs *Troodon, Maiasaura*, and the ootaxon *Continuoolithus,* as well two thin, un-ornamented varieties of eggs of unknown identity. Insect pupation structures are abundant throughout the less than 3 m section and suggest workable, well-drained soil conditions persisted with relatively low sedimentation rates throughout the time of deposition. Their abundance corroborates semi-arid, seasonally dry conditions of the Two Medicine Formation and may indicate relatively sparse vegetation. Furthermore, enigmatic hemispherical structures may represent invertebrate dwelling and feeding traces and add to the diversity of burrowing soil organisms at the locality. Vertebrate feeding traces are represented by three morphologies of coprolites and multi-individual, crania-skewed assemblages of small vertebrates (mammals and lizards) that may represent regurgitated gastric pellets and/or prey-processing locales. Though the specific producers of these feeding traces are difficult to determine, they offer unique insight into trophic interactions at the locality. Overall, the striking abundance of trace fossils suggests a suitable environment for both soil-dwelling organisms and nesting vertebrates. Large, well-preserved bones are notably absent from the site. The trace fossil assemblage is dominated by *in situ*terrestrial activity with the majority of the invertebrate (insect pupation) and vertebrate (nesting activity) traces representing subsurface activity. The record of biotic activity is a unique window into the ecology and environment of a Cretaceous dinosaur nesting locality.

Grant Information:
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Technical Session I (Wednesday, October 9, 2019, 11:00 AM)

NEW DATA ON THE NEOGENE MARINE MAMMAL FAUNAS OF THE EASTERN NORTH PACIFIC

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Marine sedimentary deposits from the eastern North Pacific region provide us with a nearly continuous record spanning the last 30+ million years. Some of the major transition in the evolutionary history of marine mammals are recorded within these deposits and allow us to look at the timing of these events at different scales. Herein we reviewed published observations and add new data of Miocene-Pliocene marine mammals based mainly on the NHMLA and OCPC collections. Our data includes specimens from formations spanning from Washington to Baja California Sur. Occurrences are vetted on a site-by-site basis, with updated chronostratigraphic and taxonomic information, allowing for more precise first and last appearance dates.
Preliminarily, some of the patterns observed hint at major changes around the mid Tortonian (~9-8 Ma) as follows. Platanistoids, present in the region since the Oligocene, disappeared ~9 Ma, roughly coinciding with the first appearance of lipotids in the late Tortonian (~8 Ma). Kentriodontids are restricted to Aquitanian to early Tortonian deposits, contrasting with Western Atlantic faunas where they persist until the Pliocene. Crown group delphinoids appear by the late Tortonian and are still present, with some (e.g., monodontids) now restricted to the Arctic. Pinniped assemblages shift from those comprised of desmatophocids, stem otariids, and basal odobenids during the Burdigalian through Langhian to those dominated by large odobenids, including the appearance of neodobenians. Herbivorous marine mammals are present in Burdigalian-Langhian deposits, including multi-species communities of desmostylians and dugongids. However, by the late Serravalian through early Tortonian, herbivore diversity declines with the local extinction of dugongines and desmostylians, after which only hydrodamalines remain.
Our data hints at major faunal changes around the mid-late Tortonian (~9-8 Ma), including the local extinction of some odontocetes, desmatophocids, and desmostylians, and the evolution and diversification of several modern groups such as delphinoids and neodobenians. The appearance and predominance of benthic-feeding taxa, and kelp-eating sirenians by the late Miocene can be correlated with increasing upwelling along the eastern North Pacific which led to changes in benthic productivity and the evolution of large, fast growing algae. Ongoing work aimed at narrowing the chronostratigraphic range of poorly constrained formations in California and Mexico will allow us to improve upon these observations.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

EVOLUTIONARY TRENDS OF *PROTYPOTHERIUM* LINEAGE THROUGHOUT THE MIOCENE-PLIOCENE OF SOUTH AMERICA

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Protypotherium (Interatheriinae, Notoungulata, Mammalia) is a well-known and very diverse genus of extinct native ungulates of South America, widely distributed from southern to middle latitudes of Argentina, Chile, and Bolivia. This genus exhibits distinctive species throughout the different biozones from the Miocene to Pliocene that display an interesting size pattern. Three species from the late Early Miocene, *P. attenuatum* (small), *P. praerutilum* (medium), and *P. australe* (large); two species from the Middle to early Late Miocene, *P. endiadys* (small) and *P. colloncurensis* (large); two species from the Late Miocene, *P. minutum* (small) and *P. distinctum* (large); and only one species from Late Miocene-Pliocene, *P. antiquum* (large). The large sample of specimens studied during several years of research allow to us to analyze the shape and size of upper and lower molars for all the species of *Protypotherium*, in order to test the hypothesis of reduction of size ranges preserving a general tooth morphology as a response to climate deterioration. Elliptic Fourier analyses (EFA) were used to capture the shape of the occlusal

morphology and the centroid size (CS) was also retained for subsequent analyses. Our results demonstrate that: 1) in general, a similar morphological tooth pattern is observed among all species from Miocene to Pliocene; 2) there is a tendency to increase the size from the smallest species of the late Early Miocene (e.g., *P. australe*) to the largest one in the Late Miocene-Pliocene (*P. antiquum*); 3) tooth shape variation is not associated with a change in size (CS), both in upper and lower molars and between small and large species; 4) a decrease in the number of species is recorded from three in the early Miocene to one in the Late Miocene-Pliocene. This striking pattern could be correlated with a global trend to lower temperatures, which indicates a deterioration of paleoenvironmental conditions. In South America, a markedly descend of temperature occurred during Miocene times that is also testified by paleoflora and the marine environmental. Given this paleoenvironmental context, a successful conservative tooth pattern, together with an increase of size and a reduction in number of species were the main evolutionary and ecological tendencies accounted in *Protypotherium* from the Miocene to Pliocene.

Technical Session XIII (Friday, October 11, 2019, 3:00 PM)

PATTERNS OF OSSIFICATION IN THE VERTEBRAL COLUMN OF AMNIOTES AND THEIR ANCESTRAL CONDITION

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Ossification in the axial skeleton of amniotes displays a great diversity with regards to relative timing and overall patterns. Unfortunately, due to the infrequent preservation of ontogenetic sequences in the fossil record and limited research interest, the evolutionary history of these patterns remains poorly understood. Thanks to several exceptionally well-preserved specimens of the early Permian mesosaurid sauropsid *Stereosternum tumidum,* we were able to observe mineralization gradients along the spine and retrace the ossification sequences of several vertebral elements. In this study, we focused our attention on four major traits for which we reviewed the state of knowledge in amniotes and performed ancestral state reconstructions: (1) the number of loci from which neural arches ossify, (2) the number of loci from which centra ossify, (3) the number of loci and direction of neural arch fusion, and (4) the spreading direction of neurocentral suture fusion. For all examined traits, it appears that the condition in *Stereosternum* represents the plesiomorphic state not only for sauropsids but for amniotes in general. Neural arch and centra ossification first occur in one locus in the anterior cervical region and progress posteriorly along the spine. Similarly, fusion of initially paired neural arch elements first occurs in the anteriormost cervicals and then follows a “zipper-like” cranio-caudal gradient. Conversely, closure of the neurocentral sutures begins in the last caudal vertebrae and then proceeds anteriorly from that point. These patterns seem to constitute a major difference between the sauropsid and the synapsid lineages, the latter being more diverse with regards to the number of loci and direction of ossifications. Modes of neurocentral suture closure appear to vary substantially within the sauropsid lineage, with marked differences between major clades, suggesting that these characters may bear more phylogenetic signal than previously realised. However, further research is necessary to refine our more detailed and deep-time understanding of the evolutionary history of these traits.

Grant Information:
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Technical Session VIII (Thursday, October 10, 2019, 3:00 PM)

A 3D GEOMETRIC MORPHOMETRIC ASSESSMENT OF INTERPOPULATIONAL CRANIAL DIVERSITY OF THE MARSUPIAL DASYURUS HALLUCATUS

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The morphological identification of mammalian species can be challenging when there is substantial intraspecific diversity in the paleontological record. Finding the morphological patterns that lead to intraspecific differentiation can be a useful tool to address this issue. Here, we use the extant Northern quoll as an ideal species for testing if, and how, local adaptation to ecologically distinct environments can lead to divergence in cranial shape between genetically close relatives. The Northern quoll used to be distributed throughout a large part of northern Australia. However, its distribution is now fragmented into genetically distinct, isolated populations separated by major biogeographic breaks, which may have begun to partition their range well before the first records from the European settlement. Despite this relatively short time of isolation, fast phenotypic adaptation is expected due to the short life span of this species. Here, we use 3D geometric morphometrics to quantify the full 3D cranial shape variation of 181 Northern quoll individuals belonging to four mainland populations and several island populations. 900 landmarks were used in this study, including 101 fixed landmarks, 93 curves and 18 patches. Procrustes ANOVA suggests significant interpopulational shape differences. Cluster analysis also reveals that these correspond to genetics-based phylogenies. Pairwise comparisons between the mean shapes of each population showed longer skulls with shorter muzzles for Queensland and Northern Territory populations, a more prominent braincase and wider muzzles for Kimberley and Pilbara populations, and smaller skulls and shorter muzzles for island populations. However, potential confounding factors include allometry, sexual dimorphism, a geographical continuum and precipitation ranges. We demonstrated a possible link to precipitation data and a longitudinal continuum, Pilbara desert individuals present acoustic-adapted basicranium shape relative to rainforest individuals with larger skulls possibly adapted to interspecific competition and a high-resource diet. For paleontological studies concerned with closely related species, our results indicate that interpopulational variation is confounded by ecological drivers and can be masked at the species differentiation level. Furthermore, the template used in this study has the potential to be applied to several mammalian taxa, allowing investigations of how these processes occur across the micro and macroevolutionary level divide.

Grant Information:
This study would have not been possible without The UQ International Research Scholarship granted to PV and the ARC Discovery Grant DP170103227 awarded to VW.

Technical Session XI (Friday, October 11, 2019, 8:00 AM)

DO RAPTOR PELLETS RECORD SMALL MAMMAL COMMUNITY COMPOSITION OR RAPTOR DIETARY PREFERENCE? A CASE STUDY IN YELLOWSTONE NATIONAL PARK

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Skeletal remains from raptor pellets have long been used to reconstruct small mammal communities, yet pellets are also commonly cited as proxies for raptor dietary preferences. While past research has shown that certain species of raptors, such as barn owls, sample local small mammal communities in proportion to their true local abundances, few studies have been conducted across multiple raptor species. This is important for understanding taphonomic biases both in modern pellet assemblages and in deeper-time accumulations of bone where raptors served as the sampling vector, as in many cave deposits.

We examined nearly 1000 pellets from seven species of avian predators including ravens and both nocturnal and diurnal raptors that were collected in the late 1990s from four localities in Yellowstone National Park, Wyoming, U.S.A. The localities differ in habitat type, vegetation structure, and climate, and therefore exhibit differences in their small mammal communities. We ask: Across these sites, do raptors differ from one another in their prey preference, or do they eat what is locally abundant? If raptor species have strong dietary preferences, we expect to find similar diets within species, across localities. If instead they eat what is locally abundant, we expect that different raptor species at the same site will have more similar diets, but their diets will differ significantly between sites.

We morphologically identified craniodental material from pellets and quantified relative abundance from the number of individual specimens. We visualized differences in small mammal prey among sites and among predator species using principal components analysis and tested for differences. Preliminary analyses show that while each raptor species does tend to eat similar subsamples of the small mammal community, most variation in raptor diet is explained by *locality*. These results suggest that raptors faithfully sample their local small mammal communities and exhibit optimal foraging instead of dietary specialization. Analysis of raptor pellets remains a promising method for accurately and non-invasively sampling past and modern small mammal communities.

Grant Information:
NSF GRFP

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

CHARACTERIZING THE ONTOGENETIC STAGE OF A VERY LARGE SPECIMEN OF *ALLOSAURUS* FROM THE JURASSIC OF WYOMING WITH SUBADULT CHARACTERISTICS

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A previously undescribed, isolated specimen of *Allosaurus* was discovered associated in 2004 in north-central Wyoming in the Jurassic Morrison Formation. Comprised of 65 cranial and postcranial elements, this specimen exhibits a unique combination of large body size with subadult characteristics. The majority of the dorsal vertebrae remain unfused, the pubes remain unfused, the coracoid is not fused to the scapula, and the majority of the cranial elements remain unfused. Additionally, the number of alveoli in the dentaries (19 and 21 alveoli) and complete right maxilla (19 alveoli) of this specimen are significantly higher than that commonly reported for *Allosaurus* (14-17 alveoli in the dentary, 15-16 maxillary alveoli). Despite these subadult characteristics, this specimen is large for an *Allosaurus* individual, with a femoral midshaft circumference of 28 cm. To reconcile the discrepancy between its size and features commonly associated with subadult individuals, we have completed a histological analysis of the only limb bone preserved, a partial right femur. As only the distal half of this bone was preserved, we made a histologic section near the broken end of the bone, approximately at midshaft. Our histologic analysis revealed expansive laminar fibrolamellar bone forming the primary cortex with minimal secondary remodeling restricted to the internal cortex. Numerous micro-fractures present throughout the cortex make the identification and tracking of the few lines of arrested growth difficult. Although closely spaced lines of arrested growth are present near the cortical edge, primary osteons remain abundant in the external most cortical rim, suggesting that an external fundamental system is not present. Therefore, we conclude this large individual was still growing but its growth had slowed down; however, it was not yet an "old" individual.

Grant Information:
Elsie Welter Endowment and Rowan University

Technical Session III (Wednesday, October 9, 2019, 3:30 PM)

JAW DISPARITY IN RELATION TO DIET IN THE ARTIODACTYLA, WITH IMPLICATIONS FOR PALEOECOLOGY

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The order Artiodactyla is a taxonomically and ecologically diverse group of mammals in the world today and has been widely studied in ecomorphological research, with important applications to paleoecological and paleoenvironmental reconstructions. Here we build on our previous study of bovids and investigate the relationship between mandibular morphology and diet in artiodactyls. We quantify mandibular shape through landmark-based geometric morphometric methods, which [illegible] limitations that arise from traditional linear measurements [illegible] mandibles [illegible] extant artiodactyl species, with an average [illegible] species per family, sampled [illegible] families within the order [illegible] Suidae, Tayassuidae, [illegible] tribes within the Bovidae, the largest [illegible] family. [illegible] mandible specimens of adult individuals from their [illegible] ranges and with no obvious pathologies were included, and specimens were sampled equally across the sexes whenever possible. Ten landmarks were chosen to capture the overall morphology of the mandible, and semi-landmarks were used to document the curvature between landmarks. Species were divided into six feeding categories based on a large dataset of detailed forage selectivity and preference compiled from the literature: obligate grazers, variable grazers, intermediate feeders, browsers, frugivores, and generalists. Results of Procrustes ANOVA show significant differences ($p<0.05$) between the jaw morphology of most feeding categories, especially in the depth of mandibular body, the length of cheek tooth row, and the shape of the angular and coronoid processes. Dietary extremes (e.g., obligate grazers vs. frugivores) are distinct in the range of their morphospace, whereas generalist and intermediate feeding categories have overlapping morphospace with other categories. We established a dietary model using the quantitative relationship between mandibular shape and diet of the artiodactyls. Our morphospace model provides a new tool for paleoecological inference for fossil ungulates, which constitute a widely distributed and diverse component of the Cenozoic fossil record of North America.

Withdrawn

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

DEALING WITH THE UNKNOWN DATA IN MAMMALIAFORM PHYLOGENY

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With accumulating fossil evidence over the last two decades, the evolutionary history of early mammals has, to a large extent, been elucidated regarding transformation and diversification of Mesozoic mammaliaforms. However, issues have been debated in recent studies concerning the divergence of crown mammals, placement of enigmatic clades, and evolutionary history of novel innovations (e.g., Definitive Mammalian Middle Ear). All topics depend on phylogeny. However, the problem of morphological character hierarchies makes phylogenetic analysis complicated and has been noticed but without any breakthrough for decades. In terms of mammaliaform phylogeny, for instance, the monophyly of allotherians has been disputed in different studies, along with swing of the placement of "haramiyidans". As such, it becomes interesting to test these disputed hypotheses by dealing with character hierarchical interdependence. Based on the newly reported single-character algorithm, we reorganize three mammaliaform character matrices from three research teams by differentiating inapplicable data from missing data, and reconstruct phylogenetic topology through ancestral state reconstruction under explicit criteria. Results from the new phylogenetic analysis show substantial differences from previous phylogenetic hypotheses on the placement of allotherians. It indicates that improvement on phylogenetic analysis method has great potential to take advantage of the inapplicable data, which is logically more informative than missing data and that the "unknown" data has great implications for the reconstruction of mammalian evolutionary history.

Grant Information:
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Technical Session XIV (Friday, October 11, 2019, 3:00 PM)

A NEW BONY CRESTED EARLY-DIVERGING AVIALAN FROM THE LOWER CRETACEOUS JEHOL GROUP OF WESTERN LIAONING, CHINA AND ITS IMPLICATION FOR EARLY AVIALAN EVOLUTION

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In the last 30 years, thousands of exceptionally well-preserved avialan fossils have been recovered from the Lower Cretaceous Jehol Group exposed in western Liaoning and the surrounding region in northeastern China. These include the early-diverging avialans Jeholornithiformes, Confuciusornithiformes, Sapeornithiformes, and Jinguofortisidae. Here we report on a new avialan specimen consisting of a nearly complete skeleton with carbonized feather traces from the Jehol Group near Jianchang. The new specimen is intermediate in size between confuciusornithiforms and sapeornithiforms; however, it is inferred to be a not-fully-grown individual based on histological features and the degree of skeletal fusion. Several unique features differentiate it from other early-diverging avialans, including an extremely short bony tail consisting of at most four free caudal vertebrae and a short pygostyle (about 40% the length of metatarsal III), a short scapula (about 70% of the femoral length), an ilium with a small pubic peduncle (also present in scansoriopterygid theropods), a long pedal digit IV (subequal to pedal digit III), and most notably a pair of short bony crests on the nasals. Cladistic analysis places this new specimen within the Pygostylia, sister taxon to all other pygostylians, thought it has a few striking plesiomorphic features such as a large maxillary fenestra, a maximum of five sacral vertebrae, and a small unreversed hallux. The new avialan closely resembles jeholornithiforms in numerous aspects of its cranial, dental, pelvic, and hindlimb morphology, but is also similar to sapeornithiforms in having a wide furcula with an interclavicular angle greater than 90 degrees, a large fenestra perforating the humeral deltopectoral crest (also present in confuciusornithiforms), a further shortened alular digit (the distal extension of the digit about the level of the distal end of the major metacarpal; also present in jeholornithiforms and jinguofortisids), a reduced minor digit (also present in jinguofortisids) and the absence of an ossified sternum and uncinate processes. In addition, the new specimen shares with confuciusornithiforms and jinguofortisids a

significantly thickened proximal phalanx of the major digit. This discovery fills a morphological gap between early-diverging clades of avialans, as well as documents a previously unknown morphology - the presence of bony nasal crests, thus contributing important new information pertaining to early avialan evolution.

Grant Information:
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Technical Session XVII (Saturday, October 12, 2019, 10:45 AM)

MORPHOGENESIS OF EXTANT FEATHER RACHIS HELPS CLARIFY THE VARIATIONS OF MESOZOIC FEATHERS

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Modern feather rachises, composed of a dense external cortex and spongy internal medulla, are flexible, yet stiff enough so the body surface can be streamlined and/or able to withstand large aerodynamic forces encountered during flight. The lack of knowledge about rachidial morphology in early feathers prevents an understanding of how this complex architecture evolved. This has led to controversy in understanding the early evolution of bird flight. Feather morphotypes previously unknown in extant birds, called “rachis-dominated feathers” (RDFs) have been reported in several lineages of non-avian and avian theropods. A recent study demonstrated that these feathers consist of only the rachidial dorsal cortex, which challenges the existing models depicting the early evolution of feathers and raise the question of how these rachidial morphotypes have evolved. We show the rachidial dorsal cortex, rachidial ridge, medulla and ventral cortex are formed sequentially in extant birds and demonstrate that diverse Mesozoic feathers documented in fossil records are not distinct feather morphotypes. Instead, they represent feathers with limited differentiation and/or keratinization of the posterior half of the cylindrical rachis. These feathers with rachises consisting only of the dorsal cortex are not as strong as those with a cylindrical rachis and may have played limited aerodynamic functions.

Grant Information:
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Technical Session I (Wednesday, October 9, 2019, 8:00 AM)

NEW COMPLETE SKELETON OF *PSEPHOCHELYS POLYOSTEODERMA* (SAUROPTERYGIA: PLACODONTIA) WITH A DEVELOPING CARAPACE

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Triassic sauropterygians include a group of armored marine reptiles called placodonts, some of them even develop complete carapaces superficially similar to turtle shells. Compared with other Triassic marine reptiles, placodont fossil remains are relatively rare, restrictively distributing in Europe, the Middle East, and southwestern China. Our knowledge of preliminarily reported Chinese placodont taxa and their carapacial development is still limited. Here we describe a new complete skeleton of placodonts from China, revealing not only more anatomical details of this placodont genus, but also the fusion pattern of the placodont carapace. This new material can be confidently referred to *Psephochelys polyosteoderma*, mainly based on its narrow, spatulate and edentulous rostrum, the carapace composed of small and numerous armor plates with the relatively smooth surface. Therefore, it represents the first known subadult individual as well as the most complete specimen of *Psephochelys*, and further confirms more diagnosis, such as transverse processes of dorsal vertebrae not anteroposteriorly expanded, two ossified tarsals, the phalangeal formula in the pes of 1-2-3-4-2, etc. The phylogeny of placodont, the family Placochelyidae in particular, is revised by employing an updated character matrix. A better-resolved result demonstrates that *Psephochelys* is a derived taxon in Placochelyidae instead of a basal member as previously obtained, and *Macroplacus* is most possibly a derived member in Placochelyidae too. Interestingly, compared with the adult type specimen, the incompletely developed carapace in this new skeleton suggests that the ossification starts in the axial region covering the vertebral column and the marginal regions contouring the shell, then the lateral walls are thickened, and after that, more armor plates are generated to fill the gaps between the axial and marginal regions. This fusion pattern superficially resembles the ontogenetic process of the shell in turtle embryo, possibly implying the potential deep homology from their common ancestor.

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

NEW DATA OF THE PALEOGENE STRATIGRAPHY AND MAMMALIAN PALEONTOLOGY IN THE ERLIAN BASIN, INNER MONGOLIA, CHINA AND ITS IMPLICATIONS TO THE ASIAN PALEOGENE BIOCHRONOLOGY

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The well-known Erlian Basin in Inner Mongolia, China has played an important role in establishing the Paleogene Asian Land Mammal Ages (ALMAs). Four ALMAs, including Arshantan, Irdinmanhan, Sharamurunaian, and Ulangochuian, were proposed on the basis of mammalian faunas known from the basin. However, the existence of some long-standing basic stratigraphic problems has hampered the understanding of the faunal composition and the recognition of the boundaries between those ages. Moreover, those boundaries are not well-constrained in age. The investigations to the Paleogene in the Erlian Basin in over a decade have clarified some basic stratigraphic confusions. According to the preliminary result of recent investigations, the terrestrial Paleogene in the Erlian Basin comprises seven formations, the Nomogen Fm, the Ashanto Fm, the Irdin Manha Fm, the Shara Murun Fm, the Ulan Gochu Fm, the Xianaogangdai Fm, and the Shangnaogangdai Fm in ascending order, corresponding to the late Paleocene Gashatan through early Oligocene Hsandagolian ALMAs. Preliminary result of mammalian biostratigraphical and magnetostratigraphic studies provide some reliable evidence for the temporary age constraint and the correlation of ALMAs with North American Land Mammal Ages (NALMAs). The Gashatan ALMA, represented by the mammalian fauna from the lower part of the Nomogen Formation, ranges from the transition of either the chrons C26r/C26n or C26n/C25r to the lower part of C24r, and can be correlated with from the late Tiffanian (Ti5) to Clarkforkian NALMA. The Bumbanian ALMA, including mammals from the upper part of the Nomogen Formation, covers from the upper part of C24r to the lower part of C23r, and is correlative to Wasatchian NALMA. The Arshantan ALMA, represented by mammals from the Arshanto Formation, spans from the mid-C23r through the lower part of C20r, and is likely correlated to North American Bridgerian and lower Uintan (Ui1). The Irdinmanhan ALMA covers from the middle part of C20r to the lower part of C19r, and can be correlated to the middle part and the lower upper part of Uintan NALMA. The Sharamurunian ALMA covers the most C19r through the basal C18n, and is correlative to the most part of upper Uintan (Ui3) NALMA. The Ulangochuian ALMA ranges from the lower C18n to the upper part of C17n, and can be roughly correlated to North American Duchesnean.

Grant Information:
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Technical Session III (Wednesday, October 9, 2019, 2:15 PM)

FUNCTIONAL MORPHOLOGY OF *WAKALEO* POSTCRANIA FROM THE MIDDLE TO LATE MIOCENE OF CENTRAL AUSTRALIA REVEALS NEW INSIGHTS IN THE EVOLUTION OF MARSUPIAL HYPERCARNIVORES

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The extinct marsupial lions *Thylacoleo* spp. (Marsupialia, Thylacoleonidae) were apex predators of the Australian Pliocene and Pleistocene. Older thylacoleonids, however, are rare in the fossil record and the interpretations of the ecology of the ancestors of *Thylacoleo* have been built upon a small number of (often) fragmentary fossils. The genus *Wakaleo* is considered to be the plesiomorphic sister-group to *Thylacoleo*, and the two genera differ significantly in cranial form, dental formula, tympanic wing structure and frontal-squamosal contact. While early species of *Wakaleo* were likely arboreal, or at least scansorial, the ecology of later *Wakaleo* spp. is not well understood. Here we present descriptions of new postcranial material of from the Australian Northern Territory. *Wakaleo vanderleueri* from mid -Miocene Bullock Creek Northern Territory (NT) and *W. alcootaensis* from the late Miocene Alcoota Local Fauna NT, the youngest species of *Wakaleo*. Our calculations suggest that these taxa were smaller than previous thought, around 25kg and 50kg respectively. The postcrania reveal increasing adaptation towards terrestrial locomotion and felid-like grappling predation within this lineage. Such patterns are in contrast to the more canid-like adaptations occurring in the other major group of terrestrial marsupial carnivores at the time, the Thylacinids. This hypothesis seems to reflect similar patterns of divergent morphological adaption for grappling versus pursuit hunting behaviors in large carnivorous forms among placental mammals, and highlights a greater diversity in the evolutionary history of medium to large sized marsupial carnivores during the Miocene in Australia than previously recognized.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

SIEVING WITHOUT TEARS. THE FIRST 40 YEARS OF AUTOMATED SEDIMENT SCREENING FOR MICROVERTEBRATES

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When collecting microvertebrates, a major challenge is to extract the fossil from the sediment with a minimum of physical effort and damage to the specimens. The traditional method with poorly consolidated sediment involves drying the sample, then soaking it in water to disaggregate it, then hand sieving the sludge in water. A refinement of this technique is to soak the sample in a sieve box, generally a high-sided tray with a mesh base, prior to sieving.

Neither of these methods, however, solve the basic problem of being labour-intensive and destructive. This was partially solved by European mammal workers in the 1960's who used bulky static sieves and a power pump to bulk process large volumes of sediment in the field. This method can be very effective but is labour intensive. The disadvantages include the weight of the equipment and problems of transporting the pump, sieves, hoses *et al.* to the site. However, an advantage is that the residue is prepared in the field and available for immediate sorting.

It was a small step to encase the static sieve in a 330-litre polythene tank and replace the hand held hose with lawn sprinklers. The sieve, with an area of about 0.5 square metres is fitted with 500µ stainless steel mesh on its sides and base. A syphon allows the tank to partially fill and empty. Sprinklers wash the disaggregated sediment off the surface of the sample, through the sieve and into the tank. The fluctuating water level in the tank gently removes any further sediment and keeps the mesh clean. Specimens detached from their sediment drop to the bottom of the sieve and congregate in an area not washed by the sprinklers. They are not damaged by prolonged abrasion against the mesh nor clasts within the sediment.

Originally this machine was developed to wash dried sediments. However, it coped quite adequately with wet clay but at a much slower rate. Dried clay can be processed at a rate of 10-15kg/hour, compared with about 50kg/ hour with a hand sieve. Wet clay is processed at about 1-2kg/hour. The slowness of the wet process is more than offset by the energy saved by not having to dry the clay and that plant material may be recovered intact. Functioning 24/7, it is feasible to wash large amounts of poorly fossiliferous sediments.

The water can be recycled after passing through settling tanks. This machine can be used in the field, with a gasoline water pump or in the laboratory using a domestic water supply. Whether the sediment is processed wet or dry, there are considerably fewer breakages compared to hand sieving. Our machine is 40 years old this year and still functions.

Technical Session XVIII (Saturday, October 12, 2019, 2:15 PM)

EXCEPTIONALLY PRESERVED SKELETONS FROM THE LATE CAMPANIAN OF MONTANA PROVIDE A UNIQUE GLIMPSE INTO THE PALEOBIOLOGY OF MULTITUBERCULATES

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Multituberculates were among the most taxonomically diverse and numerically abundant mammals in Late Cretaceous terrestrial faunas of the northern hemisphere. In North America, they are known almost exclusively from isolated teeth and a handful of jaws, whereas the few associated skeletons of Late Cretaceous multituberculates are known from Mongolia, China, and Romania. Here we report on exceptional new multituberculate specimens, which we provisionally refer to *Cimexomys judithae*, from the late Campanian-age (ca. 75.5 Ma) Egg Mountain locality of the Two Medicine Formation in western Montana, U.S.A. . The multituberculate remains at Egg Mountain consist of monospecific, multi-individual aggregates of semi-articulated craniodental and postcranial elements. In one instance, five individuals are preserved within <1 m^2, represented by five partial skulls with associated lower jaws, two partial pectoral girdles with one articulated forelimb, two articulated pelvic girdles and partially articulated hind limbs, and numerous semi-articulated to disarticulated postcranial remains in close association. Both adult and subadult individuals occur in these aggregates; adult specimens exhibit fused distal epiphyses, fused cranial sutures, and heavily worn cheek teeth, whereas subadults exhibit unerupted incisors, erupting premolars, unfused distal epiphyses, unfused cranial sutures, and unworn cheek teeth.

In addition to providing a wealth of new morphological data, these specimens offer a glimpse into the behavior of *Cimexomys judithae*. The presence of multiple well-preserved individuals of varying ontogenetic stages, to the exclusion of any other vertebrate taxa, suggests that these animals aggregated in life and died in close proximity to one another. The sedimentology and diverse invertebrate ichnology of Egg Mountain indicate that the locality was strictly terrestrial; thus, these animals may have come together in either an above-ground nest or a burrow. Evidence for low rates of sedimentation with extensive bioturbation, coupled with postcranial features in *C. judithae* that suggest burrowing capabilities, lend some support to the latter hypothesis. Taken together, these new specimens provide an unprecedented look at the paleobiology of multituberculates during the Late Cretaceous in North America.

Grant Information:
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NSF-GRF (LNW)

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

TRACE ELEMENTS OF TERRESTRIAL SURFACE WATERS AND BONE DIAGENESIS: A LEARNING CURVE

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The trace element history of fossil bone preserves evidence of environments where organisms lived (e.g., elements/isotopes incorporated during life), the age of samples (e.g., U-series dating), and the environments in which they were fossilised (e.g., secondary elements such as rare earth elements – REEs). Fundamentally, a specimen's diagenetic history must be known in order to interpret critical data, as elements taken up in life (e.g., Sr) can be overprinted by secondary uptake or preferentially leached during diagenesis. Elemental source and mobility during fossilization depend in part on the water chemistry in the environment where fossilization occurs. REEs are particularly useful in understanding water bodies as they: 1) are a self-referencing set of elements not very prone to random variation; 2) their behaviour varies systematically with redox, alkalinity, source and transport processes; and 3) their low concentration in living tissue means that, in bone, they almost entirely represent secondary uptake in the environment of fossilization. Here we demonstrate the application of REE analysis in the interpretation of selected fossils, ranging from Pleistocene vertebrates through to Cretaceous dinosaurs. In analysing Sr isotope ratios in a *Diprotodon* incisor (giant Pleistocene marsupial), secondary uptake of Sr from local basaltic soil at the site of burial

was quantified by the correlation of associated positive Eu anomalies with lower (basaltic) Sr isotope ratios and higher Sr concentrations. This allowed the original (life-derived) periodic Sr isotope fluctuations in the tooth to indicate seasonal two-way migration for *Diprotodon*. REE analysis of rodent bones aided understanding of paleoclimate by differentiating arid late Pleistocene and humid Holocene conditions in a cave environment. Humid Holocene conditions with high organic matter allowed increased uptake of redox-sensitive Ce, but little U, from anoxic groundwater. Earlier arid settings with well oxygenated groundwater yielded low Ce, but high U, uptake. However, some problems remain unresolved. Dinosaur bones preserved in carbonate concretions in the Cretaceous Winton Formation took up REEs from alkaline waters that appear similar to seawater, despite the fully terrestrial setting. New studies on REEs in lakes have yielded seawater-like REE patterns that were inherited from groundwater residing in marine limestone aquifers and different patterns inherited from local soils, but the source of other seawater-like REE patterns is still to be determined.

Grant Information:
Funding sources: Australian Research Council grants (DP120101752, DE120101533, LE0989067); Ian Potter Foundation, Petrobras

Technical Session IX (Thursday, October 10, 2019, 4:00 PM)

THE GOOD, THE BAD AND THE UGLY – ALTERATION EFFECTS ON DENTAL MICROWEAR TEXTURES AND THEIR IMPLICATIONS FOR DIET RECONSTRUCTION

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Teeth are often the only parts of vertebrates preserved in the fossil record and thus represent a valuable source of information about the diet and feeding behaviour of extinct taxa. In vertebrates, dental microwear texture analysis (DMTA) has long been used to assess the material properties of food items as well as the presence of external abrasives attached to them. Abrasion by ingested food and attrition cause the loss of surface materials resulting in microscopic wear damages which enable us to infer dietary tendencies, and distinguish soft- from hard-object feeders among herbivorous and faunivorous vertebrates. However, dietary reconstruction based on DMTA of fossil teeth can be biased by post-mortem processes. There are two types of alterations that can potentially modify diet-related surface texture features:
1. mechanical and/or chemical surface alteration during taphonomic and transport processes;
2. mechanical artefacts during excavation and preparation or moulding procedures of teeth.
Here we present examples for both types of post-mortem surface alterations, and evaluate how these affect DMTA results, applying ISO and scale sensitive fractal parameters. For surface texture artefacts, such as scratches caused by preparation and moulding mistakes, we tested whether these "bad" surfaces had distinctly different DMTA values compared to unbiased "good", diet-related wear surfaces. Taphonomic processes during transport were simulated in a two week long tumbling experiments using isolated check teeth of extant ungulates, rodents, crocodiles and sharks. Teeth were tumbled in sediment-water suspensions using four grain size fractions of fine sand to fine gravel rich in quartz (~60 wt%). Enamel surfaces of the same area were characterised by DMTA prior and after the experiments to assess alteration effects. Additionally, a sand blasting experiment with mineral dust, to test for the influence of aeolian erosion, and an acid leaching experiment to simulate stomach acid attack, were performed on dental surface textures.
Preliminary results show visible changes in enamel surface features after tumbling, however, these surface modifications are not statistically significant in any of the analysed DMTA parameters. Grazing ungulates were still clearly distinguishable from browsers. Overall, in this study we try to provide an initial database of badly preserved or prepared dental surface textures that should help to identify suitable DMTA parameters to estimate dietary tendencies from fossil teeth.

Grant Information:
This project has received funding from the European Research Council (ERC) and the Max Planck Graduate Center (MPGC).

Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 12:00 PM)

HOW PHYLOGENETICALLY INFORMATIVE IS THE 3D BASICRANIAL TOPOLOGY OF MARSUPIAL MAMMALS?

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Morphological phylogenetic analysis is important for understanding the evolution of extinct lineages and for calibrating molecular clocks for extant clades. However, the categorical nature of conventional character coding is subjective in choice and reductive of the three-dimensional complexity of the characters. This is leading to interest in the incorporation of phylogenetic information from 3D character topologies, determined through geometric morphometrics. However, it is unclear if this shape variation is phylogenetically informative as expected for traditional phylogenetic characters. Here we test this by focusing on one of the most widely used sources of phylogenetic characters, the mammalian basicranium. We "translated" two phylogenetic character matrices for the basicranium of marsupial mammals into a 3D landmarking protocol. We acquired this in 60 marsupial species (representing nearly all extant marsupial families), together with landmarks characterizing the rest of the skull. We then tested the expectation that the basicranium should have higher phylogenetic signal, slower evolutionary rates, and be less influenced by allometry and ecological proxies such as diet and locomotor mode. While there was less allometry in the basicranial region, phylogenetic signal and evolutionary rate were similar to that in the rest of the skull; by contrast, locomotor mode explained a substantial amount of the shape variation in both partitions. In addition, clustering analyses of coordinate data suggests that some ecomorphs (such as small, arboreal species) are more likely to be grouped together. However, the basicranial region displayed much lower landmark displacement magnitudes than the rest of the skull, both along the main ordination axis of shape variation and between the specimens that were most divergent in Procrustes space. Our results confirm the long-held expectation that shape variation in the basicranium is relatively low compared to the rest of the skull. However, in a 3D context, this does not translate into higher levels of phylogenetic information contained in the basicranium; rather, cranial function seems to be an important driver of marsupial basicranial topology, with strong potential for a confounding effect with phylogenetic signal.

Grant Information:
Funded by Australian Research Council DP170103227 and FT180100634 and National Science Foundation BCS 1552848/1825129 and DBI 1701714.

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 1:45 PM)

DATING THE RISE AND FALL OF ORANGUTAN (PONGO SP., *HOMINIDAE*) THROUGH THE QUATERNARY OF SOUTHEAST ASIA

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Orang-utans (*Pongo sp.*) are a key member of the dominant *Stegodon-Ailuropoda* fauna of Southeast Asia and their teeth have been discovered within most of the main cave sites within this region. This fauna is intimately connected to the evolution and dispersal of *Homo* throughout Southeast Asia and yet very little is known about the context of the assemblage, its age, environmental conditions and ecology. As *Pongo* is only able to survive in enclosed rainforest conditions their presence and absence play a critical role on reconstructions of the paleoenvironments of this region. These reconstructions can only be established within solid chronological framework that relies on multiple supporting dating techniques.
We present *Pongo* chronologies from nine cave sites (Lida Ajer, Punung, Kota Batu, Kota Badak, Tam Hang, Duoi U'oi, Nam Lot, Boh Dambang and Coc mui) within five different countries that were established using a combination of luminescence (pIR-IRSL, single grain and red thermoluminescence) dating of the surrounding sediments, electron spin resonance (ESR) dating of the teeth and Uranium-series dating of flowstone that cap the deposits. This timeline, ranging from 270-25 ka (from marine oxygen isotope stages 8-2), charts the arrival, rise and potential of fall of the *Pongo* species in the region. This represents unparalleled evidence for the evolutionary trajectory of *Pongo*

in Southeast Asia and has implications for the now extinct fauna of the Stegodon-Ailuropoda assemblage, especially the infamous giant ape (*Gigantopithecus blacki*), and for our understanding of Asian megafauna and the human story in the region.

Grant Information:
This research was funded by an Australian Research Council Discovery grant (DP1093049) to KW

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

EVALUATING THE DIET OF *HULITHERIUM* USING ORIENTATION PATCH COUNT (OPC)

WHITE, Joshua M., Dapto, Australia; MCCURRY, Matthew, Sydney, Australia; EVANS, Alistair R., Monash Univ, Monash University, Australia

In 1967, the fossil remains of an unusual diprotodontid were discovered in Papua New Guinea, named *Hulitherium tomasettii.* It was reconstructed adopting a panda-like posture based on its post-cranial morphology. It has also been suggested to occupy a similar niche to modern pandas, capable of consuming bamboo, however this claim has never been assessed. Here, we aim to infer the diet of *H. tomasettii* in contrast to other members of Diprotodontidae by measuring their dental complexity. Dental complexity is a homology-free method that measures the topographic features on the tooth's surface, and previous studies have shown it to correlate with diet. This method is also capable of distinguishing bamboo feeders from generalist herbivores. We found that *H. tomasettii* does not exhibit the dental complexity observed in bamboo specialists, and are similar to other diprotodontids. The results of this study provides more insight into the paleobiology and diversity of Diprotodontidae. Additionally, this will contribute to our understanding of how the diet of marsupials changed over time in response to environmental shifts.

Education and Outreach Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

FIELDWORK INSPIRING EXPANDED LEADERSHIP AND DIVERSITY (FIELD): OVERCOMING BARRIERS TO FIELDWORK IN PALEONTOLOGY

WHITE, Lisa D., University of California, Berkeley, Berkeley, CA, United States of America; PAGNAC, Darrin C., South Dakota School of Mines and Technology, Rapid City, SD, United States of America; BOWSER, Gillian, Colorado State University, Fort Collins, CO, United States of America

Field activity is integral to many subdisciplines of geology, paleontology, and associated field disciplines and the dominant, long-standing cultures within these disciplines continue to set the norms for fieldwork expectations. Individuals who are underrepresented in STEM (e.g., people with disabilities, ethnic minorities, women, LGBTQ individuals) particularly face barriers with field activity. These can include feelings of economic exclusion, anxiety about outdoor experiences, attitudes of ableism, and accessibility. These barriers are often ingrained in the culture of field training and research activities, which continues to emphasize physical ability, mental toughness, assertive behavior, and one-upmanship. The FIELD (Fieldwork Inspiring Expanded Leadership and Diversity) project aims to make field activity in the geosciences more accessible, culturally sensitive, and inclusive by equipping field leaders with the perspectives, skills, and solidarity to address both physical and cultural barriers in field settings. Led by a team of PIs and senior personnel from nine institutions representing paleontology, geology, field ecology, marine science, atmospheric science, and social science, the goal of FIELD is to understand the nature of field culture, understand the ways field activity can be exclusionary, and to explore potential solutions.
Here we present some of the results from a 4-day immersive leadership development institute at the Colorado State University Mountain Campus for field course leaders in October 2018. Our goals were to: (1) engage in practical skills training such as bystander intervention and diversity leadership; (2) collaboratively develop new approaches to reduce the exclusionary nature of field culture; (3) explore multidisciplinary and mixed methods that can inspire a love of field activity in a wider range of participants. The venue provided a space for often-difficult conversations about the culture of field sciences that are, in large part, a function of its leaders unquestioning socialization into it but that frequently excludes others. These activities and conversations form the basis for a model of professional development and leadership training that can be disseminated, scaled and used by others who design field projects in paleontology and similar field-based disciplines. It is our hope that through these FIELD activities, participants and leaders will be inspired and motivated to create more inclusive field activities.

Grant Information:
The FIELD project is supported by NSF awards #1645449 and #1645466

Technical Session VII (Thursday, October 10, 2019, 8:45 AM)

A NEW CROCODYLIFORM FROM THE WINTON FORMATION (*CA* 95MA) OF QUEENSLAND (AUSTRALIA)

WHITE, Matt A., University of New England, Armidale, Australia; BELL, Phil, University of New England, Armidale, Australia; CAMPIONE, Nicolas E., University of New England, Armidale, Australia; SANSALONE, Gabriele, University of New England, Armidale, Australia; BROUGHAM, Tom, University of New England, Armidale, Australia

The emergence of crown group Crocodylia, remains a poorly understood area of crocodyliform evolution. A Gondwanan origin for this group was hypothesised with the initial discovery of *Isisfordia duncani* from the mid-Cretaceous of Australia. However, a consensus on whether *Isisfordia* is a basal eusuchian or a clade of late-branching non-eusuchian neosuchians has yet to be reached, therefore a Laurasian origin for crown group Crocodylia is favoured by most authors. Here we present on a new crocodyliform from Cenomanian exposures of the Winton Formation near Winton, central Queensland, Australia. The specimen includes a nearly-complete skull and mandibles and much of the postcranial skeleton excepting the tail and hindlimbs. The paravertebral shield appears to be fully segmented as none of the osteoderms were found *invivo* position and were found scattered amongst the skeleton. The specimen differs from other crocodyliforms with the following autapomorphic features: four distinct rostral ridges, originating from the prefrontals and lacrimals, tapering near the mid-rostrum and its morphologically variant vertebrae conditions including incipiently procoelous cervical vertebrate (C3–C5); procoelous thoracic vertebrae (T1-T2); amphicoelous posterior thoracic vertebrae (T3-T8); and a weakly procoelous lumbar vertebrae (L1). Interestingly the regions housing the incipiently procoelous and procoelous vertebrae occupy major areas of rotation (ie. neck and pelvic region) inferring that this biomechanical arrangement was linked to an exceedingly more aquatic lifestyle. Its discovery heightens knowledge of the emergence of Crocodylia with the identification of these varying vertebral morphologies. The absence of an *invivo* paravertebral shield prevents a definitive description of it being biserial or tetraserial. The presence of amphicoelous posterior thoracic vertebrae indicates that there was some restriction of movement in this region compared to the completely procoelous vertebrate in extant forms (eg. *Crocodylus porosus*). A phylogenetic analysis using implied weighted maximum parsimony recovers this new taxon as a sister taxon of the clade consisting of (Hylaeochampsidae and *Allodaposuchus*) and Crocodylia. The age of this new taxon conforms with a recent tip-dated analysis of combined morphological and molecular data, which indicated a divergence date of *ca* 100Ma for extant crocodylians.

Grant Information:
Reference No: AS183/IMBL/13963 ANSTO Beam time grant.

Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

AN UNUSUAL FOSSIL LOCALITY FROM THE LATE CRETACEOUS HORSESHOE CANYON FORMATION OF SOUTHERN ALBERTA, CANADA REVEALS RARE ELEMENTS OF A PALEOCOMMUNITY.

WHITEBONE, S. Amber, University of Calgary, Calgary, AB, Canada; FUNSTON, Gregory F., University of Alberta, Edmonton, AB, Canada; CURRIE, Philip J., University of Alberta, Edmonton, AB, Canada

The Late Cretaceous rock deposits of southern Alberta, Canada yield an abundance of vertebrate fossils. However, preservational biases in terrestrial depositional systems result in certain aspects of the flora and fauna from these formations being disproportionately rare. For example, the fragile skeletons of small theropod dinosaurs are generally uncommon, as are the smaller juvenile ontogimorphs of most taxa. Within the Lower Maastrichthian Horseshoe Canyon Formation, such taxa are more frequently found in microsite assemblages (concentrations of small (<5 cm) fossils) that preserve elements from small, rare taxa alongside teeth and small bones of larger taxa. The microfossil assemblages are therefore critical for paleocommunity reconstruction. Here we describe a new microfossil bearing locality from the Horsethief member of the Horseshoe Canyon Formation. Of interest is the unusual abundance of troodontid and anuran material, as well as the presence of perinate material from various taxa. In addition, this site is not restricted to microfossils, as several larger bones (ranging from 5 – 30cm) are found in the same horizon. The depositional environment is that of an overbank deposit with little to no marine influence and likely represents a slow accumulation of sediment and the absence of secondary reworking. By extension, we suggest this faunal assemblage is a closer representation of the true biological association than assemblages from secondarily reworked microsites, allowing for novel paleoecological interpretations.

Grant Information:
Vanier Canada Graduate Scholarship held by Gregory F. Funston.

Technical Session XV (Saturday, October 12, 2019, 11:00 AM)

COMPARATIVE HISTOLOGY OF DICYNODONT TUSKS REVEALS CRYPTIC DIVERSITY OF TISSUE COMPOSITION, DEVELOPMENT, AND ATTACHMENT STRATEGIES

WHITNEY, Megan R., University of Washington, Seattle, WA, United States of America; ANGIELCZYK, Kenneth D., Field Museum, Chicago, IL, United States of America; SIDOR, Christian A., University of Washington, Seattle, WA, United States of America; PEECOOK, Brandon R., Field Museum, Chicago, IL, United States of America

Dicynodonts were a diverse and distinctive clade of non-mammalian synapsids that originated in the middle Permian and persisted until at least Late Triassic times. One of the most distinctive features of the group are the paired maxillary tusks found in most genera. Descriptions of tusk tissue composition and development report variation yet oftentimes dicynodont tusks are viewed as stereotyped and uninformative within the group. Despite tusks being the namesake of the clade, no systematic histological analysis of tusk development and tissues in a phylogenetic context has been conducted. Here we present findings from work that more precisely characterizes the tissues and development of tusks in a sample of genera that spans dicynodont phylogeny (e.g., *Diictodon, Oudenodon, Aulacephalodon, Lystrosaurus*).
Our findings reveal unsuspected variation in tusk tissues, composition, and attachment, as well as developmental strategies. We found a consistent correlation between development and tooth attachment, with permanent gomphosis in ever-growing tusks and an ankylosis in closed-root tusks. However, the tissues of the tusk were varied and less consistent with development and mode of attachment. Of particular note is our recognition of an enamel capping tissue in some Dicynodontoidea indet. tusks from the upper Madumabisa Mudstone Formation of Zambia. Preliminary data suggest that these tusks were ever-growing, yet unlike ever-growing teeth in extant mammals like rodents, enamel surrounds the entirety of the tusk. Together these data provide additional characters for dicynodont systematics, insight into the correlative evolution of dental characters, and reveal possible novel developmental patterns in the ever-growing teeth of extant taxa.

Grant Information:
National Geographic Society 158R-18
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Symposium: From Molecules to Macroevolution (Wednesday, October 9, 2019, 8:15 AM)

FOSSIL SOFT TISSUES RESOLVE THE VERTEBRATE TREE OF LIFE AND RECORD METABOLIC RATES

WIEMANN, Jasmina, Yale University, New Haven, CT, United States of America; BRIGGS, Derek E., Yale University, New Haven, CT, United States of America

Paleontologists rely largely on morphological and histological information to reconstruct the relationships of vertebrates and their physiology, approaches plagued by inadequate preservation and lack of directly comparable extant taxa. Sequence data from living vertebrates cannot resolve branching in deep time, and older fossil vertebrates do not preserve sequenceable materials. Proteins are a direct translation product of the genetic code which also record oxidative stress corresponding to the basal metabolic rate (BMR) in the form of heterocyclic polymers. Proteinaceous soft tissues have been shown to preserve in deep time through crosslinking with lipids and sugars into heterocyclic polymers. Here we analyze 43 vertebrate eggshells, bones, teeth, soft tissues, and 30 associated sediment host rocks for compositional heterogeneities providing a potential phylogenetic and metabolic signal in their protein fossilization products (PFPs). We fingerprinted sample composition using *in situ* Raman microspectroscopy (532 nm laser). Spectral intensities were selected for PFP-diagnostic peaks and transformed into a variance-covariance matrix which was subjected to Principal Component and Discriminant Analyses. PFPs in vertebrate fossils are found to differ significantly from sediment organics based on their peptide bonds. Our analyses revealed that vertebrate remains show tissue-specific PFP alteration during fossilization: eggshell PFPs degrade the least, followed by vertebrate soft tissues, whereas PFPs in bones and teeth exhibit the highest levels of alteration. Phylogenetic signals are recorded in PFPs in eggshell and soft tissue, whereas metabolic signals are dominant in PFPs in bones and teeth. Cluster analyses of the data generate remarkably accurate phylogenies for eggshells (100% correct) and soft tissues (90 %), and produce moderately accurate phylogenies for bones and teeth (60 %). BMRs are calculated from the ratio of crosslinks to peptides, and are calibrated for extant taxa. PFP-derived BMRs correspond with estimates based on the histology of extinct vertebrates but allow more accurate predictions: bipedal/volant dinosaurs, pterosaurs, plesiosaurs, bipedal archosaurs, and mammals are recovered as endotherms. Basal synapsids are shown to be barely endothermic, and quadrupedal dinosaurs have even lower BMRs. Lepidosaurs are recovered as ectotherms. Phylogenetic and metabolic information from PFPs in fossil vertebrates provides a powerful, new tool to trace extinct vertebrate macroevolution.

Grant Information:
This project is supported by: Yale Institute for Biospheric Studies Dissertation Improvement Grant & Graduate Student Research Grant of the Geological Society of America.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

THE GRIN OF THE CHESHIRE CAT: ISOLATED TOOTH ROWS AND OTHER DENTITION EVIDENCE FOR A RHAMPHOTHECA COMBINED WITH TEETH IN EUSAUROPOD DINOSAURS.

WIERSMA, Kayleigh, Institute of Geosciences, University of Bonn, Bonn, Germany; SANDER, P. Martin, Institute of Geosciences, University of Bonn, Bonn, Germany

Sauropod dinosaurs were the largest terrestrial vertebrates ever and are characterized by gigantic bodies with pillar-like extremities, exceptionally elongated necks and tails, and comparably minute skulls. The last decade has seen a renewed interest in sauropod dental morphology, tooth replacement, and feeding. Model calculations involving body mass, metabolic rate, and nutritional value of potential food plants indicate that adult sauropods must have consumed hundreds of kilograms of green plant matter per day. A peculiar kind of fossil, isolated yet still articulated tooth rows, are only known for Eusauropoda and may be an autapomorphy of the group. Isolated tooth rows (ITRs) have been found across the eusauropod tree, including *Shunosaurus*, diplodocoids, *Europasaurus*, *Giraffatitan*, *Abydosaurus*, and *Phuwiangosaurus*, yet the importance of these isolated tooth rows for food uptake has not been considered.
While studying the feeding apparatus of *Camarasaurus* and *Europasaurus* in detail, we noticed unusual features such as long, exposed tooth necks, in-situ teeth with strongly resorbed roots no longer implanted in the jaw bone, and a sharp boundary between the strongly wrinkled enamel of the crown base and apical enamel smoothed by wear. Together with ITRs, these features suggest the presence of tough connective tissue in which the teeth were embedded, with the strongly wrinkled enamel providing mechanical connectivity between tooth crown surface and connective tissue. This connective tissue, akin to the horny beak (rhamphotheca) in birds and some non-avian theropods, probably was keratinous. A well-preserved *Camarasaurus* skull shows a patch of sediment with soft tissue impressions covering the teeth up to the middle part of the crown, possibly representing the remains of such a beak.
We thus suggest that eusauropods, in general, possessed a structure akin to the rhamphotheca in birds and some non-avian theropods, differing from these in that teeth were deeply embedded in the rhamphotheca, only exposing the upper part of their crown. This tooth-studded beak would have formed an efficient cropping apparatus adapted to the fast wear caused by high food intake. This hypothesis is consistent with the extremely rapid tooth replacement documented for sauropods, in the range of weeks to a few months.

Preparators' Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

ACID PREPARATION OF CARBONACEOUS FOSSIL MATERIAL USING A MEDICAL INTRAVENOUS KIT FOR TARGETED DELIVERY OF 7% ACETIC ACID SOLUTION.

WILKINSON, Joanne E., Queensland Museum, HENDRA, Australia

The chemical techniques used to remove acid-soluble matrix from fossil bone are effective because the matrix, calcium carbonate (CaCO3), is susceptible to attack by diluted acetic acid (CH3COOH) whereas fossil bone, made up mostly of calcium phosphates (Ca5 (PO4)3(OH, F, Cl), is not.
In 1992, acid preparation began of a near complete ankylosaur (QMF18101) found near Richmond, Queensland, Australia. Now named *Kunbarrasaurus ieversi,* the specimen was preserved in a calcareous nodule broken into 41 interlocking blocks.
The acid preparation process involved coating all exposed bone with a protective polymer (Paraloid B72), submerging each block in a 7% solution

of acetic acid, and then washing thoroughly with water. This process was repeated many times until the desired level of preparation was achieved.
During preparation, however, bone deterioration and loss of detail threatened to become a problem. *Kunbarrasaurus* has a layer of small dermal ossicles, about 3 - 5mm in diameter, that we aimed to keep intact wherever possible. Areas containing these small elements were coated with extra layers of Paraloid B72, however after continual exposure to acid small 'pinprick' holes appeared, even when additional coats were applied between acid treatments. This resulted in undesired dissolution of the matrix and loss of some of the ossicles.
It was best practice to keep high-risk areas out of acid altogether by propping the specimen but often these areas had to be submerged to allow the acid level to reach unprepared matrix. Mechanical preparation was too risky because the ossicles were so small and embedded randomly in matrix where micro-fracturing would threaten them.
In 1994, a new technique was adopted which involved targeted application by dripping acid from an intravenous drip kit mounted above the specimen. The apparatus was set up to deliver continuous drops of acid directly to the matrix where preparation was required; most commonly along the side of a bone. Advantages of this new technique included keeping high-risk areas away from acid altogether and increased control of acid delivery. Disadvantages included small amounts of acetate crystals appearing on the edge of the acid flow and slower preparation time.
After using the technique in conjunction with standard immersion methods for a period of 12 months, the results showed that we could prepare quite selectively along the edge of fossil bone without effecting the rest of the block. Over the past 20 years, this technique has been used for other specimens with similarly beneficial results.

Technical Session II (Wednesday, October 9, 2019, 8:15 AM)

WHAT IS AND CAN BE KNOWN ABOUT THE WINTON FORMATION? UNDERSTANDING THE GEOLOGY OF THE WINTON FORMATION AND INTEGRATING NEWLY DISCOVERED FOSSIL FIELDS FROM SOUTH-WEST QUEENSLAND, AUSTRALIA

WILKINSON, Melville, Santos, Brisbane, Australia; HOCKNULL, Scott A., Queensland Museum, Brisbane, Australia; MACKENZIE, Robyn, Eromanga Natural History Museum, Eromanga
The Winton Formation (WF) is the largest terrestrial depositional system from the Cretaceous part of the Eromanga Basin, occurring across QLD, NSW, SA, and the NT. Our study evaluates what conclusions can be drawn from the available geological and paleontological data, much of which is based on limited local core and localised outcrop data with fossil sites concentrated in the northern part of the basin. We have incorporated extensive regional subsurface data and local observations from newly discovered fossil sites from the central-eastern portion of the basin near Eromanga and Quilpie. Considerable complexity in preservation and depositional history of the WF is observed at regional and local levels resulting in poor resolution of stratigraphic and temporal relationships. Significant post depositional structural and depositional events have caused extensive modification, resulting in the loss of the proximal and distal margins of the WF, burial of up to 1100 metres of section and extensive differential weathering. The WF consists of a spatially and temporally complex mosaic of depositional environments ranging from marginal marine and coastal plain to large scale "anastomosing" fluvial systems consisting of widely spaced "trunk" rivers separated by large relatively flat floodplains subject to frequent avulsion. We present for the first time a regional isopach map, with all known fossil sites, occurring in the basal 250-400 metres. Fossil sites to the NE of Winton are lowest in the section, being closest to the preserved basin margin. The map is constrained to a resolution of 100 metres at best, due to limited and uncertain data, with trends reflecting structural events. Therefore, use of such an isopach to make fine scale stratigraphic comparisons between fossil sites must be cautioned. For example, equivalent isopachs do not imply coeval time due to differential subsidence and the diachronous nature of the WF. Depositional environments observed at fossil sites are interpreted to be associated with large floodplains, with those in Eromanga more distal and labile relative to those from NW Winton, while sites NE of Winton may be closer to the coastal plain. To date, no fossil sites have been found within large fluvial channels. On the basis of the variable local depositional environments, complexity of preservation, and isopach uncertainty across the WF, any finer scale stratigraphic comparisons are precluded. Therefore proposed macro floral and faunal chronologies are unsupported or equivocal, even when detrital zircon data is considered.

Preparators' Session (Thursday, October 10, 2019, 3:15 PM)

MOVING MAMMOTHS AND MOR: HOW TO SURVIVE YOUR COLLECTIONS MOVE

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No matter the size of a museum, moving a collection can be a stressful, time consuming, and expensive endeavor. The Museum of the Rockies (MOR) recently moved thousands of fossil specimens, molds, and casts from offsite storage to newly available collections space within the museum. Intensive paleontology field collecting begun by MOR in 1982 had produced a collection that by 1992 had outgrown the existing collections facility and required the use of offsite storage. Stored material included over 400 plaster jackets, 500 boxes of unprepared specimens, and hundreds of molds and casts. By 2016 this collection filled a 6000 sq ft offsite facility several miles from MOR. In 2017 the historical and cultural collections of MOR were moved into a new addition to the museum. Space previously occupied by the historical and cultural collections was made available for the paleontology department.
From January through early June 2018, MOR planned and executed a twofold project: refit the fossil preparation lab to allow for more utilitarian applications followed by moving all offsite storage material to the newly available collections space at MOR. The move needed to be accomplished with a limited budget. Part one began in January 2018 with a strategy retreat for MOR paleontology staff. Meetings were then held with paleontology volunteers to clarify logistics for the move. Over six weeks the fossil lab was thoroughly cleaned, organized and developed into a more open, centralized space for a variety of projects. Simultaneously, new shelving, reinforced pallets, and battery-operated pallet lifters were obtained and used to prepare the new space for paleontology collections. Following the completion of part one, MOR staff and volunteers started moving all material from the offsite storage facility back to MOR. Hundreds of old boxes containing specimens were rehoused for transport. Plaster jackets, molds and casts were palletized for easier transport. To track the material, boxes and pallets were assigned numbers and jackets were painted colors denoting geologic formations. The palletized specimens and newly boxed material was moved to MOR using field trailers and trucks. The project was completed two days ahead of schedule and has facilitated access to fossils at MOR. This project offers tested solutions for a successful collections move with limited time and a limited budget. From tracking objects to overcoming obstacles and maintaining a move timeline, this model illustrates strategies, techniques, and solutions for other institutions' collections moves.

Grant Information:
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Technical Session XVIII (Saturday, October 12, 2019, 2:45 PM)

A REVISED, HIGH-RESOLUTION AGE MODEL FOR THE PALEOCENE OF THE SAN JUAN BASIN, NEW MEXICO, U.S.A. AND IMPLICATIONS FOR FAUNAL AND FLORAL DYNAMICS DURING THE DAWN OF THE AGE OF MAMMALS

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The San Juan Basin (SJB) of New Mexico, U.S.A., contains one of the most complete early Paleocene terrestrial records spanning over four million years from just after the Cretaceous-Paleogene (K-Pg) boundary through most of the Danian. It provides a unique chronicle of the recovery of terrestrial ecosystems and evolution of biota following the end-Cretaceous mass extinction.
Using new magnetostratigraphy and Ar/Ar and U/Pb dates correlated to the existing litho-, bio-, and isotopic stratigraphic record of the early Paleocene SJB, we have created a new age model for the Nacimiento Formation (Tn)

and its rich fossil record. Mammal fossils of the Paleocene Tn tend to be found in discrete fossiliferous intervals. These intervals have been used to define eight local mammal biostratigraphic zones: Pc1 – Pc2 (in chron C29n; Puercan) and Tj1 – Tj6 (spanning chrons C28n – C27n; Torrejonian). More recently, a diverse early Paleocene megaflora has been collected, particularly from the lower Tn and underlying Ojo Alamo Sandstone. Together, these provide an unsurpassed record of faunal and floral change through the early Paleocene.

Among the implications of the revised age model are new age determinations of the Puercan fossil horizons. The "lower" horizons, which yield the type faunas for the middle Puercan (Pu2) are not isochronous; those from the De-na-zin Wash area are older and near the base of C29n. Those of Kimbeto and Betonnie-Tsosie Wash are as much as 0.3 Ma younger. Together, they reveal that "large" herbivorous peryptichid "condylarths" (e.g., *Ectoconus* [~100 kg] and *Carsioptychus* [~25 kg] were present within 0.4 Ma of the K-Pg boundary. Moreover, the diverse Pu2 faunas of Kimbeto and Betonnie-Tsosie washes are a mere 100 ka older than the late Puercan (Pu3) faunas of De-na-zin Wash and consequently, indicate extremely high levels of mammalian turnover between these faunas. A long gap, the "barren interval", spanning about 1.18 Ma separates Puercan and basal Torrejonian faunas, which first appear near the base of C28n, hampering investigation of the turnover in mammals across the Puercan/Torrejonian boundary. However, the megafloral record is much more complete across this interval, and documents a major restructuring of plant communities across the Pu2-P3 and Pu3-To1 transitions, very low rates of origination throughout Pu3, and a large extinction at the Pu3-To1 boundary. Taken together these data indicate that the Puercan and Torrejonian terrestrial biota in the SJB were characterized by significant and rapid biotic turnover.

Grant Information:
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Technical Session I (Wednesday, October 9, 2019, 8:30 AM)

INFERENCES ON PLESIOAURIAN METABOLIC RATE AND VASCULAR SYSTEM FROM NUTRIENT FORAMINA IN LONG BONES

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Plesiosaurs were secondarily aquatic reptiles showing a unique and uniform bauplan highly adapted to the marine environment. Plesiosaurs are a long-lived and diverse clade, with records all over the globe dating from the latest Triassic to the terminal Cretaceous. Quantitative and qualitative analysis of long bone histology suggests that plesiosaurs were endothermic marine reptiles with fast growth and elevated metabolic rates in the range of birds. Beside histological evidence, blood flow through the nutrient blood vessels of long bones connecting the medullary region with the non-skeletal vascular system may provide evidence for a high metabolic rate. Blood flow is correlated with the diameter of the nutrient foramen, and measurements in fossil thus can be used to infer blood flow based on data from recent tetrapods. Plesiosaurs have distinctive and large nutrient foramina in their propodials (humerus and femur look very similar and sometimes indistinguishable), providing a proxy for blood flow easily accessible to measuring on the bone surface and in CT scans. However, the vascular system in fully aquatic tetrapods is different from that of terrestrial tetrapods, especially in deep divers. Extant terrestrial amniotes may thus be unsuitable for comparison with plesiosaurs, leading us to collect comparative data for extant marine amniotes. We hypothesized that, as in terrestrial amniotes, relative foramen size depends on activity metabolic rate (low in sea turtles vs. high in cetaceans, pinnipeds, and penguins) in addition to body mass. We collected data for nutrient foramen diameter from numerous femora and humeri of plesiosaurs of Triassic to Cretaceous age, but also from Triassic basal sauropterygians such as nothosaurs and pistosaurids. The relative diameter of the plesiosaur propodial nutrient foramen is in the range of endothermic marine amniotes, consistent with the histological evidence, whereas basal sauropterygians have smaller foramina.

Nutrient foramen diameter and thus blood flow in plesiosaurs may have been influenced by other parameters as well. Thus, it is unclear if plesiosaurs could have lowered blood pressure during deep diving by constricting the main vessels, as seen in modern whales, and how this would have affected foramen diameter. Furthermore the special vascular system linked to neotony in the cervical vertebrae of plesiosaurs may have influenced blood flow as well.

Symposium: Quarternary Extinctions (Friday, October 11, 2019, 2:30 PM)

REASSERTING THE SIGNIFICANCE OF THE QUATERNARY MEGAFAUNAL NECROPOLIS FROM LAKE CALLABONNA, SOUTH AUSTRALIA

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Lake Callabonna, a large, episodically dry salt lake in north-eastern South Australia's desert region, became famous for Quaternary megafaunal remains following the discovery of *Diprotodon* and giant bird bones there in 1892. Nine months of excavations for the South Australian Museum in 1893 revealed many fossils described by EC Stirling and AHC Zietz in a succession of papers over the following decade. Notable among these were a series of papers describing Australia's largest marsupial (*Diprotodon optatum*) and its then largest bird *Genyornis newtoni* (Dromornithidae). The site then lapsed into obscurity and was not visited again until 1973 in an expedition led by Dick Tedford, leading to recovery of important new macropodid remains. There have been few expeditions to explore the fossil bone resources since then, yet important questions remained. Notably, what was the age span of these fossil deposits? What are the relative abundance of taxa? In expeditions in 2013, 2014 and 2018, we sought data to address these issues to help clarify the paleoecology of Late Quaternary megafauna. Specifically, we mapped about 450 surface exposures of individual skeletons. Stratigraphic observations combined with an extensive Optical Dating programme in sites spread over about 12 km of the lake suggest that all fossils derive from a narrow time interval reflecting a drought period of several millennia between 50 and 40 kyrs. This period overlaps with presence of humans in Australia and on the Flinders Ranges only some 50-80 km distant. Twelve megafaunal taxa are now known from the site including *Diprotodon*, *Phascolonus*, 7 kangaroos (3 sthenurines, 2 *Protemnodon* sp, 1 *Baringa*,1 *Macropus*), two birds – *Genyornis* and *Dromaius* – and the giant varanid *Varanus priscus.* The extinct taxa are thus firmly placed in temporal overlap with humans, thereby showing that humans cannot be discounted from having a causal role in their extinction. Important discoveries include pouch young in thus the first sexed articulated *Diprotodon* and *Protemnodon* skeletons, well preserved gut contents in *Diprotodon*, feather and skin impressions, and the first well preserved skull material of *Genyornis*. The latter shows *Genyornis* had a highly derived skull similar to those of other dromornithids, but with a much shorter, although still very deep and narrow bill, and thus had affinity to *Ilbandornis*. Collectively, a thorough examination of Lake Callabonna helps clarify the timing of megafaunal extinction in Central Australia and provides significant insights into the biology of several taxa.

Grant Information:
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Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 8:45 AM)

CRUSHING IT: THE SPECIALISED CRANIAL MECHANICS OF AN EXTINCT SHORT-FACED KANGAROO

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The sthenurines were a subfamily of robust kangaroos that arose in the Miocene and diversified in the Pliocene/Pleistocene. This now extinct clade included the largest species of kangaroo to ever exist (max ~250kg, *Procoptodon goliah*); substantially larger than the largest extant species, the red kangaroo (max ~90kg, *Macropus rufus*). Yet, little of their ecology has been quantified. More accurately predicting diets within this once diverse and widely distributed group of iconic Australian megafauna will improve our understanding of not only their ecology, but also of past environments. Cranial morphology correlates with foraging behaviours and mechanical properties of plant tissues among extant kangaroos and relatives (Macropodiformes). Here, we first used shape analysis (Geometric Morphometrics) and biomechanical simulations (Finite Element Analysis) to examine cranial shape and compare the mechanics of biting at the incisors across several extant diprotodont herbivores. Based on these findings we predict the diet of a well-represented species of sthenurine, *Simosthenurus occidentalis*. We found that a combination of craniofacial proportions and dental arrangements aligned this species with obligate browsers, supporting previous suggestions. However, its large size and robust morphology could potentially incorporate particularly thick, resistant vegetation into its diet. Further biomechanical analyses were conducted focussing on unilateral biting along the cheek teeth. Using predictions of the constrained lever model of feeding mechanics, our simulations demonstrate that its greatly hypertrophied zygomatic arch likely

housed an enlarged zygomaticomandibularis muscle, which reduced the risk of jaw dislocation during rear molar bites of extraordinarily high mechanical efficiency. Furthermore, we show that the flared frontal plates of this species align with the axes of torsional forces, reinforcing the cranium against axial twisting during hard unilateral bites on resistant foods. This supports previous suggestions that the toughest vegetation was likely fed directly to the large premolars and crushed; possibly in a similar manner to the way a panda crushes mature bamboo culms. These findings provide evidence of a herbivorous niche, incorporating particularly tough plant matter, not represented among marsupial herbivores today. Such a niche may have been realised in response to the unpredictable availability of quality forage during Pliocene/Pleistocene glacial cycles.

Technical Session X (Friday, October 11, 2019, 11:15 AM)

PROGRESS IN THE RESEARCH ON THE CENOZOIC FISH FAUNA FROM THE TIBETAN PLATEAU

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Research on life history of the Tibetan Plateau (TP) has intensified for the past ten years. The fossil fish materials we have collected are abundant and widely distributed on TP. These newly found fossils reveal the major shift of the fish fauna during the Cenozoic and highlight the role of the rising Tibet played in the formation of the intercontinental distribution of some freshwater fishes.
Our studies show that the modernization in the fish fauna on TP may have occurred no earlier than the Pliocene. The fossils of primitive snow carps were discovered from the lower Miocene of the central TP and the Pliocene of Qaidam basin, when these areas were relatively low, and the highly specialized snow carps were known from the upper Pliocene of Kunlun Pass in the NE Tibetan Plateau and the Pliocene of Zhada basin in SW Tibetan Plateau, now the territories of the highly specialized snow carps. The composition of the fish fauna was also greatly changed. A tropical/subtropical fish fauna comprising climbing perches, catfishes and barbine carps was present in the central TP during the late Oligocene. The diversity declined since the early Neogene and not until the late Pliocene did the fish fauna with modern composition take shape, exemplified by the fossils from the Kunlun Pass with the plateau loaches being more numerous than the highly specialized snow carps.
The discoveries of some tropical/subtropical fishes from the Paleogene of Tibet shed new light on the paleobiogeographical history of these fishes. In the case of climbing perches, based on an updated time-calibrated anabantiform phylogeny that integrates a number of relevant anabantiform fossils, the divergence between Asian and African climbing perches is estimated to have occurred in the middle Eocene (ca. 40 Ma), when India had already joined with Eurasia. The key fossil lineage is †*Eoanabas*, the oldest anabantid known so far, from the upper Oligocene of TP. Ancestral range reconstructions suggest a Southeast Asian origin in the early Eocene (ca. 48 Ma) and subsequent dispersals to Tibet and then India. Thereby we propose their westbound dispersal to Africa via the biotic bridge between India and Africa. If so, climbing perch precursors had probably followed the paleobiogeographical route of snakehead fishes, which have a slightly older divergence between African and Asian taxa. As such, our study provides a particular biogeographical model to highlight the role of the pre-uplift Tibet and the docked India in shaping the disjunct distribution of some air-breathing freshwater fishes around the Indian Ocean.

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Technical Session IV (Wednesday, October 9, 2019, 2:45 PM)

DENTAL MORPHOLOGY AND REPLACEMENT PATTERN OF LATE CRETACEOUS BRAZILIAN ENANTIORNITHINE BIRDS

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The occurrence of polyphyodonty—multiple generations of tooth replacement—in Mesozoic birds has been known since the 19th century, yet this phenomenon has only been investigated superficially. For example, it has not been known whether stem birds had the same alternating pattern as their non-avian dinosaur relatives, and whether this kind of dental replacement pattern is conserved in archosaurs. With the purpose of investigating these questions, an enantiornithine premaxilla (MPM 90, Museu de Paleontologia de Marília) and a partial dentary (MPM 351) from the Upper Cretaceous Adamantina Formation of southern Brazil were µCT scanned at 3 µm resolution. The results show preservation of replacement teeth and their tooth families. 3D reconstruction of the replacement tooth rows shows a conserved alternating pattern as seen in other archosaurs. In addition, we apply a new morphologic framework (quantitative and qualitative) for organizing tooth diversity in enantiornithines. Using parameters such as crown base length, crown height, apical length, curvature, enamel ornamentation, number of teeth on each tooth-bearing bone, and dental spacing, the dental anatomy of the two Brazilian specimens clusters together with that of other enantiornithine tooth morphotyes. In sum, we show that the alternating tooth replacement pattern of toothed birds is shared with that of crocodilians, indicating a conserved pattern in archosaurs. Our results thus imply a conserved underlying control mechanism for this pattern of tooth cycling. The characters we used to analyze the range of dental morphology in enantiornithines provide a morphologic framework that can be applied to other toothed avian clades in order to understand dental evolution in stem birds.

Regular Poster Session II (Thursday, October 10, 2019, 4:15 - 6:15 PM)

EVOLUTIONARY HOMOLOGY IN THE FIN-TO-LIMB TRANSITION: EVALUATING THE MORPHOLOGY OF FORAMINA IN A LATE DEVONIAN HUMERUS FROM THE CATSKILL FORMATION, CLINTON COUNTY, PENNSYLVANIA

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The evolution of early tetrapods is marked by several morphological shifts, including the evolution of a neck and weight-bearing limbs. The humerus plays a central role in the reorientation of the appendage from a posteriorly-directed fin to a laterally-directed limb used in terrestrial locomotion. Through the reorientation of the forelimb, a humeral process called the ventral ridge transitions from a diagonal to parallel orientation relative to the humeral head. Throughout this transition, the ventral ridge is pierced by proximodistally trending foramina, as well as a dorsoventrally trending foramen that has been homologized with the entepicondylar foramen, which houses the brachial artery and median nerve in living taxa. These ventral ridge foramina have been briefly interpreted as vascular canals, however the structures that pass through these foramina, their homology, and their evolutionary origin have yet to be critically evaluated in the context of the fin-to-limb transition. We used micro-computed tomography to reconstruct the humeral foramina morphology in a stem tetrapod (ANSP 21350) from the Late Devonian of Pennsylvania. We hypothesize that these foramina are an osteological result of the ventral ridge ossifying around neurovasculature. The ventral ridges of early-diverging tetrapodomorph humeri such as *Eusthenopteron* possess at least four fully perforating foramina, but only a single foramen perforates the entire ventral ridge in ANSP 21350. To speculate on the role of the single, large foramen in ANSP 21350, we used the homology of the similar-sized entepicondylar foramen and suggest that the large foramen in ANSP 21350 housed both a nerve and vasculature. The retention of neurovasculature within the ridge through the reorientation of the humerus suggests that neurovasculature that supplied signals to the distal limb were conserved within the ventral ridge, whereas accessory vasculature moved outside of the ridge. Furthermore, we infer that the functional evolution of the forelimb in the fin-to-limb transition drove shifts in the location of forelimb neurovasculature.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

A REVIEW OF MESOZOIC FOSSIL FEATHER MORPHOLOGIES: PROBLEMS AND PROSPECTS

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Recent discoveries of feathers and feather-like integumentary structures in various archosaurian fossils, particularly those present in theropod fossils, have significantly advanced our understanding of the origin and early evolution of feathers. At the macroscopic level, the major feather morphotypes, including flight feathers with asymmetrical vanes, have been

identified among non-avialan archosaurians. However, the occurrence of certain major feather structural components (e.g., calamus, after feathers, and barbules) and their morphological details, are not well known in most previously reported Mesozoic fossil feathers or feather-like integuments. At the microscopic level, many theropod and other vertebrate fossils have demonstrable preservation of melanosome pigment structures including some highly specialized ones with a limited taxonomic distribution among extant birds, and some are hypothesized to preserve keratin proteins, but the identifications of both the structures and chemical composition of the fossils have been questioned.

Here, I review the major discoveries of Mesozoic fossil feathers and feather-like integuments, comment on the preserved morphologies at both the macro- and microscopic levels in these fossils, and discuss the distribution of these morphologies across space, time, and phylogeny. I highlight some issues that remain under debate or are otherwise unresolved, including: at what point in archosaurian phylogeny the first feathers originated; how some major structural components of feathers evolved; whether early feathers developed ontogenetically in the same way as modern feathers; whether they share similar biochemical components with modern feathers; whether the major features of feathers appeared incrementally during their evolution (or with some having appeared simultaneously); whether feather-related features have evolved in concert at the macro- and microscopic levels; and lastly examining what were the primary functions of various early feathers. In addition, I highlight several problems pertaining to the study of the origin and early evolution of feathers such as how to define what a feather is and how to optimize feather-related features on the phylogeny while considering the difficulty of differentiating the absence of evidence, from evidence of absence, in the study of fossil soft tissues, and finally, I provide tentative suggestions for future research directions.

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Symposium: Origin of a Sunburnt Country (Saturday, October 12, 2019, 9:15 AM)

THE LAST 10 MILLION YEARS OF AUSTRALIAN CROCODYLIAN HISTORY: A CASE OF OUT WITH THE OLD AND IN WITH THE NEW

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The history of crocodylians in Australia over the last 10 Ma is one of turnover, with an old endemic clade called Mekosuchinae being replaced by the genus *Crocodylus* which dispersed into Australia from Asia. However, the turnover was not simple and involved three independent invasions of Australia by *Crocodylus*. Mostly the arrivals of *Crocodylus* do not appear to be correlated with any of the extinction events that affected both mekosuchines and *Crocodylus* over this period.

The first extinctions seem to have hit near the end of the Miocene and resulted in the loss of the large *Baru*, and an unnamed dwarf mekosuchine. These extinctions may be part of a worldwide drop in crocodylian diversity related to global cooling. Other mekosuchines survived, including *Quinkana, Kalthifrons* and an unnamed taxon traditionally placed in '*Pallimnarchus'*.

The oldest *Crocodylus* fossil from Australia is from the mid Pliocene of Queensland and has been referred to the extant *C. porosus*. However, there are no autapomorphies or unique combination of characters to support this and at least one feature suggests that it is not *C. porosus*. Indeed, none of the other Australian fossils referred to *C. porosus* withstand scrutiny, leaving *C. porosus* without an Australian fossil record.

Crocodylus dispersed to the Lake Eyre Basin of South Australia by the late Pliocene. The South Australian *Crocodylus* appear related to, but specifically distinct from, the Pliocene *Crocodylus* of Queensland. The new species replaced *Kalthifrons*, whereas in Queensland '*Pallimnarchus'* continued to live alongside *Crocodylus*. The South Australian fossils are complete enough to allow the diagnosis of a new species. Phylogenetic analysis indicates that it is more closely related to *C. palaeindicus* from the Pliocene of Asia than it is to the extant Australian species. By the end of the Pliocene *Crocodylus* was extinct in Queensland while '*Pallimnarchus'* continued to survive, as did *C.* sp. nov. in the Lake Eyre Basin. At some point prior to the late Pleistocene a new lineage of *Crocodylus* entered Australia and evolved into the endemic *C. johnstoni*. Extreme aridity in the Late Pleistocene wiped out *Crocodylus* n. sp. in the Lake Eyre Basin, while a later pulse of extinction, probably associated with the loss of megafauna at around 42 Ka, saw the loss of *Quinkana* and '*Pallimnarchus'* from more mesic habitats. *C. johnstoni* survived this extinction and was joined by *C. porosus*. The timing of the arrival of *C. porosus* is unknown but it could postdate the late Pleistocene megafaunal extinctions.

Technical Session II (Wednesday, October 9, 2019, 11:45 AM)

DIFFERENT DEVELOPMENTAL TRAJECTORIES IN TWO GROUPS OF ORNITHISCHIAN DINOSAURS, HADROSAURS AND CERATOPSIANS, REVEALED BY DEEP LEARNING

Hadrosaurs and ceratopsians are two major groups of ornithischian dinosaurs. During their evolutionary history, they acquired many similar changes including increase of body size, bipedal-quadrupedal transition, and dental battery structures. However, the developmental trajectories of these evolutionary changes are barely known mainly due to paucity of fossils in early developmental stages and technical limitations.

CT scan has been widely used in many fields for 3D imaging, however, whose subsequent classification, labelling, and segmentation, are often laborious and prone to error. Since 2013, Deep Neural Networks (DNNs) have reached significant success in computer vision tasks. As CT scan and other 3D imaging techniques are more frequently applied in paleontological research, traditional data processing methods cannot fulfill the requests from either enormous sample size or higher image resolution. Current segmentation and labelling methods are facing major weaknesses with complicated specimens (too fragmentary, similar density of fossil and matrices, etc.).

Here, I present a fully automated fossil segmentation method for CT scans based on DNNs, which were trained on a small number of manually labelled CT slices and reached human-equivalent accuracy in segmenting and labelling fossil materials. *Protoceratops* and *Maiasaura* skulls ranging from embryos/hatchlings, which are poorly ossified and too fragile to be further prepared, to adults were CT-scanned and processed under this network. They showed different ontogenetic patterns in dental batteries as well as ornamental structures, indicating two distinctive developmental trajectories in crown ornithischian dinosaurs, hadrosaurs and ceratopsians. This is the first attempt to apply deep learning in paleontological studies. The application of deep learning for automated segmentation and labelling can avoid the possibility of damaging precious fossils during preparation or observation, and save considerable time for paleontologists from 3D data processing.

Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

THE FIRST NORTH AMERICAN *PROPTERODON* (MAMMALIA: HYAENODONTA) FROM THE LATE UINTAN OF UTAH

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Hyaenodontans were a moderately diverse component of the carnivorous guild during the Uintan (late middle Eocene) of North America. In the late Uintan, four genera have been recorded, *Limnocyon*, *Oxyaenoides*, *Sinopa*, and a small taxon currently in open nomenclature. This marks an increase over the early Uintan, in which only *Limnocyon* and *Sinopa* are present. To this late Uintan diversity can be added a new taxon, recognized on the basis of a partial dentary preserving m2-3 from Leota Quarry in the Myton Member of the Uinta Formation, Uintah County, Utah.

The new form has an advanced hypercarnivorous dental morphology with open trigonids with elongate prevallid shearing blades, rudimentary metaconids, and reduced, trenchant talonids. The morphology of the new form supports referral to the hyaenodontine genus *Propterodon*, a taxon previously restricted to the Irdinmanhan and Sharamurunian of Asia. The new species is similar to the two best represented species of the genus, *P. morrisi* and *P. tongi*, differing in its larger size and retention of a relatively larger talonid on m3. Direct comparisons to the other two named species of *Propterodon*, *P. pishigouensis* and *P. panganensis*, are impossible due to a lack of overlapping material. However, reevaluation of *P. pishigouensis* indicates that this species is not referable to either *Propterodon* or Hyaenodonta. Instead, *P. pishigouensis* shares significant features (ventrally deflected anterior dentary, tall p4 paraconid, distally broadened p4, subequal p4 and m1, tall, elongate m1 talonid) with the machaeroidine oxyaenid *Apataelurus* and represents the first documented Asian representative of Machaeroidinae.

Alongside the shared presence of the hyaenodont *Sinopa* and the mesonychid *Harpagolestes*, recognition of both a North American species of *Propterodon* and an Asian machaeroidine similar to *Apataelurus* increases the similarity between Uintan, particularly late Uintan, and Irdinmanhan carnivore faunas. This similarity suggests that immigration from Asia may account for the increase in hyaenodont diversity between the early and late Uintan. It further suggests that an Asian origin may be sought for other carnivorous taxa appearing in late Uintan faunas without clear Bridgerian or early Uintan antecedents, including the hyaenodont *Oxyaenoides*, the miacoid *Tapocyon*, and the enigmatic *Simidectes*.

Colbert Prize Poster Session (Wednesday - Saturday, October 9-12, 2019, 4:15 - 6:15 PM)

JAW MUSCULATURE IN PARAREPTILES: DIGITAL RECONSTRUCTION AND ECOLOGICAL IMPLICATIONS OF MUSCLE FORCES FOR PAREIASAURS AND PROCOLOPHONIDS

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Parareptiles were a group of amniotes that included pareisaurs - one of the largest representatives of the first herbivorous tetrapod communities in the Permian, and procolophonids - important representatives of post-mass-extinction recovery faunas in the Triassic, among other less taxonomically diverse clades. Albeit crucial for the Permian and Triassic ecosystems (that were precursors to the dinosaur faunas of the Late Triassic), pareisaurs and procolophonids have been historically underrepresented in studies that did not focus on anatomical descriptions or amniote phylogeny. Here we present the first stage of a comparative biomechanical study of selected parareptiles, a detailed reconstruction of the adductor musculature of three procolophonoid taxa (*Tichvinskia*, *Kapes*, and *Pentaedrusaurus*) and three pareiasaur taxa (*Deltavjatia*, *Scutosaurus*, and *Elginia*) based on three-dimensional models. Such models allow for more accurate measurements of muscle properties from which muscle and bite force estimates were calculated using the anatomical cross-sectional area of the reconstructed muscles (as ratio of muscle volume and muscle length) and the isometric stress value of 0.3 N/mm^2. For calculating mechanical advantage, the lower jaws were observed as a third-class lever system with the inlever being distance from the jaw joint to adductor muscle attachment, and the outlever being distance from the jaw joint to the anterior-most and posterior-most dentary teeth. We find there is little variety in bite force and mechanical advantage within each group, but procolophonids as a group show higher bite forces and more relative adductor muscle mass than pareiasaurs. Relatively low bite forces in pareiasaurs were suitable for collecting, but not so much for further oral processing of soft plants. Stronger bite force in procolophonids was achieved by posterior elongation of the skulls and enlarging adductor muscle attachment sites on the mandible. With a lower mechanical advantage, *Tichvinskia* was possibly adapted to fast piercing of arthropods, and later taxa for crushing fauna and flora. Higher mechanical advantage possibly allowed limited oral processing in procolophonids, relevant as the group lacked the enlarged gut of pareiasaurs. These muscle reconstructions and digital models will be used in the future studies to perform stress-strain analyses on the skulls and mandibles, using Finite Element Analysis.

Grant Information:
This study has been funded by the Faculty of Science, University of Bristol. Grant code: GELY HF7922 (6303)

Technical Session XVII (Saturday, October 12, 2019, 9:30 AM)

EVOLUTIONARY RATES IN TYRANNOSAUROIDS SUPPORT A MODEL OF ECOLOGICAL RELEASE LINKED TO THE EXTIRPATION OF CARCHARODONTOSAURIANS

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Intensified sampling of mid-Cretaceous paleobiotas across Laurasia is providing new data on predator dynamics, specifically the opportunistic ascent of tyrannosauroids to top tier trophic guilds. Recent advances in the North American record include: recognition that carcharodontosaurians survived as apex predators into the Late Cretaceous; confirmation that large-bodied carcharodontosaurians and small-bodied tyrannosauroids were cohabitant predators, presumably by means of niche partitioning; documentation that the earliest Late Cretaceous tyrannosaurs had a diminutive bauplan; and a resultant winnowing of the interval for hypothesized rapid mass increases along the tyrannosaur lineage to <15 million years. If the shift from secondary to apex predator roles among tyrannosaurs is attributable to mesopredator release (i.e., is inextricably linked to the extirpation of carcharodontosaurians), we would predict several phenomena to be evident in the Turonian to early Campanian record: an interval of increased rates of phenotypic evolution coinciding with rapid niche expansion (broadened resource use); and a trend of increasing body mass (BM) resulting from selective pressure to occupy apex predator roles previously filled by colossal carcharodontosaurians. To test these hypotheses we explored shifting rates of morphological evolution (e.g., femur length (FL) as a proxy for BM, and widespread skeletal trait variation) in tyrannosauroids using multiple phylogenetic comparative methods (PCMs; continuous model fitting, phylogenetic matrix rate tests, and ridge regressions). Our data indicate that a panoptic view of body size in tyrannosaurs across their >100 million years of evolution is best explained by random (Brownian) evolution; however, we document a significant trend of increasing rates and phenotypic means in BM evolution after the hypothesized extirpation of carcharodontosaurs in the Turonian (mean sustained increase in FL of 1.35 cm [range 1.15 to 1.70 cm] per 1 myr), supporting a hypothesis of ecological release with directional selection (98.8% of sampled MPTs). This backdrop of increasing rates of BM, coincides with high rates of skeletal evolution (tested via morphological character datasets), which spike above background levels near the origin of Eutyrannosauria, as predicted, and stabilize within the clade (*Daspletosaurus* + (*Tyrannosaurus* +*Tarbosaurus*)). Our results are consistent with a hypothesis of ecological release as a driver of tyrannosauroid evolution during the Late Cretaceous.

Technical Session VII (Thursday, October 10, 2019, 12:00 PM)

TOWARDS AN ADVANCED WEIGHTING APPROACH TO ACCOUNT FOR CHARACTER INTERDEPENDENCIES IN AN ADJUSTED PARSIMONY METHOD, FOR PHYLOGENETIC INFERENCE USING PHENOTYPIC DATA

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Parsimony based methods remain a powerful tool for estimating phylogenies from morphological data. In the minimum step method, extra steps are added across all the characters. Meanwhile, the extra step changing range often differs substantially among characters, or even among different coding schemes of the same character. When conflicts are present among the different phylogenetic contents contributed by individual characters, a consequence of this practice is that characters with a higher range of potential extra steps will have more influence on the analyses than characters with a lower range of potential extra steps. Whereas a large number of characters, of which the phylogenetic expressions are withheld for this reason, may still provide a meaningful reconstruction of the phylogeny, it is still worthwhile to explore alternatives for the minimum step method.
Here we test an adjusted parsimony (AP) approach in which the scaling issue of character steps is taken into account. In addition, because the logical basis of scaling is built on one of the prerequisites for parsimony analysis, that is, each character is assumed to be independent from each other. It is, thus, necessary to consider character weighting, not commonly taken into account in the minimum step method. Character interdependencies rising from, for example, developmental bias need to be justified by weighting characters *a priori*. Character weighting *a priori*, however, does not have to be performed in the character analysis stage. Rather, weighting can be linked to the numerical analysis of character matrix. In the AP method, the phylogenetic content expressions of each character (E_i) is calculated. When m characters interact and compete against each other for their phylogenetic contents (m can be any subset of the whole given data matrix), how E_i ($i = 1, 2, 3, \ldots, m$) change among each other potentially reveals how characters are interdependent. Another advantage of this approach is that character interdependencies found by AP are informative for the investigations aiming to uncover developmental or genetic links between different characters. A pilot set of data on murine dental characters analyzed using AP shows that the method can identify character interdependencies that are known to exist based on developmental biology studies. In future studies, it is expected that a well-structured weighting approach can provide a more refined way of using morphological data in phylogeny reconstructions.

Technical Session XII (Friday, October 11, 2019, 11:45 AM)

OSTEOLOGY OF *LIAONINGOSAURUS PARADOXUS* (ORNITHISCHIA: ANKYLOSAURIA) FROM THE LOWER CRETACEOUS OF LIAONING, CHINA AND THE EARLY EVOLUTION OF ANKYLOSAURIDAE

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The Early Cretaceous *Liaoningosaurus paradoxus* from western Liaoning is among the best-represented ankylosaurians in terms of the quantity and quality of the recovered specimens, but it has never been fully described since the brief report naming the taxon. Here we provide new morphological information derived from close examination of the holotype and three new specimens of *Liaoningosaurus paradoxus*. The revised diagnosis of *Liaoningosaurus paradoxus* includes the elongated atlantal rib extending posteriorly to the posterior end of the third cervical centrum, the axial neural spine sub-rectangular in lateral view, the anterior caudal centra subequal in

their anteroposterior length to mediolateral width, the manual phalangeal formula of 2-3-3-2-2, the femur about the same length as the tibia, shell-like ventral armor present, and pes approximately twice as long as manus. Additional significant features of *Liaoningosaurus paradoxus* include the plesiomorphic presence of premaxillary teeth and of the antorbital fenestra and the apomorphic presence of the elongated prezygapophyses and postzygapophyses of the posterior caudals interlocking the vertebrae to form a rigid tail club handle. Our phylogenetic analysis on a dataset comprising 59 taxa and 191 characters places *Liaoningosaurus paradoxus* as the most basal ankylosaurid. We discuss the evolution of major ankylosaurid characteristics of the skull and tail within the new phylogenetic framework, and suggest that mosaic evolution characterizes the early ankylosaurids, and in particular, the tail became specialized phylogenetically earlier than the skull in ankylosaurid evolution.

Grant Information:
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and Stratigraphy, China (No. 163120) and the Jurassic Foundation.

Technical Session X (Friday, October 11, 2019, 8:00 AM)

EARLY OSTEICHTHYAN EVOLUTION: INSIGHTS FROM NEW DATA OF THE SILURIAN *MEGAMASTAX*

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Megamastax amblyodus from the Kuanti Formation (Late Ludlow, about 423 million years ago) of Yunnan, China, is by far the largest pre-Devonian vertebrate yet discovered, with an estimated length of about one meter. It was identified as a sarcopterygian because its external dermal bones are covered in cosmine with numerous embedded pores. However, reconstructing its phylogenetic position has been impeded by the limited data (two isolated mandible and one maxilla). During recent years, more specimens of *Megamastax amblyodus*, including an articulated one with part of trunk and nearly complete head and cheek bones, have been found from the type locality and horizon. After almost two years' mechanical preparation, the articulated specimen has been CT scanned to reveal details of the neurocranium, palatoquadrates, dermal skull roof and cheeks, and dentition. The braincase lacks an intracranial joint and has chondrichthyan-like enclosed aortic canals. The dermal cheek bones resemble those of primitive osteichthyans such as *Psarolepis* and basal actinopterygians, but the skull roof pattern differs dramatically from known osteichthyans and instead resembles the 'maxillate placoderm' *Entelognathus*. Structures previously described as "blunt coronoid teeth" are actually the attachment bases for tooth cushions like those of the stem osteichthyans *Lophosteus* and *Andreolepis*. The squamation is composed of very small and thin rhomboid scales, and lacks large median dorsal plates. This combination of chondrichyan, osteichthyan and 'maxillate placoderm' traits is unique and unexpected. It suggests that *Megamastax* occupies a position close to the gnathostome crown group node and opens novel perspectives on how early osteichthyan evolved their diagnostic features.

Grant Information:
Strategic Priority Research Program of Chinese Academy of Sciences (XDA19050102, XDB26010400), and National Natural Science Foundation of China (41530102).

Technical Session X (Friday, October 11, 2019, 8:15 AM)

A NEW SILURIAN BONY FISH CLOSE TO THE COMMON ANCESTOR OF CROWN GNATHOSTOMES

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Modern jawed vertebrates or crown-group gnathostome include the last common ancestor of living bony and cartilaginous fishes and all its descendants. The gross morphology of the earliest modern jawed vertebrates, and how they arose from stem gnathostomes, were previously unknown due to a lack of articulated fossils. The recent discovery of the Xiaoxiang Fauna from the Silurian of South China revolutionarily adds to the diversity of Silurian jawed vertebrates. However, considerable morphological gap is still present between stem- and crown-group gnathostomes. Here, we report a new bony fish very close to the crown-group gnathostome node, also from the Xiaoxiang Fauna. The attributed specimens include a head, jaws and an articulated postcranial skeleton. The new fish displays a unique suite of characters: the dermal pectoral girdle condition transitional between *Entelognathus* and osteichthyans, the braincase profile recalling the condition in *Janusiscus* and early chondrichthyans, and the premaxillae and lower jaw largely showing osteichthyan features. This mosaic character combination suggests the tentative phylogenetic position of this new taxa in the most basal segment of the osteichthyan stem, possibly forming a quintessential component of the evolutionary transition between placoderms and osteichthyans. For the first time, we are able to look into a near-complete bony fish close to the last common ancestor of all the living jawed vertebrates, and reconstruct the acquisition sequence of osteichthyan characters based on a series of fossils in morphological proximity. The fact that most of these fossils are from the Silurian Xiaoxiang Fauna, suggests that this fauna is unprecedentedly close to the initial radiation of jawed vertebrates.

Grant Information:
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Regular Poster Session IV (Saturday, October 12, 2019, 4:15 - 6:15 PM)

PALEOENVIRONMENTAL ANALYSIS OF AN UNUSUAL FOSSIL LOCALITY FROM THE LATE MIOCENE IN NORTHERN FLORIDA

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'Montbrook' is an extremely fossiliferous late Miocene to early Pliocene deposit located on the Ocala Platform in Levy County, Florida. The site has been excavated by the Florida Museum of Natural History since its discovery in 2015, producing over 40,000 catalogued fossils. Taxa such as *Teleoceros*, *Hexameryx simpsoni*, *Rhynchotherium* sp., and *Borophagus hilli* constrain the age, making it the only late Hemphillian locality in Florida with a predominantly terrestrial fauna. However, the fossil assemblage is mixed, spanning from terrestrial vertebrates to freshwater and marine fossils. Our initial site formation analysis was conducted to reconstruct the paleoenvironmental narrative utilizing a multiproxy approach. Paleomagnetic samples were analyzed to evaluate the biostratigraphic ages assigned to Montbrook. In order to place the site in a regional geologic context, three ~13-31 meter sediments cores were drilled and correlated with known local deposits. Chondrichthyan taxa such as *Brachycarcharias* and *Carcharocles chubutensis* indicate reworked Eocene and early Miocene contributions, respectively. Given that Montbrook likely represents a fluvial environment eroding through older strata, rare earth element (REE) analysis of *in situ* fossils is being conducted to determine if other marine fossils were reworked or contemporaneous with terrestrial and freshwater material. High diagenetic alteration and low intensity paleomagnetic results prevented our ability to constrain the age further. Sediment cores revealed the vertical boundary of underlying bedrock is Eocene age Avon Park and Ocala Limestone formations, as well as associated karstic features. Smear slides of the cores place Montbrook within the Hawthorn Group, although they constitute a unique environmental lithofacies not yet described. Montbrook is a complex marginal environment, representing fluvial to estuarine deposition, with intermittent marine tidal influence, offering some of the first direct insights into transitional terrestrial ecosystems from 5.5-5.0 Ma in the southeastern U.S.A. .

Grant Information:
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Regular Poster Session I (Wednesday, October 9, 2019, 4:15 - 6:15 PM)

AN ASSOCIATED SPECIMEN OF THE LAMNIFORM SHARK *CARCHAROCLES ANGUSTIDENS* FROM VICTORIA, AUSTRALIA, AND EVIDENCE OF POST-MORTEM FAUNAL SUCCESSION

ZIEGLER, Tim, Museums Victoria, Carlton,VIC, Australia; HOCKING, David, Museums Victoria, Carlton, VIC, Australia; FITZGERALD, Erich M., Museum Victoria, Melbourne, Australia

Isolated teeth dominate the Australian fossil record of Cenozoic sharks and rays (Chondrichthyes). Associated chondrichthyan remains preserve extremely rarely in the fossil record, due to the group's weakly articulated and mostly cartilaginous skeletons. Until now, an undescribed partial lamniform dentition from the lower Miocene Batesford Limestone comprised the only report of an associated shark fossil in the Australian Cenozoic. Many fossil taxa erected from isolated shark teeth worldwide are of dubious value, confounded by morphological differences due to tooth position, ontogenetic variation, and intraspecific variability. Associated specimens are also productive sources of biostratinomic and taphonomic context, and can inform paleoecological interpretations of depositional environment.

We report on the discovery of a partial associated specimen of the lamniform shark *Carcharocles angustidens* (NMV P253864) in the upper Oligocene (25–23 Ma) Jan Juc Marl in Victoria, Australia. This third known example worldwide represents a notable expansion of the heretofore sparse and isolated chondrichthyan fossil record from this richly fossiliferous coastal outcrop. The specimen, representing an individual of total length ≥7.7m, comprises 16 functional erupted and 17 incompletely developed unerupted teeth, including representative examples of anterior, intermediate, lateral and posterior files, and one associated fragmentary vertebra. This assemblage was further augmented by the discovery of 12 fossil hexanchid shark teeth (NMV P253894) associated with the *C. angustidens* remains. All are erupted and well-preserved, showing no evidence of digestion, but several display mechanical damage to tooth crowns.

We suggest this specimen preserves a shallow-water "shark-fall" faunal succession, with initial exploitation of the *C. angustidens* carcass by hexanchid sharks within days to months of its arrival at the sea floor. Fossilised invertebrate epifauna preserved on the vertebra surface indicate the subsequent development of invertebrate faunal communities, including sulphophilic direct scavengers and suspension feeders exploiting hard substrata. Most such communities, fossil and modern, have been observed on whale-fall carcasses, but few whales globally reached or exceeded the size of large lamniform sharks from the Oligocene to late Miocene. This discovery illustrates the likely significance of shark-fall events in providing organic content to nutrient-poor seafloor environments during the mid-Cenozoic.

Grant Information:
Australian Research Council Linkage Project LP150100403 awarded to EMGF supported fieldwork associated with this project.

Regular Poster Session III (Friday, October 11, 2019, 4:15 - 6:15 PM)

CRANIOFACIAL ONTOGENY IN *TYLOSAURUS PRORIGER*

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Tylosaurus proriger was a large mosasaur that lived in the Western Interior Seaway during the Late Cretaceous. Its fossils are found in the Niobrara Chalk of Western Kansas, but despite a multitude of specimens of varying maturity, the precise sequence of growth changes that occurred in its craniofacial skeleton is unclear. The goals of this project were to use quantitative cladistic analysis to (1) recover the growth series of *T. proriger*; (2) evaluate whether skull length is an appropriate proxy for relative maturity in this species; (3) test for sexual dimorphism; and (4) test the hypotheses that *Tylosaurus kansasensis* represent juveniles of *Tylosaurus nepaeolicus* and that *T. proriger* is a paedomorph of *T. nepaeolicus*. Nine specimens were coded for ten hypothetical growth characters from photographs and the literature, and one specimen was studied first-hand. A hypothetical embryo was included as the outgroup.

An exhaustive search yielded three trees with a length of 16, CI of 0.625, HI of 0.375, RI of 0.700, and RC of 0.438. Ontogram topology was tested through Bremer index approach; resolution was lost after the addition of two steps. Nine growth stages were identified: Stage 1: predental rostrum less than 5% total skull length (TSL), broadly defined quadrate infrastapedial process; Stage 2: predental rostrum longer than 5% TSL, acutely defined quadrate infrastapedial process; Stage 3: deep dentary, quadrate height 14-15% TSL; Stage 4: length between the first and sixth maxillary teeth greater than 25% TSL; Stage 5: length between the first and sixth dentary teeth less than or equal to 25% TSL; Stage 6: length between the first and sixth dentary teeth less than or equal to 35% dentary length; Stage 7: reversal to length between the first and sixth maxillary teeth less than 25% TSL; Stage 8: TSL greater than 1 m; Stage 9: reversal to slender dentary.

A Spearman rank-order correlation test found no correlation between TSL and growth stage ($r_{S(0.05,\ 10)} = 0.626$, $p = 0.053$; size rank data are normally distributed, Shapiro-Wilk $p = 0.892$), suggesting that TSL is not a reliable proxy for maturity in *T. proriger*. The ontogram does not split into two groups of specimens, and so did not show evidence for sexual dimorphism. Finally, to test the hypotheses that *T. kansasensis* is an immature form of *T. nepaeolicus* and that *T. proriger* is a paedomorph of the latter, representative specimens of each were separately analyzed in the *T. proriger* matrix; the resulting topologies were consistent with the first hypothesis, but not the second.

Technical Session XI (Friday, October 11, 2019, 8:15 AM)

TAPHONOMY OF VERTEBRATE FOSSILS FROM LANG TRANG CAVE: CHARACTERISTICS OF A PORCUPINE-GENERATED FAUNAL ASSEMBLAGE

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The origin of Pleistocene cave-hosted vertebrate accumulations has been the subject of numerous studies. Bone-accumulating agencies include physical vectors (e.g., gravity and flash floods), anthropological vectors (hominin hunter-gatherers) and zoological vectors (e.g., hyaenas, leopards, porcupines). Pleistocene fossils in Lang Trang Cave (Ba Thuoc District, Thanh Hoá Province, Vietnam) are interpreted to be the result of porcupine bone collecting and gnawing. Although the literature describes numerous examples of porcupine-influenced cave assemblages, few of these illustrate evidence of porcupine activity and the diagnostic attributes of porcupine-modified assemblages have yet to be summarized.

Lang Trang Cave is characterized by an abundant (~25,000 specimens) and diverse assemblage of fossil mammal remains representing at least 25 mammalian genera. Postcranial elements, skulls and mandibles are rare (>1% of material) whereas isolated teeth are abundant (>99% of material). Most teeth exhibit clear evidence of porcupine modification in the form of the gnawing trace fossil *Machichnus* and in the dominance of root-wedging on the teeth.

Porcupine-generated *Machichnus* are characterized by wide, approximately flat-bottomed gouges, commonly with 1 or more internal striae oriented parallel to the lateral gouge margins. The gouges are consistent in width with *Hystrix brachyura* incisors collected from the cave. The internal striae are consistent with imperfections (pits, spurs and gouges) characteristic of the tips of the *H. brachyura* incisors.

Many of the teeth exhibit a phenomenon informally referred to herein as root-wedging. Root-wedged teeth retain a minor, pyramidal-shaped wedge of dentin beneath the enamel crown. Short *Machichnus* may be visible on the surfaces of the wedge however they are not always apparent. Wedging was rare on the teeth of the smallest mammalian taxa collected (e.g., *Macaca, Presbytis*), omnipresent on the teeth of medium-scale mammals (e.g., *Ailuropoda, Ursus, Sus*) and occasionally present on the teeth of large mammals (e.g., *Rhinoceros, Bos, Elephas, Stegodon*).

The paucity of fossils belonging to very small and very large mammals in the collection likely reflects the gnawing preferences of the primary Lang Trang bone-collecting agent: porcupines. The degree to which Lang Trang vertebrate fossils exhibit evidence of porcupine gnawing (>95% of fossils collected) exceeds that of any other cave accumulation reported to date.

Grant Information:
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