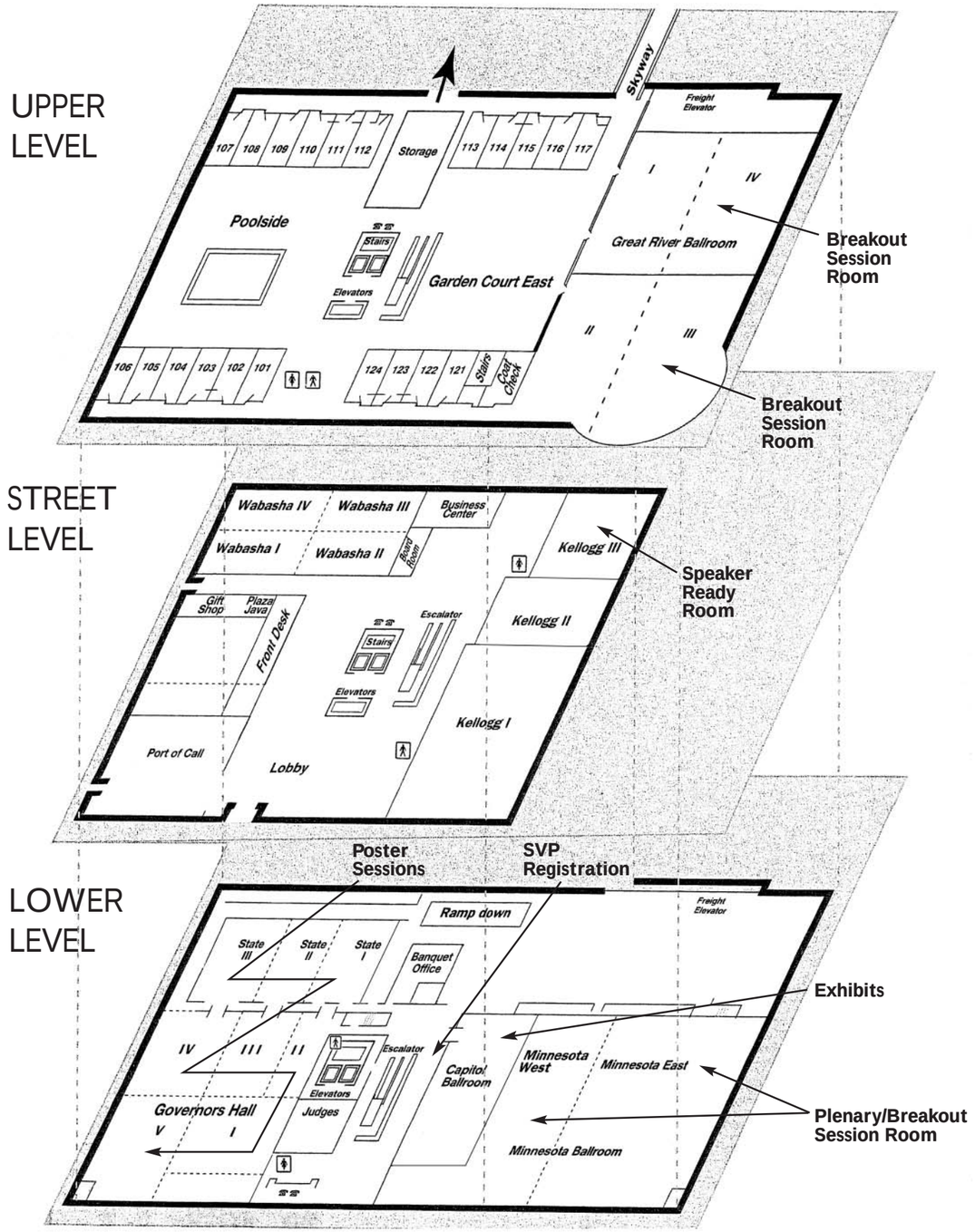
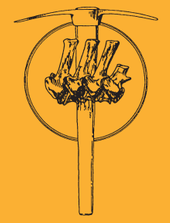
Radison Riverfront Hotel



VOL. 23, SUPPLEMENT TO NUMBER 3 JOURNAL OF VERTEBRATE PALEONTOLOGY ABSTRACTS SEPTEMBER 2003

Volume 23, Supplement to Number 3
12 September 2003



JOURNAL of
VERTEBRATE PALEONTOLOGY

ABSTRACTS OF PAPERS

SIXTY-THIRD ANNUAL MEETING
SOCIETY OF VERTEBRATE PALEONTOLOGY
SCIENCE MUSEUM OF MINNESOTA
ST. PAUL, MINNESOTA

OCTOBER 15-18, 2003

SOCIETY OF VERTEBRATE PALEONTOLOGY

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VOLUME 23, SUPPLEMENT TO NUMBER 3

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SIXTY-THIRD ANNUAL MEETING
SOCIETY OF VERTEBRATE PALEONTOLOGY
SCIENCE MUSEUM OF MINNESOTA
ST. PAUL, MINNESOTA
OCTOBER 15-18, 2003

HOST COMMITTEE:

Kristina Curry Rogers (Chair), Chris Brochu, Bruce Erickson, David Fox, Joe Hartman, Jackie Hoff, Ellen Holt-Werle, Ron Lawrenz, Ali Lozoff, Jessica Madole, Rebecca Newberry, Andy Redline, Ray Rogers

CONVENORS OF SYMPOSIA:

Jason Anderson, Hans-Dieter Sues, Marilyn Fox, Judd Case, Jaelyn Eberle, Mark Goodwin, Sandy Carlson

PROGRAM COMMITTEE:

Donald Prothero (Chair and Editor), Greg Buckley, Kristina Curry Rogers, David Froehlich, Mike Gottfried, and Eric Dewar

2003 SVP SCHEDULE OF EVENTS

(may be subject to change)

Event/Functions	Tuesday, October 14	Wednesday, October 15	Thursday, October 16	Friday, October 17	Saturday, October 18
Registration/ Membership	4 p.m. – 7:00 p.m. Coat Check	7 a.m. – 5:00 p.m. Coat Check	7 a.m. – 6:00 p.m. Coat Check	8 a.m. – 5:00 p.m. Coat Check	8 a.m. – 5:00 p.m. Coat Check
Symposium		8 a.m. – 11:45 a.m. Minnesota Ballroom			
Symposium		8 a.m. – 11:45 a.m. Great River 2/3			
Symposium		1:30 p.m. – 5:00 p.m. Minnesota Ballroom			
Symposium		1:30 p.m. – 6:00 p.m. Great River 2/3			
Preparators' Workshop		1:30 p.m. - 5:30 p.m. Great River 1/4			
Plenary Session			8 a.m. – 12:15 p.m. Minnesota Ballroom		
Technical Session				8 a.m. – 12:30 p.m. Minnesota Ballroom	8 a.m. – 12:30 p.m. Minnesota Ballroom
Technical Session				8 a.m. – 12:30 p.m. Great River 2/3	8 a.m. – 12:30 p.m. Great River 2/3
Technical Session				8 a.m. – 12:30 p.m. Great River 1/4	8 a.m. – 12:30 p.m. Great River 1/4
Technical Session			1:30 p.m. – 3:15 p.m. Minnesota Ballroom	1:30 p.m. – 3:15 p.m. Minnesota Ballroom	1:30 p.m. – 5:45 p.m. Minnesota Ballroom
Technical Session			1:30 p.m. – 3:15 p.m. Great River 2/3	1:30 p.m. – 3:15 p.m. Great River 2/3	1:30 p.m. – 5:45 p.m. Great River 2/3
Technical Session			1:30 p.m. – 3:15 p.m. Great River 1/4	1:30 p.m. – 3:15 p.m. Great River 1/4	1:30 p.m. – 5:45 p.m. Great River 1/4
Posters		7 a.m. – 8:00 a.m. Symposium Poster Set-up Garden Court East	7 a.m. – 9:30 a.m. Poster Presentation I Set-up Governor's Hall/State Suites	7 a.m. – 9:30 a.m. Poster Presentation I Set-up Governor's Hall/State Suites	
Posters		8 a.m. – 5:30 p.m. Symposium Poster Viewing Garden Court East	9:30 p.m. – 5:00 p.m. Poster I Viewing Governor's Hall/State Suites	9:30 p.m. – 5:30 p.m. Poster II Viewing Governor's Hall/State Suites	9:30 p.m. – 1:30 p.m. Poster II Viewing Governor's Hall/State Suites
Posters		5:30 p.m. Symposium Poster Teardown Garden Court East	5:00 p.m. Poster I Teardown Governor's Hall/State Suites		1:30 p.m. Poster II Teardown Governor's Hall/State Suites
Exhibits			9:30 a.m. – 5:00 p.m. Capitol Ballroom	9:30 a.m. – 5:30 p.m. Capitol Ballroom	9:30 a.m. – 1:30 p.m. Capitol Ballroom

2003 SVP SCHEDULE OF EVENTS

(may be subject to change)

Event/Functions	Tuesday, October 14	Wednesday, October 15	Thursday, October 16	Friday, October 17	Saturday, October 18
Business Meeting			5 p.m. – 6:00 p.m. Minnesota Ballroom		12:30 p.m. – 1:30 p.m. Executive Committee Open Meeting Minnesota Ballroom
Press Conference			10:30 a.m. – 11:30 a.m. Wabasha 3/4		
Social Events		**Welcome Reception** 7 p.m. – 10:00 p.m. Science Museum of Minnesota	**Poster Reception** 3:00-5:00 p.m. Governor's Hall/State Suites/ Capitol Ballroom	**Poster Exhibit Reception** 3:30 p.m. – 5:30 p.m. Governor's Hall/State Suites/ Capitol Ballroom **Auction/Reception** 6:30 p.m. – 10:30 p.m. **Radisson City Center** Atrium/Town Ballroom	**Awards Reception/Banquet** 7:30 p.m. – 10:00 p.m. Great River Ballroom **After Hours Party** 10:00 p.m. – 2:00 a.m. Kellogg 1/2/3
Beverage Service		7 a.m. – 8:00 a.m. Garden Court East/ Minnesota Ballroom Foyer	7 a.m. – 8:00 a.m. Minnesota Ballroom Foyer	7 a.m. – 8:00 a.m. Garden Court East/ Minnesota Ballroom Foyer	7 a.m. – 8:00 a.m. Garden Court East/ Minnesota Ballroom Foyer
Beverage Service		10 a.m. – 10:15 a.m. Garden Court East/ Minnesota Ballroom Foyer	10 a.m. – 10:15 a.m. Minnesota Ballroom Foyer	10 a.m. – 10:15 a.m. Garden Court East/ Minnesota Ballroom Foyer	10 a.m. – 10:15 a.m. Garden Court East/ Minnesota Ballroom Foyer
Beverage Service		3:15 p.m. – 3:30 p.m. Garden Court East/ Minnesota Ballroom Foyer			3:15 p.m. – 3:30 p.m. Garden Court East/ Minnesota Ballroom Foyer
Student Roundtable Forum			6:30 p.m. – 8:00 p.m. Wabasha 1-4		
Town Hall Meeting on Evolution		Noon – 2:00 p.m. Wabasha Suite			
Scholar One Workshop			12:30 p.m. - 1:30 p.m. Wabasha 3/4	12:30 p.m. - 1:30 p.m. Wabasha 3/4	
Speaker Ready Room		7 a.m. – 6:00 p.m. Kellogg 3	7 a.m. – 6:00 p.m. Kellogg 3	7 a.m. – 6:00 p.m. Kellogg 3	7 a.m. – 5:00 p.m. Kellogg 3
Committee Meeting Rooms		7 a.m. – 6:00 p.m. Wabasha 1/2	7 a.m. – 6:00 p.m. Wabasha 1/2	7 a.m. – 6:00 p.m. Wabasha Boardroom	7 a.m. – 5:00 p.m. Wabasha Boardroom
Committee Meeting Rooms		7 a.m. – 6:00 p.m. Wabasha 3/4	7 a.m. – 6:00 p.m. Kellogg 2	7 a.m. – 6:00 p.m. Wabasha 1/2	7 a.m. – 5:00 p.m. Wabasha 1/2
Committee Meeting Rooms		7 a.m. – 6:00 p.m. Kellogg 2		7 a.m. – 6:00 p.m. Wabasha 3/4	7 a.m. – 5:00 p.m. Wabasha 3/4
Committee Meeting Rooms				7 a.m. – 6:00 p.m. Kellogg 2	7 a.m. – 5:00 p.m. Kellogg 2

PROGRAM AT A GLANCE

	WED. 1	WED.2	THURS.1	THURS.2	THURS.3	FRI.1	FRI.2	FRI.3	SAT.1	SAT.2	SAT.3
8:00	Intro	Cavin	WELCOME			Monks	Polly	Krause	Wright	Joyce	Mihlbachler
8:15	Wilson	Schulp	Hill			Sidor	Alroy	Meredith	Witmer	Bever	Holbrook
8:30	Larsson	Smith	Sato			Sues	Makovicky	Horovitz	Tsuihiji	Rieppel	Nelson
8:45	Clack	Masek	Tumarkin			Langer	Flynn	Gaudin	Noriega	O'Keefe	Colbert
9:00	Anderson	Mason	Organ			Willis	Brochu	Bailey	Sullivan	Muller	Prothero
9:15	Reisz	Murphy	Carr			Witzke	Bonnan	Gunnell	Barrett	Budney	Bajpai
9:30		Wilkening	Wings			Paik	Rega	Croft	Henderson	Head	Fisher
9:45	Caldwell	Davidson	Parish			Decherd	Motani	Penkrot	Rothschild	Stayton	Todd
10:00	MORNING BREAK										
10:15	Padian	PREP.	Clarke			O'Connor	Main	Libed	Wilson	Sedlmayr	Green
10:30	Hopson	POSTERS	Secord			Eberth	Rayfield	Geisler	Parrish	Whatley	Marcolini
10:45		Keillor	Clifford			Lamanna	Greaves	Nummela	Harris	Wilhite	Davis
11:00	Luo	Herbel	Wesley			Turner	Semprebon	Gingerich	Heathcote	Holliday	Hopkins
11:15	O'Leary	Fox	Bair			Grellett-Tinner	Morton	Uhen	Carrano	Nesbitt	Sundell
11:30		Brown	McCarville			Chadwick	Elliott	Madar	Therrien	Novak	Trujillo
11:45	Beard	Groenke	Brinkman			Williamson	Greeniaus	Barnes	Sampson	Modesto	Wilson
12:00			Seiffert			Steele	Downs	Berta	Peyer	Parker	Hunter
12:15						Fricke	Hanke	Demere	Smith	Martz	Shockey
12:30	LUNCH										
12:45											
1:00											
1:15											
1:30	Wopenka	Fiorillo	Peters	Carroll	Angielczyk	Hwang	Smith	Foss	Kobayashi	Hungerbuhler	Flynn
1:45	Barreto	Gangloff	MacDonald	Ruta	Martin	Derstler	Grogan	Ferrusquia	Britt	Clark	Wyss
2:00	Martin	Clemens	Elvidge	Garcia	Meng	Mustafa	Coates	Hoffman	Sanders	Pol	MacFadden
2:15	Skinner	Brinkman	Unwin	Milner	Gottfried	Phillips	Stewart	Solounias	Loewen	Aumont	Jaffri
2:30	Kohn	Martin	Bennett	Jeannot	Rougier	Friedman	Lund	Williams	Hutchinson	Walker	Feranec
2:45	Hoppe	Case	Andres	Kissel	Scott	Chure	Hilton	Bobe	Snively	Bloch	Ruez
3:00	Teaford	Malyshkina	Kellner	Mueller	Weil	Rowland	Newbrey	Maga	Gishlick	Perry	Koch
3:15	AFTERNOON BREAK										
3:30	Koenigswald	Albright	POSTER SESSION I			POSTER SESSION II			Parsons	Sanders	Harris
3:45	Fox	Eberle							Baier	Koretsky	Barnosky
4:00	Goodwin	McKenna							Jasinoski	Newsome	Behrensmeyer
4:15	Stanton	Dawson							Claessens	Goswami	Badgley
4:30	de Ricqles	Fordyce							Sipla	Van Valkenburgh	Randall
4:45	Curry Rogers	Rybczynski							Milner	Wang	Nave
5:00	Sander		BUSINESS MTG.						Longrich	Wheeler	Spaeth
5:15	Jackson								Galton	Fox-Dobbs	Steele
5:30	Schweitzer								Dyke.	Anyonge	Moore
5:45	Trueman										

WEDNESDAY MORNING, OCTOBER 15, 2003

SYMPOSIA

EVOLUTIONARY TRANSITIONS AMONG VERTEBRATES
A Symposium in Honor of Robert Lynn Carroll
MINNESOTA BALLROOM
CONVENORS: JASON S. ANDERSON AND HANS-DIETER SUES

8:00 **Welcome**
8:05 **Wilson, M.V.H., and Hanke, G**.: HOMOLOGIES OF PAIRED FINS AND TEETH ACROSS THE AGNATHAN-GNATHOSTOME TRANSITION
8:25 **Larsson, H.**: EVOLUTIONARY INNOVATION OF THE AUTOPODIUM: TESTING DEVELOPMENTAL MECHANISMS OF THE FIN-LIMB TRANSITION
8:45 **Clack, J., Blom, H., and Ahlberg, P.E.:** NEW INSIGHTS INTO THE POSTCRANIAL SKELETON OF *ICHTHYOSTEGA*
8:55 **Anderson, J.** THE ORIGIN OF LISSAMPHIBIA
9:15 **Reisz, R.:** COTYLOSAUR PHYLOGENY AND THE INITIAL DIVERSIFICATION OF AMNIOTES
9:35 **Caldwell, M**.: ON THE ORIGIN OF SNAKES
9:55 BREAK
10:15 **Padian, K.:** EVOLUTIONARY TRANSITIONS IN THE ORIGIN OF BIRDS
10:35 **Hopson, J.:** THE TRANSITION FROM NONMAMMALIAN CYNODONTS TO MAMMALS
10:55 **Luo, Z.:** SUCCESSIVE DIVERSIFICATION OF MESOZOIC MAMMAL CLADES AND ACCUMULATIVE EVOLUTION OF THEIR ANATOMICAL APOMORPHIES
11:15 **O'Leary, M.:** THE POSITION OF WHALES AMONG MAMMALS: INCORPORATING NEW DISCOVERIES INTO CONTINUED COMBINED ANALYSIS.
11:35 **Beard, K.C.:** ANTHROPOID ORIGINS: MOSAIC EVOLUTION, BIOGEOGRAPHY, AND THE GENESIS OF THEIR PALEOECOLOGICAL DOMINANCE

PREPARATORS' SYMPOSIUM
GREAT RIVER BALLROOM 2/3
CONVENOR: MARILYN FOX

8:00 **Cavin, J., Herbel, C.L., Lien, D.B., Foss, S.E., and Benton, R.C.:** TEN YEARS OF ACCOMPLISHMENT AT THE BIG PIG DIG: AN IMPORTANT OLIGOCENE SITE, BADLANDS NATIONAL PARK, SOUTH DAKOTA
8:15 **Schulp, A.:** USING AN 'OPEN PREP LAB' IN EXHIBITION STORYLINE DEVELOPMENT
8:30 **Smith, M., Fremd, T.J., and Foss, S.E.:** FURNISHING A NEW PALEONTOLOGICAL CURATION AND RESEARCH FACILITY AT JOHN DAY FOSSIL BEDS NATIONAL MONUMENT, OREGON
8:45 **Masek, R.:** LARGE-SCALE TRANSFER PREPARATION
9:00 **Mason, J.:** MECHANICAL TO CHEMICAL: THE FINAL PREPARATION OF A DICYNODONT FROM THE KINGORI SANDSTONE USING MICROSCRIBES AND DIMETHYL SULFOXIDE.
9:15 **Murphy, N., Thompson, M., and Murphy, M.:** PREPARATION OF FOSSILIZED SOFT TISSUE STRUCTURES IN A NEW HADROSAURIAN MUMMY FROM THE JUDITH RIVER FORMATION OF MONTANA
9:30 **Wilkening, D.:** FOSSIL ACQUISITION BY SCREEN WASHING
9:45 **Davidson, A.:** ADHESIVES AS LIQUIDS
10:00 BREAK AND POSTER SESSION (authors will be present)
10:45 **Keillor, T.:** NOVEL APPROACHES TO SKULL RECONSTRUCTIONS
11:00 **Herbel, C.:** IMPORTANT CONSIDERATIONS REGARDING CONSERVATION AND ETHICS IN MOLD MAKING
11:15 **Fox, M.:** BASICS OF MOLDMAKING—FILLING AND MOLD DESIGN CONSIDERATIONS

11:30 **Brown, G.W:** THE SEAMY SIDE OF MOLD MAKING: DESIGN CONSIDERATIONS FOR SMALL MULTI-PART MOLDS

11:45 **Groenke, J., and Sanders, W.J.:** REPRODUCTION OF FOSSILS: FROM MOTHER MOLDS TO FULL-GROWN MOUNTED SKELETONS (AN OVERVIEW AND SUGGESTIONS)

POSTERS ASSOCIATED WITH PREPARATORS' SYMPOSIUM

(Authors will be present 10:00-10:45)

Booth #

1. **Jabo, S.:** AN INEXPENSIVE MOLD/CAST PROCEDURE SUITABLE FOR ELEMENTARY STUDENTS
2. **Kroehler, P.A.:** MOLDING AND CASTING *ODOBENOCETOPS*, AN UNUSUAL WHALE SKULL
3. **Christopher, M.:** A LIGHTWEIGHT ALTERNATIVE TO LARGE SILICONE BLOCK MOLDS
4. **Burnham, D., Martin, L.D., and Walton, A.W.:** UNUSUAL PRESERVATION EVEN FOR A LIAONING BIRD

WEDNESDAY AFTERNOON

HIGH-LATITUDE MESOZOIC AND CENOZOIC VERTEBRATES: EVOLUTION, PALEOCLIMATE, AND PALEOGEOGRAPHY
MINNESOTA BALLROOM
CONVENORS: JAELYN EBERLE AND JUDD CASE

1:30 **Fiorillo, A., and Gangloff, R.:** PRELIMINARY NOTES ON THE TAPHONOMIC AND PALEOECOLOGIC SETTING OF A *PACHYRHINOSAURUS* BONEBED IN NORTHERN ALASKA

1:45 **Gangloff, R., and Fiorillo, A.;** THE RECORD OF ARCTIC DINOSAURS FROM NORTHERN ALASKA, PALEOGEOGRAPHIC AND PALEOECOLOGIC IMPLICATIONS

2:00 **Clemens, W.A.:** LATE CRETACEOUS MAMMALS FROM THE PRINCE CREEK FORMATION, COLVILLE RIVER, ALASKA.

2:15 **Brinkman, D., Tarduno, J., Friedman, M., and Currie, P.:** A NON-MARINE VERTEBRATE ASSEMBLAGE FROM THE LATE CRETACEOUS (TURONIAN-CONIACIAN) CANADIAN HIGH ARCTIC

2:30 **Martin, J.E., Case, J.A., Jagt, J.W.M., Schulp, A.S., and Mulder, E.W.A.:** THE FIRST DIDELPHID MARSUPIAL (MAMMALIA) FROM EUROPE AND ITS SIGNIFICANCE CONCERNING LATE CRETACEOUS BIOGEOGRAPHY

2:45 **Case, J., Martin, J.E., Chaney, D.S., and Reguero, M.:** LATE CRETACEOUS DINOSAURS FROM THE ANTARCTIC PENINSULA: REMNANT OR IMMIGRANT FAUNA?

3:00 **Malyshkina, T.:** LATE PALEOCENE ELASMOBRANCHII FROM THE BASE OF SEROV FORMATION IN WESTERN PART OF THE WEST-SIBERIAN PLATE

3:15 BREAK

3:30 **Albright, L.B., Woodburne, M.O., Case, J.A., and Chaney, D.S.:** A LEATHERBACK SEA TURTLE FROM THE EOCENE OF ANTARCTICA: IMPLICATIONS FOR THE ANTIQUITY OF GIGANTOTHERMY IN DERMOCHELYIDAE

3:45 **Eberle, J., Dawson, M., Lee, C., Riediger, C., and Hutchison, J.H.:** TOWARDS A REFINED VERTEBRATE BIOSTRATIGRAPHY FOR EOCENE STRATA OF THE EUREKA SOUND GROUP, CANADIAN HIGH ARCTIC

4:00 **McKenna, M.C.:** SEMI-ISOLATION AND LOWERED SALINITY OF THE ARCTIC OCEAN IN LATE PALEOCENE TO EARLIEST EOCENE TIME

4:15 **Dawson, M.:** PHYLOGENETIC AND GEOGRAPHIC AFFINITIES OF THE EARLY MIOCENE VERTEBRATE FAUNA OF DEVON ISLAND, NUNAVUT, CANADA

4:30 **Fordyce, R.E.:** EARLY CROWN-GROUP CETACEA IN THE SOUTHERN OCEAN: THE TOOTHED ARCHAIC MYSTICETE *LLANOCETUS*

4:45 **Rybczynski, N.:** FOSSIL CUT-WOOD FROM THE CANADIAN HIGH ARCTIC: NEW INSIGHTS INTO THE EVOLUTION OF WOOD-CUTTING IN CASTORIDS

BIOMINERALIZATION: PATTERNS, PROCESSES, AND ANALYSIS OF MODERN AND FOSSIL VERTEBRATE SKELETAL TISSUES
GREAT RIVER BALLROOM 2/3
CONVENORS: MARK B. GOODWIN AND SANDRA J. CARLSON

1:30 **Wopenka, B., and Pasteris, J.:** BIOLOGICAL APATITES: A COMPARISON OF BONE AND TOOTH MINERALIZATION

1:45 **Barreto, C., and Marshall, C:** THE EVOLUTIONARY SIGNIFICANCE OF THE GROWTH PLATE

2:00 **Martin, R.B.:** THE IMPORTANCE OF FATIGUE FAILURE IN THE EVOLUTION OF BONE REMODELING

2:15 **Skinner, H.C.W.:** APATITE COMPOSITION: A SENTINEL MINERAL FOR VERTEBRATES

2:30 **Kohn, M.:** RATES OF ENAMEL FORMATION IN HERBIVORES AND IMPLICATIONS FOR INFERRING PALEOSEASONALITY

2:45 **Hoppe, K., Muenchau, B., and Chamberlain, P.:** USING ISOTOPIC ANALYSES OF HERBIVORE TEETH AS A PALEOENVIRONMENTAL PROXY: A STUDY OF ISOTOPIC PATTERNS IN MODERN GREAT PLAINS BISON

3:00 **Teaford, M., Darnell, L., Weihs, T., and Weiner, M.:** CHANGING PERSPECTIVES ON THE PHYSICAL PROPERTIES OF TEETH

3:15 BREAK

3:30 **von Koenigswald, W.:** THREE GENERAL TYPES OF SCHMELZMUSTER IN RODENT MOLARS

3:45 **Fox, D., Knurr, R., and Fisher, D.C.:** COMPARISON OF ELEMENTAL AND OXYGEN ISOTOPE VARIATION PROFILES IN PROBOSCIDEAN TUSK DENTIN

4:00 **Goodwin, M., and Barnes, L.: C**ARBON ISOTOPE ANALYSIS AND MINERALIZATION IN FOSSIL AND MODERN MYSTICETE WHALE BALEEN PLATES

4:15 **Stanton Thomas, K.J., and Carlson, S.J.:** ECOLOGICAL IMPLICATIONS OF MICROSCALE $\delta\,^{13}C$ ISOTOPIC ANALYSIS OF AN ONTOGENETIC SERIES OF THE HADROSAURIAN DINOSAUR *EDMONTOSAURUS*

4:30 **de Ricqles, A., and Yans, Y.:** BERNISSART'S *IGUANODON*: THE CASE FOR "FRESH" VERSUS "OLD" DINOSAUR BONE

4:45 **Curry Rogers, K., Erickson, G., and Norell, M.:** DINOSAURIAN LIFE HISTORY STRATEGIES, GROWTH RATES, AND CHARACTER EVOLUTION: NEW INSIGHTS GARNERED FROM BONE HISTOLOGY AND DEVELOPMENTAL MASS EXTRAPOLATION

5:00 **Sander, M.:** LONG AND GIRDLE BONE HISTOLOGY IN SAUROPOD DINOSAURS: METHODS OF STUDY AND IMPLICATIONS FOR GROWTH, LIFE HISTORY, TAXONOMY, AND EVOLUTION

5:15 **Jackson, F., Garrido, A., Schmitt, J.G., Chiappe, L.M., Dingus, L., and Loope, D.B.:** ABNORMAL, MULTILAYERED TITANOSAUR (DINOSAURIA: SAUROPODA) EGGS FROM *IN SITU* CLUTCHES AT THE AUCA MAHUEVO LOCALITY, NEUQUEN PROVINCE, ARGENTINA

5:30 **Schweitzer, M., Channing, A., Horner, J.R., and Chiappe, L.M.:** MICROBIAL BIOMINERALIZATION AND EXCEPTIONAL PRESERVATION OF VERTEBRATE FOSSILS

5:45 **Trueman, C., Behrensmeyer, A.K., Tuross, N., and Weiner, S.:** BIOMINERALIZATION, FOSSILIZATION, AND BIOCHEMISTRY: HOW THE ORIGINAL PHYSICAL AND CHEMICAL PROPERTIES OF BONE DICTATE ITS PRESERVATION

THURSDAY MORNING, OCTOBER 16, 2003

PLENARY ROMER PRIZE SESSION
MINNESOTA BALLROOM
MODERATORS: MATT CARRANO AND LANCE GRANDE

8:00 **Welcome**

8:15 **Hill, R.:** RECONSTRUCTING AMNIOTE PHYLOGENY USING MORPHOLOGY OF THE SKELETON, INTEGUMENT, AND OSTEODERMS

8:30 **Sato, T:** EFFECT OF DATA SELECTION IN PHYLOGENETIC ANALYSIS OF THE ELASMOSAURIDAE (REPTILIA: SAUROPTERYGIA)

8:45 **Tumarkin-Deratzian, A:** EVALUATION OF TEXTURAL AGING AS A METHOD FOR DETERMINING RELATIVE ONTOGENETIC AGE IN MODERN AND FOSSIL ARCHOSAURS

9:00 **Organ, C.:** EPAXIAL MUSCLES AND TENDONS IN ARCHOSAURS: THEY'RE NOT JUST FOR DUCK-BILLS ANYMORE

9:15 **Carr, T.:** NEW INSIGHT INTO THE EVOLUTION OF TYRANNOSAUROID THEROPODS: "EVENT PAIR CRACKING" AND THE INTEGRATION OF ONTOGENETIC AND PHYLOGENETIC DATA IN PALEONTOLOGY

9:30 **Wings, O.:** THE FUNCTION OF GASTROLITHS IN DINOSAURS—NEW CONSIDERATIONS FOLLOWING STUDIES ON EXTANT BIRDS

9:45 **Parish, J.:** EVOLUTIONARY HISTORY OF THE ANKYLOSAURIA (DINOSAURIA: ORNITHISCHIA)

10:00 BREAK

10:15 **Clarke, J.:** THE MORPHOLOGY, TAXONOMY, AND SYSTEMATIC POSITION OF *ICHTHYORNIS*: A CASE STUDY OF ALPHA TAXONOMIC PRACTICE IN A PHYLOGENETIC FRAME

10:30 **Secord, R.:** CLIMATE-DRIVEN DIVERSITY CHANGE IN PALEOCENE MAMMALS OF THE NOTHERN ROCKY MOUNTAIN REGION

10:45 **Clifford, A.:** PROBOSCIS EVOLUTION IN MAMMALS: RULES OF CONSTRUCTION AND FUNCTIONAL MORPHOTYPES

11:00 **Wesley, G.:** THE MORPHOLOGICAL DIVERSIFICATION OF CARNIVORES IN NORTH AMERICA

11:15 **Bair, A.:** A GEOMETRIC MODEL OF ONTOGENETIC TOOTH WEAR IN MAMMALS: STRUCTURE, FUNCTION, AND EVOLUTION OF HYPSODONT MORPHOLOGIES

11:30 **McCarville, K.:** A NEW INTERPRETATION FOR A CLASSICAL LOCALITY: FOSSIL LAKE, OREGON

11:45 **Brinkman, P.:** DARWIN'S CONVERSION RECONSIDERED: THE *BEAGLE* VOYAGE AND FOSSIL VERTEBRATE SUCCESSION

12:00 **Seiffert, E.:** INTERRELATIONSHIPS OF LIVING AND EXTINCT AFROTHERIAN PLACENTALS

TECHNICAL SESSION I
MINNESOTA BALLROOM
MODERATOR: DAVID UNWIN

1:30 **Peters, D.:** THE CHINESE VAMPIRE AND OTHER OVERLOOKED PTEROSAUR PTREASURES

1:45 **MacDonald, K., and McQuilkin, K.:** VIRTUAL PTEROSAURS: THE USE OF LASER SCANNING EQUIPMENT AND 3-D ANIMATION SOFTWARE FOR EXHIBITION AND RESEARCH

2:00 **Elvidge, D., and Unwin, D.:** LOCOMOTOR MODULES, LINKAGE AND MORPHOLOGICAL DISPARITY IN PTEROSAURS AND OTHER FLYING VERTEBRATES

2:15 **Unwin, D.:** EXPLOITING THE COMPLEX INTERFACE BETWEEN PALAEOICHNOLOGY AND PALAEOBIOLOGY: THE CASE OF *PTERAICHNUS* AND PTEROSAURS

2:30 **Bennett, S.C.:** NEW INFORMATION ON THE GENERA *PTERODACTYLUS* AND *GERMANODACTYLUS* FROM THE SOLNHOFEN LIMESTONE OF SOUTHERN GERMANY

2:45 **Andres, B., and Ji, C.:** TWO NEW PTEROSAUR SPECIES FROM LIAONING, CHINA, AND THE RELATIONSHIPS OF THE PTERODACTYLOIDEA

3:00 **Kellner, A.:** THE TAPEJARIDAE—A MONOPHYLETIC GROUP OF PTERODACTYLOID PTEROSAURS

TECHNICAL SESSION II
GREAT RIVER BALLROOM 1/4:
MODERATOR: ROBERT CARROLL

1:30 **Carroll, R.L., and Green, D.:** ORIGIN OF TERRESTRIAL LOCOMOTION IN VERTEBRATES
1:45 **Ruta, M., Coates, M., and Jeffery, J.:** A SUPERTREE OF EARLY TETRAPODS
2:00 **Garcia, W.:** A NEW COLOSTEID WITH UNUSUAL DERMAL SQUAMATION FROM HANCOCK COUNTY, KENTUCKY
2:15 **Milner, A., and Sequieria, S.:** BRANCHIOSAURS, LARVAE AND METAMORPHOSIS
2:30 **Jeannot, A.M., and Damiani, R.J.:** CRANIAL ANATOMY OF THE TEMNOSPONDYL *LYDEKKERINA HUXLEYI* (STEREOSPONDYLI: LYDEKKERINIDAE)
2:45 **Kissel, R., and Reisz, R.:** REMAINS OF A SMALL DIADECTID (TETRAPODA: DIADECTOMORPHA) FROM THE DUNKARD GROUP OF OHIO, WITH CONSIDERATION OF DIADECTOMORPH PHYLOGENY
3:00 **Mueller, B., and Chatterjee, S.:** SKULL ANATOMY OF *LIBOGNATHUS SHEDDI* (PARAREPTILIA: PROCOLOPHONIA) FROM THE UPPER TRIASSIC COOPER CANYON FORMATION OF WEST TEXAS

TECHNICAL SESSION III
GREAT RIVER BALLROOM 2/3
MODERATOR: ANNE WEIL

1:30 **Angielczyk, K., and Rubidge, B.:** DICYNODONT EXTINCTIONS IN THE PERMIAN: ONE, MANY OR NONE?
1:45 **Martin, T., and Pfretzschner, H.-U.:** FUNCTIONAL MORPHOLOGY AND EVOLUTION OF DOCODONT MOLARS (MAMMALIA) FROM THE MIDDLE JURASSIC OF JUNGGAR BASIN (NW CHINA)
2:00 **Meng, J., Hu, Y., Wang, Y., and Li, C.:** CRANIODENTAL MORPHOLOGIES OF THE EARLY CRETACEOUS TRICONODONT MAMMAL *REPENOMAMUS*: NEW EVIDENCE FOR MAMMALIAN EVOLUTION
2:15 **Gottfried, M., Krause, D., O'Connor, P., Roberts, E., and Tulu, Y.:** A GONDWANATHERIAN? MAMMAL FROM THE CRETACEOUS OF TANZANIA
2:30 **Rougier, G., Novacek, M.J., Ortiz-Jaureguizar, E., Pol, D., and Purerta, P.:** REINTERPRETATION OF *REIGITHERIUM BUNODONTUM* AS A REIGITHERIIDAE DRYOLESTOID AND THE INTERRELATIONSHIPS OF THE SOUTH AMERICAN DRYOLESTOIDS
2:45 **Scott, C.:** NEW MULTITUBERCULATES (MAMMALIA, ALLOTHERIA) FROM THE LATE PALEOCENE OF ALBERTA, CANADA, AND EVOLUTION OF MULTITUBERCULATES IN WESTERN CANADA
3:00 **Weil, A., and Tomida, Y.:** DETAILED CRANIAL ANATOMY AND PHYLOGENETIC AFFINITIES OF THE MULTITUBERCULATE *MENISCOESSUS*

POSTER SESSION I
Authors must be present 3:00-4:30
Posters must be removed by 6:00

Booth #
1. **Hembree, D., Martin, L.D., and Hasiotis, S.:** CONTINENTAL AMPHIBIAN BURROWS FROM THE LOWER PERMIAN SPEISER SHALE OF KANSAS: EVIDENCE FOR DROUGHT-INDUCED AESTIVATION IN PERMIAN TETRAPODS
2. **Venczel, M., and Gardner, J.:** THE GEOLOGICALLY YOUNGEST ALBANERPETONTID AMPHIBIAN
3. **Balanoff, A.:** SKELETAL DEVELOPMENT OF THE VERTEBRAL COLUMN IN *ASCAPHUS TRUEI* (AMPHIBIA: ANURA)
4. **Corsini, J., Doppheide, A., and Leite, M.:** FOSSIL TURTLES OF NEBRASKA'S WHITE RIVER GROUP: A BIAS TOWARD THE CARAPACE-UP POSITION
5. **Gensler, P.A., and Kelly, A.:** PRELIMINARY REPORT OF A NEARLY COMPLETE SKELETON OF *CLEMMYS OWYHEENSIS* (REPTILIA: EMYDIDAE) FROM THE UPPER BLANCAN (PLIOCENE) GLENNS FERRY FORMATION, HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

6. **Suzuki, S.:** THE POSTCRANIAL MORPHOLOGY OF THE ARCHAIC TURTLE *MONGOLOCHELYS EFREMOVI* (TESTUDINES, CRYPTODIRA)
7. **Bishop, G.:** NESTING TRACES OF SEA TURTLES: A RETROSPECTIVE PERSPECTIVE
8. **Merck, J.:** AN ARBOREAL RADIATION OF NON-SAURIAN DIAPSIDS
9. **Ksepka, D., Goa, K., and Norell, M.A.:** A NEW SPECIES OF *TCHOIRIA* (DIAPSIDA, CHORISTODERA) FROM DHOUS, MONGOLIA
10. **Gillette, D., and Albright, L.B.:** FURTHER DISCOVERIES OF CENOMANIAN-TURONIAN (EARLY LATE CRETACEOUS) PLESIOSAURS FROM THE TROPIC SHALE, SOUTHERN UTAH
11. **Irwin, K., and Schumacher, B.:** AN ADDITIONAL RECORD OF A POLYCOTYLID PLESIOSAUR FROM THE UPPER CAMPANIAN OF NORTH AMERICA
12. **Bardet, N., Perea Suberbiola, X., and Jalil, N.-E.:** NEW POLYCOTYLID PLESIOSAUR FROM THE LATE CRETACEOUS OF MOROCCO
13. **Druckenmiller, P., and Russell, A.:** A PRELIMINARY REPORT ON A DIVERSE ASSEMBLAGE OF EARLY CRETACEOUS PLESIOSAURS AND ICHTHYOSAURS FROM THE CLEARWATER FORMATION, NORTHERN ALBERTA, CANADA
14. **Massare, J., and Young, H.:** GASTRIC CONTENTS OF A JURASSIC ICHTHYOSAUR
15. **Dutchak, A.:** NEW MATERIAL FROM AN OLD SPECIMEN: A CRANIAL DESCRIPTION OF *OPETIOSAURUS BUCCICHI* FROM THE LOST COUNTERPART
16. **Nelson, J.:** A NEW SPECIES OF MOSASAUR FROM THE FOX HILLS FORMATION OF SOUTH DAKOTA
17. **Behlke, A., and Boyd, C.A.:** A SPECIMEN OF *CLIDASTES PROPYTHON* WITH AN ARTICULATED FOREPADDLE
18. **Voci, G., and Nydam, R.:** REVISION OF THE LIZARDS FROM THE UPPER CRETACEOUS OF THE KAIPAROWITS PLATEAU
19. **Weinbaum, J., and Hungerbühler, A.:** A NEW SPECIMEN OF *POPOSAURUS* (ARCHOSAURIA: CROROTARSI) FROM THE LATE TRIASSIC TECOVAS FORMATION OF TEXAS
20. **Woody, D., and Parker, W.:** A NEW SKELETON OF THE AETOSAUR *STAGONOLEPIS WELLESI* (ARCHOSAURIA: CROROTARSI) FROM PETRIFIED FOREST NATIONAL PARK AND PRELIMINARY RESULTS FROM A SIGNIFICANT NEW BONEBED FROM THE LOWER CHINLE FORMATION (LATE TRIASSIC) OF ARIZONA
21. **Hurlburt, G., Heckert, A., and Farlow, J.:** ESTIMATING PHYTOSAUR BODY MASS FROM SKELETAL DIMENSIONS USING EQUATIONS BASED ON ALLIGATORS AND OTHER CROCODILIANS
22. **Allen, D.:** WHEN *TERRESTRISUCHUS GRACILIS* REACHES PUBERTY IT BECOMES *SALTOPOSUCHUS CONNECTENS*!
23. **Salisbury, S., Frey, E., Martill, D., and Buchy, M.-C.:** A NEW CROCODILIAN FROM THE LOWER CRETACEOUS CRATO FORMATION OF NORTH-EASTERN BRAZIL
24. **Buckley, G., Brochu, C.A., and Georgi, J.:** A NEW SLENDER-SNOUTED CROCODYLIFORM FROM THE UPPER CRETACEOUS MAEVARANO FORMATION, MADAGASCAR
25. **Wahl, W., and Hogbin, J.:** *DEINOSUCHUS* MATERIAL FROM THE MESAVERDE FORMATION OF WYOMING: FILLING IN A GAP
26. **Lucas, S.G., and Sullivan, R.M.:** *CHRYSOCHAMPSA* IS *ALLOGNATHOSUCHUS*
27. **Farlow, J., Hurlburt, G., Elsey, R., and Britton, A.:** FEMORAL DIMENSIONS AND BODY SIZE OF *ALLIGATOR MISSISSIPPIENSIS*: ESTIMATING THE SIZE OF FOSSIL CROCODYLIANS AND THEIR KIN
28. **Suzuki, D., and Hiruta, A.:** EVALUATION OF BONE-TENDON MORPHOLOGY OF FOSSIL SKELETONS BASED ON RECENT CROCODILIAN ANCHORING FIBERS: A PRELIMINARY REPORT
29. **Wroblewski, A.:** SYSTEMATIC AND BIOSTRATIGRAPHIC IMPLICATIONS OF A NEW ORNITHOCHERID PTEROSAUR FROM WYOMING
30. **Bird, J., Burge, D., and Carpenter, K.:** THE RECONSTRUCTION OF THREE ANKYLOSARIDS FROM THE CEDAR MOUNTAIN FORMATION OF EASTERN UTAH
31. **Fujita, M., Azuma, Y., Goto, M., Tomida, Y., Hayashi, S., and Arakawa, Y.:** FIRST ANKYLOSAUR FOOTPRINTS IN JAPAN AND THEIR SIGNIFICANCE
32. **Knoll, F., and Barrett, P.M.:** SYSTEMATIC REVISION OF '*YANDUSAURUS' MULTIDENS*, A MIDDLE JURASSIC ORNITHOPOD FROM CHINA
33. **Main, D., and Fiorillo, A.:** REPORT OF NEW CENOMANIAN HADROSAUR (DINOSAURIA: ORNITHISCHIA) POSTCRANIA FROM THE WOODBINE FORMATION OF NORTH CENTRAL TEXAS

34. **Prieto-Marquez, A., Weishampel, D.B., and Horner, J.R.:** TAXONOMY AND SYSTEMATICS OF THE HOLOTYPE OF *HADROSAURUS FOULKII* (DINOSAURIA, ORNITHOPODA) FROM THE LATE CRETACEOUS OF EASTERN NORTH AMERICA
35. **Evans, D.:** CRANIAL OSTEOLOGY AND ONTOGENY OF *CORYTHOSAURUS* (ORNITHISCHIA: HADROSAURIDAE).
36. **Hernandez, R., Kirkland, J.I., Paul, G.S., Serrano, C.B., and Garcia, J.P.:** A LARGE HADROSAURINE FROM THE SABINAS BASIN, COAHUILA MEXICO
37. **Boyd, C., and Behlke, A.:** THE HOLE TRUTH: INVESTIGATING THE PRESENCE OF OBTURATOR FORAMINA IN THE ISCHIA OF *EDMONTOSAURUS ANNECTENS*
38. **Gould, R., Larson, R., and Nellermoe, R.:** AN ALLOMETRIC STUDY COMPARING METATARSAL II'S IN *EDMONTOSAURUS* FROM A LOW-DIVERSITY HADROSAUR BONE BED IN CORSON CO., S.D.
39. **Williams, D., and Weigweiser, M.:** PHENETIC DISTINCTIONS OF LAMBEOSAURINE RIBS FROM THIS SIDE OF HELL, WYOMING
40. **Chinnery, B., and Horner, J.R.:** NEW BASAL NEOCERATOPSIAN FROM THE LOWER TWO MEDICINE FORMATION OF MONTANA PROVIDES A LINK BETWEEN ASIAN AND NORTH AMERICAN TAXA
41. **Getty, M., Roberts, E., and Loewen, M.:** TAPHONOMY OF A CHASMOSAURINE CERATOPSIAN SKELETON FROM THE CAMPANIAN KAIPAROWITS FORMATION, GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, UTAH
42. **Ryan, M., and Russell, A.P.:** NEW CENTROSAURINE CERATOPSIDS FROM THE LATE CAMPANIAN OF ALBERTA AND MONTANA AND A REVIEW OF CONTEMPORANEOUS AND REGIONAL PATTERNS OF CENTROSAURINE EVOLUTION
43. **Happ, J.:** PERIOSTEAL REACTION TO INJURIES OF THE SUPRAORBITAL HORN AND SQUAMOSAL OF AN ADULT *TRICERATOPS* (DINOSAURIA: CERATOPSIDAE)
44. **Leal, L.A., and Azevedo, S.A.K.:** A PRELIMINARY PROSAUROPODA PHYLOGENY WITH COMMENTS ON BRAZILIAN BASAL SAUROPODOMORPHA
45. **Lovelace, D., Wahl, W.R., and Hartman, S.A.:** EVIDENCE FOR COSTAL PNEUMATICITY IN A DIPLODOCID DINOSAUR (*SUPERSAURUS VIVIANAE*)
46. **Fowler, D., Simmonds, K., Green, M, and Stevens, K.A.:** THE TAPHONOMIC SETTING OF TWO MIRED SAUROPODS (WESSEX FM, ISLE OF WIGHT, UK), PALAEOECOLOGICAL IMPLICATIONS AND TAXON PRESERVATION BIAS IN A LOWER CRETACEOUS WETLAND
47. **Bandyopadhyay, S., Sengupta, D.P., and Gillette, D.D.:** DENTITION OF *BARAPASAURUS TAGOREI* FROM THE KOTA FORMATION (UPPER JURASSIC) OF INDIA
48. **Rodrigues, L., and Santos, V.:** QUANTITATIVE DESCRIPTION OF SAUROPOD TRACKS–A GEOMETRIC MORPHOMETRICS STUDY
49. **Ikejiri, T.:** SEQUENCE OF CLOSURE OF NEUROCENTRAL SUTURES IN *CAMARASAURUS* (SAUROPODA) AND IMPLICATIONS FOR PHYLOGENY IN REPTILIA
50. **Samman, T., Currie, P.J., and Stevens, K.A.:** NECK BIOMECHANICS OF THEROPOD DINOSAURS
51. **Bittencourt, J., and Cavalcanti, M.:** PHYLOGENETIC AUTOCORRELATION IN BODY WEIGHT OF THEROPOD DINOSAURS
52. **Zanno, L.E., and Sampson, S.D.:** A NEW CAENAGNATHID SPECIMEN FROM THE KAIPAROWITS FORMATION (LATE CAMPANIAN) OF UTAH
53. **Foster, J.:** *ALLOSAURUS* AS A GENERALIZED PREDATOR IN THE MORRISON FORMATION PALEOECOSYSTEM (LATE JURASSIC; NORTH AMERICA)
54. **Pinegar, R.T., Loewen, M.A., Cloward, K.C., Hunter, R.J., and Weege, C.J.:** A JUVENILE ALLOSAUR WITH PRESERVED INTEGUMENT FROM THE BASAL MORRISON FORMATION OF CENTRAL WYOMING
55. **Smith, D.:** CRANIAL VARIATION WITHIN *ALLOSAURUS FRAGILIS*
56. **Hunt, R., and Chure, D.:** AN EARLY CRETACEOUS THEROPOD FROM SOUTHWESTERN ARKANSAS
57. **Wolff, E., and Horner, J.R.:** THE FIRST OCCURRENCE OF *ORODROMEUS MAKELAI* POSTCRANIA FROM THE LATE-CAMPANIAN JUDITH RIVER FORMATION OF EASTERN MONTANA
58. **Lu, J-C., Zhang, B., and Li, J.:** A NEW OVIRAPTORID DINOSAUR FROM THE LATE CRETACEOUS OF SHIXIN, NANXIONG BASIN OF GUANGDONG PROVINCE, SOUTHERN CHINA
59. **Headden, J.:** HENRY FAIRFIELD OSBORN AND REVISING THE *OVIRAPTOR* MYTH
60. **Buckley, L.:** ADDRESSING THE POTENTIAL FOR CRANIAL KINESIS IN *TYRANNOSAURUS REX*: A COMPARISON OF THE PALATE COMPLEXES OF *TYRANNOSAURUS REX* TO *VARANUS*

61. **Paul, G.S.:** WHO SAYS DROMAEOSAURS COULDN'T FLY?
62. **Larson, R., Nellermoe, R., and Gould, R.:** A STUDY OF THEROPOD TEETH FROM A LOW-SPECIES-DENSITY HADROSAUR BONE BED IN THE LOWER HELL CREEK FORMATION IN CORSON CO. S.D.
63. **Sankey, J.:** NEW THEROPOD AND BIRD TEETH FROM THE UPPER CRETACEOUS (MAASTRICHTIAN) HELL CREEK AND LANCE FORMATIONS
64. **Holtz, T.:** EVIDENCE FOR THE EVOLUTION OF WING-ASSISTED INCLINE RUNNING IN NON-AVIALIAN THEROPODS
65. **Smith, N.:** IMPLICATIONS OF A PENTADACTYL GROUND STATE FOR THE AVIAN HAND ON THE HOMOLOGY OF THE THEROPOD MANUS: SHOULD THE FRAME-SHIFT HYPOTHESIS BE SHIFTED?
66. **Goehlich, U., and Mourer-Chaviré, C.:** REVISION OF THE PHASIANIDS (AVES, GALLIFORMES) FROM THE LOWER MIOCENE OF ST.-GÉRAND-LE-PUY (FRANCE)
67. **Leggitt, V.L., and Cushman, R.:** FLAMINGO NEST MOUNDS FROM A CROCODILIAN NESTING SITE IN THE EOCENE WASATCH FORMATION: LINCOLN COUNTY, WYOMING
68. **Waterhouse, D., and Dyke, G.:** A NEW FOSSIL CHARADRIIFORM BIRD FROM THE LOWER EOCENE GREEN RIVER FORMATION OF WYOMING
69. **Gulas-Wroblewski, B.:** *LIMNOFREGATA*—NOT A FRIGATEBIRD ANY MORE
70. **Heaton, T.H., and Grady, F.:** THE LATE PLEISTOCENE SEA BIRD FAUNA OF ON YOUR KNEES CAVE, SOUTHEAST ALASKA
71. **Lockley, M., Matsukawa, M., and Li, J.:** CRETACEOUS BIRD TRACKS FROM CHINA: THEIR ASIAN AND GLOBAL CONTEXT
72. **Small, B., and Sanders, F.:** EARLY PERMIAN TETRAPOD ICHNOFAUNA FROM THE MAROON FORMATION, COLORADO: AGE, PALEOECOLOGICAL, AND BIOSTRATIGRAPHIC SIGNIFICANCE
73. **Santos, V., and Rodrigues, L.:** DINOSAURS TRACKS FROM THE ALGARVE BASIN, PORTUGAL
74. **Dalman, S., and Getty, P.:** A STUDY OF SMALL DINOSAUR FOOTPRINTS (*ANOMOEPUS*) FROM THE EARLY JURASSIC GARY GAULIN TRACKSITE, HOLYOKE, MA
75. **Getty, P.:** *IN SITU* DINOSAUR FOOTPRINTS AT THE MURRAY QUARRY (UPPER JURASSIC ?EAST BERLIN FORMATION), HOLYOKE, MA
76. **Deblieux, D.D., Smith, J.A., McGuire, J.L., Santucci, V.L., Kirkland, J.L., and Butler, M.:** A PALEONTOLOGICAL INVENTORY OF ZION NATIONAL PARK, UTAH, AND THE USE OF GIS TECHNOLOGY TO CREATE PALEONTOLOGICAL SENSITIVITY MAPS FOR USE IN RESOURCE MANAGEMENT
77. **Mickelson, D., King, M.R., Getty, P., and Mickelson, K.A.:** OCCURRENCES OF SUBAQUEOUS TETRAPOD SWIM TRACKS FROM THE MIDDLE JURASSIC (BAJOCIAN) GYPSUM SPRING FORMATION: BIGHORN BASIN, WYOMING
78. **Southwell, E., Breithaupt, B.,, Erickson, B., and Flynn, M.:** JURASSIC DINOSAURS FROM NORTHEASTERN WYOMING: WYOMING'S QUIET CORNER.
79. **Platt, B., and Hasiotis, S.:** A NEW SAUROPOD TRACKSITE FROM THE UPPER JURASSIC MORRISON FORMATION WITH PRESERVED SKIN AND FOOT-PAD IMPRESSIONS
80. **Watabe, M., Tsogbaaatar, K., Tsuihiji, T., and Barsbold, R.:** THE FIRST DISCOVERY OF DIVERSE JURASSIC DINOSAUR FAUNAS IN MONGOLIA
81. **Kirkland, J., Ludwvigson, G., Gonzalez, L., Joeckel, R.M., and Madsen, S.:** CORRELATING EARLY CRETACEOUS DINOSAUR SITES USING STRATIGRAPHIC TRENDS IN ^{13}C FROM PEDOGENIC CARBONATES: AN EXAMPLE FROM THE CEDAR MOUNTAIN FORMATION IN UTAH
82. **Hodnett, J.-P.:** A PRELIMINARY REVIEW OF THE VERTEBRATE FAUNA OF THE TURNEY RANCH FORMATION (ALBIAN/CENOMANIAN) OF PIMA COUNTY ARIZONA
83. **Smith, J., Sampson, S., Roberts, E., Gates, T., Getty, M., and Zanno, L.:** FOSSIL VERTEBRATES FROM THE KAIPAROWITS FM, GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT: AN IMPORTANT WINDOW INTO THE LATE CRETACEOUS OF UTAH
84. **Imhof, M., and Albright, L.B.:** PRELIMINARY MAGNETOSTRATIGRAPHIC ANAYLSIS OF THE UPPER CRETACEOUS KAIPAROWITS FORMATION, SOUTHERN UTAH
85. **Ikegami, N., and Tomida, Y.:** EARLY LATE CRETACEOUS VERTEBRATE FAUNA OF THE MIFUNE GROUP IN KUMAMOTO PREFECTURE, JAPAN
86. **Huh, M., Hwang, K.-G., Paik, I.-S., Chung, C.-H., and Park, J.:** CRETACEOUS DINOSAUR TRACKS OF SOUTH KOREA: OCCURRENCES AND PALEOBIOLOGICAL IMPLICATIONS
87. **Sullivan, R., and Lucas, S.G.:** VERTEBRATE FAUNAL SUCCESSION IN THE UPPER CRETACEOUS, SAN

JUAN BASIN, NEW MEXICO, WITH IMPLICATIONS FOR CORRELATIONS WITHIN THE NORTH AMERICAN WESTERN INTERIOR

88. **Pappas, J.A., O'Grady, B.R., and Parris, D.C.:** A JUDITHIAN MICROFAUNAL LOCALITY IN ELK BASIN, PARK COUNTY, WYOMING
89. **Wegweiser, M., Breithaupt, B., Babcock, L.E., Skinner, E., and Scheffield, J.:** DINOSAUR SKIN FOSSILS FROM THIS SIDE OF HELL, WYOMING: PALEOENVIRONMENTAL IMPLICATIONS OF AN UPPER CRETACEOUS KONSERVAT-LAGERSTÄTTE IN THE LANCE FORMATION
90. **Matthews, N., Wegweiser, M., and Breithaupt, B.:** CAUGHT IN DANTE'S INFERNO—STUDYING DINOSAUR TRACKS NEAR THIS SIDE OF HELL QUARRY, WYOMING
91. **Schumacher, B.:** NEW TRACKWAYS OF *MAGNOAVIPES*: FURTHER EVIDENCE OF GREGARIOUS BEHAVIOR IN SMALL CRETACEOUS THEROPOD DINOSAURS
92. **Park, K.-H., and Paik, I.-S.:** GEOCHEMISTRY OF DINOSAUR BONES FROM THE CRETACEOUS HASANDONG FORMATION OF THE GYEONGSANG BASIN, KOREA
93. **Casey, M.M., Rogers, R.R., Jackson, M.J., and Buckley, G.A.:** MAGNETIC STRATIGRAPHY OF THE UPPER CRETACEOUS MAEVARANO FORMATION (CAMPANIAN(?)-MAASTRICHTIAN), NORTHWESTERN MADAGASCAR
94. **Rodrigues de la Rosa, R.A., Eberth, D.A., Brinkman, D.B., Sampson, S.D., and Lopez-Espinosa, J.:** DINOSAUR TRACKS FROM THE LATE CAMPANIAN LAS AGUILAS LOCALITY SOUTHEASTERN COAHUILA, MEXICO
95. **Larson, P.L.:** AN IMPORTANT TRACKWAY SITE FROM THE LANCE FORMATION (LATE CRETACEOUS) OF NIOBRARA COUNTY, WYOMING, WITH NEW INFORMATION ON BEHAVIOR IN *TYRANNOSAURUS REX*
96. **Tapanila, L., Roberts, E.M., and O'Leary, M.:** PHOSPHATE-MEDIATED TAPHONOMY: A CONCENTRATED BONE AND BIOERODED COPROLITE BED FROM THE MAASTRICHTIAN OF MALI
97. **Gallagher, W., Parris, D., Grandstaff, B., Camburn, J., and Camburn, S.:** COMPARATIVE TAPHONOMY OF VERTEBRATE FOSSIL CONCENTRATIONS IN THE LATE CRETACEOUS-EARLY TERTIARY SEQUENCE OF NEW JERSEY
98. **Santos, D., Henriques, D., and Azevedo, S.A.:** THE USE OF CT-SCAN IN TAPHONOMIC INTERPRETATIONS
99. **Rensberger, J., Collier, S.M., Dauwalder, C.C., Decker, S.R., and Richards, C.D.:** UNUSUAL PRESERVATION OF THE 3-DIMENSIONAL ORGANIZATION OF FIBERS IN DINOSAUR BONE TISSUE
100. **Gatesy, S., Kenny, K.S., Middleton, K.M., Jenkins, F.A., Jr., and Shubin, N.H.:** SKIN IMPRESSION MICROTOPOGRAPHY IN TRIASSIC THEROPOD TRACKS
101. **Ng-Thow-Hing, V., Anderson, F., and Hutchinson, J.:** MASS SETS FOR INTERACTIVE COMPUTATION OF BODY SEGMENT DIMENSIONS AND BIOMECHANICAL ANALYSIS OF ANIMAL LOCOMOTION
102. **Grawe, L.:** THE PALEONTOLOGY OF DINOSAURS MOVEABLE MUSEUM: EXTENDING MUSEUM EDUCATIONAL RESOURCES
103. **Evans, D., and Larson, P.:** TUMORS, TEARS, FUSION, DECALCIFICATION, FRACTURES AND INFECTION—TOUGH TIMES FOR A TYRANNOSAUR

STUDENT POSTER SESSION

Posters will be set up by 8 a.m. on Thursday, Oct. 16, and remain until 5:00.

109. **Bader, K.:** THE LOCAL FLORA AND FAUNA OF A SITE IN THE UPPER MORRISON FORMATION (UPPER JURASSIC) OF NORTHEASTERN WYOMING
110. **Bonde, J.:** THE IMPLICATIONS OF PLEISTOCENE (RANCHOLABREAN) PLUVIAL LAKE SYSTEMS ON THE PALEOECOLOGY AND PALEOBIOGEOGRAPHY OF *CANIS DIRUS* (MAMMALIA: CARNIVORA) IN THE GREAT BASIN, UNITED STATES
111. **Bullard, T.:** REVISIONS TO THE SYSTEMATICS OF TYLOSAURINE MOSASAURS (REPTILIA: SQUAMATA)
112. **Burris, J.:** FOSSIL AND RECENT CENTRA OF CARCHARHINIFORM SHARKS: MORPHOLOGY AND PHYLOGENY
113. **Carney, R.:** PHYLOGENETICALLY TESTING THE HYPOTHESIS OF SECONDARY FLIGHTLESSNESS IN MANIRAPTORIFORMES
114. **Corfe, I.:** TRITYLODONTIDS FROM AN EARLY JURASSIC FISSURE FILL, GLAMORGANSHIRE AND A REEVALUATION OF THE GENUS *OLIGOKYPHUS*
115. **Cuthbertson, R.:** MORPHOLOGICAL ANOMALIES IN A MOSASAUR, *PLATECARPUS*, FROM MANITOBA

116. **Edmunds, B.**: ANTEATER, SLOTH, AND ARMADILLO BIOMECHANICS THEN AND NOW: ADAPTATIONS OF MODALITY IN THE ORDER XENARTHRA THROUGH TIME
117. **England, B.**: LATE CRETACEOUS MARINE VERTEBRATES FROM THE PEE DEE RIVER VALLEY, FLORENCE COUNTY, SOUTH CAROLINA
118. **Farke, A.**: CERATOPSID DINOSAUR CRANIAL MORPHOLOGY AND BEHAVIOR REINTERPRETED: EVALUATING THE BOVID PARADIGM
119. **Fedak, T.**: A NEW INTERPRETATION AND DESCRIPTION OF THE *ANCHISAURUS POLYZELUS* (SAURISCHIA: SAUROPODOMORPHA) BRAINCASE AND ITS IMPLICATIONS FOR PROSAUROPOD SYSTEMATICS
120. **Froebisch, J.**: CONSTRUCTIONAL MORPHOLOGY OF THE PELVIC GIRDLE AND HIND LIMB OF *TETRAGONIAS NJALILUS* (SYNAPSIDA, ANOMODONTIA) FROM THE MIDDLE TRIASSIC OF EAST AFRICA AND THE PROBLEM OF APPLYING REPTILIAN MYOLOGICAL NOMENCLATURE IN NON-MAMMALIAN THERAPSIDS
121. **Hamm, S.**: PTYCHODONTID SHARKS IN THE UPPER CRETACEOUS EAGLEFORD GROUP OF NORTHERN TEXAS
122. **Herrmann, K.R.:** THE PHYLOGENETIC INTERRELATIONSHIPS OF THYREOPHORAN DINOSAUR SPECIES (STEGOSAURIA, ANKYLOSAURIA, AND BASAL THYREOPHORA)
123. **Kozisek, J.**: NEW IMPLICATIONS FOR THE CRETACEOUS-TERTIARY ASTEROID IMPACT THEORY BASED UPON THE PERSISTENCE OF EXTANT TROPICAL HONEYBEES (HYMENOPTERA: APIDAE)
124. **Kutter, M.**: NEW MATERIAL OF *ZEPHYROSAURUS SCHAFFI* (DINOSAURIA: ORNITHISCHIA) FROM THE CLOVERLY FORMATION (APTIAN-ALBIAN) OF MONTANA
125. **Labs-Hochstein, J.:** QUANTIFICATION OF DIAGENESIS IN FOSSIL LAMNOID SHARK CENTRA
126. **López-Antoñanzas, R.:** CLADISTIC ANALYSIS OF THE THRYONOMYID RODENTS: PRELIMINARY RESULTS
127. **Matney, S.:** A PROPOSED SYSTEM FOR RECORDING THE POSITION OF SKELETAL REMAINS USING MORPHOLOGICAL LANDMARKS
128. **Myers, T.:** CATASTROPHIC MASS MORTALITY OF A HERD OF YOUNG DIPLODOCID SAUROPODS FROM THE MORRISON FORMATION OF MONTANA
129. **Nance, H.:** CRANIAL OSTEOLOGY IN THE CORDYLIFORMES: NEW PARSIMONY-INFORMATIVE CHARACTERS FOUND USING DISARTICULATED MATERIAL
130. **Samuels, J.:** MORPHOMETRIC ANALYSIS OF LOCOMOTOR HABITS IN EXTINCT BEAVERS (CASTORIDAE)
131. **Schmitz, L.:** THE MIXOSAURS (ICHTHYOSAURIA) FROM THE MIDDLE TRIASSIC OF NEVADA (USA): IMPLICATIONS FOR THE SYSTEMATICS OF THE GROUP
132. **Scott, J.:** DIAGENESIS AND THE PALEOECOLOGICAL ANALYSIS OF A LATE PLEISTOCENE FOOTPRINT SITE IN THE BARINGO-BOGORIA BASIN, KENYA RIFT VALLEY
133. **Seaton, T.:** LUMBOSACRAL DORSOSTABILITY IN GREAT APES: HOMOLOGY OR HOMOPLASY?
134. **Snyder, D.:** NEW *ALLIGATOR* REMAINS FROM THE MIOCENE OF FLORIDA, AND NOTES ON *ALLIGATOR* PHYLOGENY
135. **Sorkin, B.:** PALEOECOLOGY OF THE GIANT SHORT-FACED BEARS *AGRIOTHERIUM* AND *ARCTODUS*
136. **Stoecker, N.:** A NEW SPECIES OF *CYMBOSPONDYLUS* (REPTILIA, ICHTHYOSAURIA) FROM THE MIDDLE TRIASSIC OF NEVADA AND ITS IMPLICATIONS FOR THE SKULL OSTEOLOGY OF THIS GENUS
137. **Triche, N.:** OSTEOLOGICAL DESCRIPTION OF *CAIMAN CROCODYLUS* AND IMPLICATIONS FOR ITS SYSTEMATIC PLACEMENT

FRIDAY MORNING, OCTOBER 17, 2003

TECHNICAL SESSION IV
MINNESOTA BALLROOM
MODERATORS: CHRIS SIDOR AND TOM WILLIAMSON

8:00 **Monks, J.:** DRAMA IN THE PALEOZOIC: A STRUGGLE FOR SURVIVAL

8:15 **Sidor, C., Larsson, H., Steyer, J.S., O'Keefe, R., and Smith, R.:** LATE PERMIAN TETRAPODS FROM THE SAHARA

8:30 **Sues, H.-D., Carter, J., Olsen, P., Novak, S., and Peyer, K.:** LIFE AND DEATH IN THE LATE TRIASSIC: AN EXTRAORDINARY TETRAPOD ASSEMBLAGE FROM THE NEWARK SUPERGROUP OF NORTH CAROLINA

8:45 **Langer, M.:** CONTINENTAL LATE TRIASSIC TETRAPOD BIOCHRONOLOGY: A SOUTHERN PERSPECTIVE

9:00 **Willis, K., Rayfield, E., Barrett, P.M., and McDonnell, R.:** AN INVESTIGATION OF TRIASSIC LAND VERTEBRATE FAUNACHRONS (LVFS) USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

9:15 **Witzke, B.:** INTERPRETATIONS OF NORTH AMERICAN CRETACEOUS DINOSAUR DIVERSITY TRENDS

9:30 **Paik, I.S., Kim, H.J., Huh, M., and Park, K.-H.:** DINOSAUR DEPOSITS OF KOREA: STRATIGRAPHY, PALEOENVIRONMENTS AND PRESERVATION

9:45 **Decherd, S., Barrick, R., Goldfarb, B., Piantadosi, C., Russell, D., and Wheeler, E.:** PRODUCERS AND CONSUMERS: HOW DID WESTERN INTERIOR PLANTS SUPPORT THE MEGAHERBIVORE FAUNA?

10:00 BREAK

10:15 **O'Connor, P., Gottfried, M., Roberts, E., Stevens, N.J., Jackson, F., and Rasmusson, E.:** CLOSING THE AFRICAN GAP: A NEW CRETACEOUS VERTEBRATE FAUNA FROM TANZANIA

10:30 **Eberth, D., Sampson, S.D., Rodrigues de la Rosa, R.A., Aguillon-Martinez, M.C., Brinkman, D.B., and Lopez-Espinosa, J.:** LAS AGUILAS: AN UNUSUALLY RICH CAMPANIAN-AGE VERTEBRATE LOCALE IN SOUTHERN COAHUILA, MEXICO

10:45 **Lamanna, M., Luna, A.M., Casal, G.A., Martinez, R.D., Ibiricu, L., and Sciutto, J.C.:** NEW CROCODYLIFORM AND DINOSAUR DISCOVERIES FROM THE UPPER CRETACEOUS (CAMPANIAN-?MAASTRICHTIAN) UPPER MEMBER OF THE BAJO BARREAL FORMATION, SOUTHERN CHUBUT PROVINCE, ARGENTINA

11:00 **Turner, A.:** CROCODYLIFORM BIOGEOGRAPHY DURING THE MID-LATE CRETACEOUS AND THE TIMING AND ORDER OF GONDWANA CONTINENTAL DIVISION

11:15 **Grellet-Tinner, G., Chiappe, L.M., and Coria. R.M.:** TITANOSAURID EGGS FROM AUCA MAHUEVO (ARGENTINA)

11:30 **Chadwick, A., Tuner, L., and Spencer, L.:** RECREATING AN UPPER CRETACEOUS DINOSAUR ASSEMBLAGE WITH GIS SOFTWARE

11:45 **Williamson, T., Carr, T., and Weil, A.:** LATEST CRETACEOUS DINOSAURS IN THE SAN JUAN BASIN, NEW MEXICO

12:00 **Fricke, H.:** ELUCIDATING THE NATURE OF DINOSAUR ECOLOGY AND BEHAVIOR USING CARBON ISOTOPE RATIOS OF TOOTH ENAMEL AND ASSOCIATED SEDIMENTARY ORGANIC MATTER

12:15 **Steele, E., Fricke, H., and Rogers, R.:** CARBON ISOTOPE EVIDENCE FOR ECOLOGICAL NICHE PARTITIONING AMONG HERBIVOROUS DINOSAURS OF THE JUDITH RIVER FORMATION, MONTANA

TECHNICAL SESSION V
GREAT RIVER BALLROOM 1/4
MODERATORS: LARRY FLYNN AND RYOSUKE MOTANI

8:00 **Polly, P.D.:** PALEOPHYLOGEOGRAPHY AND PHYLOGENETIC RECONSTRUCTION

8:15 **Alroy, J., Behrensmeyer, A.K., Carrano, M., Clyde, W., Fara, E., Fortelius, M., Head, J., Hunter, J., Uhen, M., and Wang, X.:** THE 5% PROJECT: JUST HOW GOOD IS THE FOSSIL RECORD OF TETRAPODS?

8:30 **Makovicky, P.:** TELLING TIME FROM FOSSILS: A PHYLOGENETIC APPROACH TO ORDERING BIOTAS THROUGH TIME

8:45 **Flynn, L.:** FOSSILS TEST HOW THE MOLECULAR CLOCK TICKS

9:00 **Brochu, C., and Theodor, J.M.:** CALIBRATION SENSITIVITY AND QUARTET DATING: SYSTEMATIC UNDER- AND OVERESTIMATION OF DIVERGENCE TIMES FROM MOLECULAR DATA

9:15 **Bonnan, M.:** GIANTS TIE IN ARMS RACE: GEOMETRIC SIMILARITY IN SAUROPOD DINOSAUR AND WHALE HUMERUS GROWTH

9:30 **Rega, E., Hanna, R.R., and Wolff, E.D.S.:** A NEW TOOL FOR PALEOPATHOLOGICAL ANALYSIS: DEVELOPMENT OF A DESCRIPTION-BASED CLASSIFICATION SYSTEM FOR PATHOLOGICAL BONES

9:45 **Motani, R.:** FRAMEWORK FOR EXPLICIT FUNCTIONAL INFERENCES USING 3D DATA, AND TEST OF PHYSICAL CONSTRAINTS IN VERTEBRATE EVOLUTION

10:00 BREAK

10:15 **Main, R., and Biewener, A.:** BONE STRAIN IN THE GOAT RADIUS THROUGHOUT ONTOGENY: HOW *IN VIVO* BONE STRAINS RELATE TO BONE GEOMETRY AND TISSUE MICROSTRUCTURE

10:30 **Rayfield, E.:** THE ADAPTIVE SIGNIFICANCE OF CRANIAL KINESIS INVESTIGATED USING FINITE ELEMENT ANALYSIS

10:45 **Greaves, W.:** TWO ANATOMICAL FEATURES CHARACTERIZE MOST MAMMALIAN JAWS

11:00 **Semprebon, G.M., Solounias, N., Godfrey, L.R., and Sutherland, M.R.:** THE EFFICACY OF LOW-MAGNIFICATION STEREOMICROSCOPY IN DIAGNOSING DIET ACROSS ORDERS OF MAMMALS

11:15 **Morton, B., Havrilla, G., Miller, T., Gislason, J., and Huntley, K.:** IMAGING FOSSILS FOR HARD AND SOFT TISSUE SIGNATURES USING ELEMENTAL X-RAY AREA MAPS

11:30 **Elliott, D., Mark-Kurik, El., Daeschler, T., Shubin, N.H., and Jenkins, F.A., Jr.:** PSAMMOSTEIDS (AGNATHA, HETEROSTRACI) FROM THE LATE DEVONIAN OF ARCTIC CANADA

11:45 **Greeniaus, J., and Wilson, M.:** GROWTH AND DERMAL BONE DEVELOPMENT IN *LEPIDASPIS SERRATA*

12:00 **Downs, J.:** VARIATION IN HISTOLOGICAL MICROSTRUCTURES AMONG THE SKELETAL ELEMENTS OF *BOTHRIOLEPIS CANADENSIS* (PLACODERMI)

12:15 **Hanke, G., Davis, S., and Wilson, M.:** RE-EXAMINATION OF THE DEVONIAN ACANTHODIANS *URANIACANTHUS SPINOSUS* AND *GLADIOBRANCHUS PROBATON*

TECHNICAL SESSION VI
GREAT RIVER BALLROOM 2/3
MODERATORS: JONATHAN GEISLER AND MARK UHEN

8:00 **Krause, D.W.**: DISCOVERY OF A RELATIVELY COMPLETE MAMMALIAN SPECIMEN FROM THE LATE CRETACEOUS OF MADAGASCAR

8:15 **Meredith, R.:** NEW GENUS OF PRIMITIVE DIPROTODONTOID FROM THE LATE OLIGO-MIOCENE ETADUNNA FORMATION OF SOUTH AUSTRALIA

8:30 **Horovitz, I., and Sanchez-Villagra, M.:** A MORPHOLOGICAL ANALYSIS OF MARSUPIAL EVOLUTIONARY RELATIONSHIPS

8:45 **Gaudin, T.:** PHYLOGENY OF SLOTHS (MAMMALIA, XENARTHRA, TARDIGRADA)—A CRANIO-DENTAL ANALYSIS REVISITED

9:00 **Bailey, B.:** NEW FOSSIL SHREW REMAINS FROM WESTERN NEBRASKA AND A SUGGESTED SUBFAMILIAL REVISION OF THE SORICIDAE (MAMMALIA; INSECTIVORA)

9:15 **Gunnell, G.:** NEW PRIMITIVE MICROBAT (CHIROPTERA) FROM THE GREEN RIVER FORMATION (UPPER LOWER EOCENE), FOSSIL BASIN, SOUTHWESTERN WYOMING

9:30 **Croft, D.A., Flynn, J.J., and Wyss, A.R.:** DIVERSIFICATION OF MESOTHERIIDS (MAMMALIA: NOTOUNGULATA: TYPOTHERIA) IN THE MIDDLE LATITUDES OF SOUTH AMERICA

9:45 **Penkrot, T., Zack, S., Rose, K., and Bloch, J.:** POSTCRANIA OF EARLY EOCENE *APHELISCUS* AND *HAPLOMYLUS* (MAMMALIA: "CONDYLARTHRA")

10:00 BREAK

10:15 **Libed, S.**, **and Lucas, S.G.:** A NEW LATE PALEOCENE "CONDYLARTH" (MAMMALIA) FROM THE SAN JUAN BASIN OF NEW MEXICO AND PHENACODONTID PHYLOGENY

10:30 **Geisler, J.:** COMBINING MORPHOLOGICAL AND MOLECULAR DATA TO ADDRESS THE PHYLOGENY OF THE CETACEAN CROWN GROUP

10:45 **Nummela, S., Bajpai, S., and Thewissen, J.G.M.:** HEARING IN EOCENE WHALES (CETACEA, MAMMALIA)
11:00 **Gingerich, P.D.:** EVOLUTION OF EOCENE ARCHAEOCETI (CETACEA) IN RELATION TO SKELETAL PROPORTIONS AND LOCOMOTION OF LIVING SEMIAQUATIC MAMMALS
11:15 **Uhen, M.:** BIOGEOGRAPHIC DISTRIBUTION OF DORUDONTINE ARCHAEOCETES IN NORTH AMERICA
11:30 **Madar, S., and Thewissen, J.G.M.:** THE LOMOTOR REPERTOIRE OF PAKICETID CETACEANS: COMBINED EVIDENCE OF GROSS MORPHOLOGY AND SKELETAL ULTRASTRUCTURE
11:45 **Barnes, L.G., McLeod, S., Kearin, M., and Deering, M.:** THE MOST PRIMITIVE KNOWN PLATANISTID (CETACEA; ODONTOCETI), A NEW EARLY MIOCENE SPECIES FROM SOUTHERN CALIFORNIA
12:00 **Berta, A., Deméré, T., and Gatesy, J.:** SYSTEMATICS AND EVOLUTION OF THE MYSTICETI
12:15 **Deméré, T., and Berta, A.:** A NEW SPECIES OF BALEEN WHALE (CETACEA: MYSTICETI) FROM THE PLIOCENE OF CALIFORNIA AND ITS IMPLICATIONS FOR HIGHER MYSTICETE PHYLOGENETIC RELATIONSHIPS

FRIDAY AFTERNOON

TECHNICAL SESSION VII
MINNESOTA BALLROOM
MODERATOR: DAN CHURE

1:30 **Hwang, S.H.:** PATTERNS OF ENAMEL MICROSTRUCTURE IN DINOSAURS
1:45 **Derstler, K.:** COMPARISON OF HADROSAUR SKIN PRESERVATION IN THE LANCE AND JUDITH RIVER FORMATIONS (UPPER CRETACEOUS; WESTERN NORTH AMERICA)
2:00 **Mustafa, H., Zalmout, I., Smadi, A., Hassan, A.A., and Khammash, A.:** AN EXCEPTIONALLY PRESERVED MARINE VERTEBRATE FAUNA FROM THE MUWAQQAR FORMATION (LATE CRETACEOUS) OF JORDAN
2:15 **Phillips, P.L., Ludvigson, G., Joeckel, R.M., Gonzalez, L., Brenner, R.L., and Witzke, B.:** THE ROLE OF SYNSEDIMENTARY CARBONATE CEMENTATION IN THE PRESERVATION OF DINOSAUR TRACK SITES: AN EXAMPLE FROM THE DAKOTA FORMATION
2:30 **Friedman, M.:** NEW MATERIAL OF THE LATE DEVONIAN LUNGFISH *SOEDERBERGHIA GROENLANDICA* (SARCOPTERYGII: DIPNOI) FROM EAST GREENLAND WITH COMMENTS ON THE STATUS OF THE RHYNCHODIPTERIDAE
2:45 **Chure, D.:** BULLETS, BOMBS, AND BONES: THE IMPACT OF 20TH CENTURY WARFARE ON FOSSIL VERTEBRATE COLLECTIONS
3:00 **Rowland, S.:** PALEONTOLOGY IN THE WRITINGS OF MARK TWAIN

TECHNICAL SESSION VIII
GREAT RIVER BALLROOM 1/4
MODERATOR: RICHARD LUND

1:30 **Smith, C., and Wilson, M.:** NEW SPECIES OF *ISCHNACANTHUS* (ACANTHODII: ISCHNACANTHIFORMES) FROM CANADA: SIMILARITIES TO EXTANT SPECIES FLOCKS
1:45 **Grogan, E.:** DESCRIPTION OF LITTLE TWO SPINE, A NEW EUCHONDROCEPHALAN CHONDRICHTHYAN FROM THE BEAR GULCH LIMSTONE (SERPUKOVIAN, NAMURIAN E2B) OF MONTANA
2:00 **Coates, M.:** ARMS, ARMOUR, CONVERGENCE AND CONSERVATISM: A LOWER CARBONIFEROUS HYBODONT SHARK
2:15 **Stewart, J.D.:** QUANTIFIABLE CHANGE IN THE *ISURUS HASTALIS* POPULATIONS IN MIDDLE AND UPPER MIOCENE ROCKS OF CALIFORNIA
2:30 **Lund, R., Grogan, E., and Dierks, N.:** THREE ACTINOPTERYGIANS FROM THE BEAR GULCH LIMESTONE (NAMURIAN E2B, SERPUKHOVIAN), AND THE RELATIONSHIPS OF THE PLATYSOMIFORMES.
2:45 **Hilton, E., and Grande, L.:** THE FOSSIL RECORD OF STURGEONS (ACTINOPTERYGII: ACIPENSERIFORMES: ACIPENSERIDAE)
3:00 **Newbrey, M., and Ashworth, A.:** FISH COMMUNITY DYNAMICS, GROWTH OF YELLOW PERCH, AND CORRELATIONS WITH CLIMATE AND FIRE IN AN EARLY HOLOCENE LAKE IN NORTH DAKOTA

TECHNICAL SESSION IX
GREAT RIVER BALLROOM 2/3
MODERATOR: SCOTT FOSS

1:30 **Foss, S., and Theodor, J.M.:** NEW MORPHOLOGICAL SUPPORT FOR THE PHYLOGENETIC AFFINITY OF ARTIODACTYLA AND CETACEA

1:45 **Ferrusquia, I.:** THE FIRST PALEOGENE MAMMAL RECORD OF MIDDLE AMERICA: HELOHYIDAE NEW GEN. AND SP.

2:00 **Hoffman, J., and Prothero, D.R.:** REVISION OF THE DWARFED LEPTAUCHENIN OREODONT *SESPIA* FROM THE LATE OLIGOCENE OF CALIFORNIA AND THE HIGH PLAINS

2:15 **Solounias, N., and Mihlbachler, M.C.:** PALEODIETARY TRENDS AMONG THE MERYCOIDODONTIDAE (OREODONTS) FROM THE LATE EOCENE TO LATE MIOCENE USING THE ABRASION-ATTRITION WEAR GRADIENT METHOD

2:30 **Williams, S., Wall, C., Vinyard, C., and Hylander, W.:** STRAIN IN THE MANDIBULAR SYMPHYSIS OF ALPACAS AND THE EVOLUTION OF SYMPHYSEAL FUSION IN CAMELIDS

2:45 **Bobe, R.:** PATTERNS OF DIVERSITY IN PLIOCENE AND PLEISTOCENE BOVIDS FROM THE TURKANA BASIN, KENYA AND ETHIOPIA

3:00 **Maga, M., and Gordon, A.:** COMPARING PHYLOGENIES: SIMULATION PERSPECTIVE

POSTER SESSION II
Authors will be present 3:30-5:00

Booth #

1. **Soehn, K., and Wilson, M.H.V.:** ISOLATED OCCURRENCES OF TWO NEW THELODONTS FROM THE SILURIAN OF THE MACKENZIE MOUNTAINS, NORTHWEST TERRITORIES, CANADA
2. **Purdy, R., and Compagno, L.:** DOES LAMNOID TOOTH TERMINOLOGY NEED REVISION?
3. **Ginter, M., and Hairpetian, V.:** MICROEVOLUTIONARY TRENDS IN TOOTH MORPHOLOGY OF FAMENNIAN SHARKS
4. **Corrado, C.A., Wilhelm, D.A., Shimada, K., and Everhart, M.J.:** A NEW SKELETON OF THE LATE CRETACEOUS LAMNIFORM SHARK, *CRETOXYRHINA MANTELLI*, FROM WESTERN KANSAS
5. **Carvalho, M., Grande, L., and Maisey, J.:** THE EVOLUTION OF STINGRAYS (CHONDRICHTHYES: MYLIOBATIFORMES), WITH SPECIAL REFERENCE TO THE FRESHWATER STINGRAYS OF THE GREEN RIVER FORMATION OF WYOMING (EARLY EOCENE)
6. **Mutter, R.:** DEEPENED FLANK SCALES IN TRIASSIC ACTINOPTERYGIANS AS A PHYLOGENETIC SIGNAL
7. **Hakel, M., and Steward, J.D.:** A NEARLY COMPLETE SKELETON OF *PACHYRHIZODUS CANINUS*
8. **Ghedotti, M., and Davis, M.:** PHYLOGENETIC RELATIONSHIPS OF THE PLIOCENE KILLIFISH *FUNDULUS DETILLAE* (TELEOSTEI: CYPRINODONTIFORMES)
9. **Stringer, G.L.:** DISCOVERY AND SIGNIFICANCE OF GOBIID OTOLITHS FROM THE MIDDLE EOCENE (EARLY LUTETIAN) CANE RIVER FORMATION OF LOUISIANA
10. **Schwimmer, D., and Williams, G.D.:** NEW FOSSIL OF THE LARGEST KNOWN COELACANTH, FROM THE LATE CRETACEOUS OF SOUTHEASTERN USA
11. **Irmis, R., and Elliott, D.:** TAPHONOMY OF MARINE VERTEBRATES FROM THE NACO FORMATION (MIDDLE PENNSYLVANIAN), CENTRAL ARIZONA
12. **Chin, K., Kirkland, J.I., Milner, A.R.C., and Mickelson, D.L.:** DISTINCTIVE ACCUMULATIONS OF FOSSIL FISH DEBRIS IN THE MOENAVE FORMATION TELL A STORY OF LIFE AND DEATH IN A BIOTICALLY PRODUCTIVE, EARLY JURASSIC LAKE NEAR ST. GEORGE, UTAH
13. **Everhart, M., Everhart, P., Manning, E., and Hattin, D.:** A MIDDLE TURONIAN MARINE FISH FAUNA FROM THE UPPER BLUE HILL SHALE MEMBER, CARLILE SHALE, OF NORTH CENTRAL KANSAS
14. **Cope, D., England, B., Brown, R.B., Westgate, J., and Pittman, J.:** A LATE CRETACEOUS (CAMPANIAN)

MARINE VERTEBRATE MICROFAUNA FROM THE AGUJA FORMATION OF CHIHUAHUA, MEXICO

15. **Shin, J.-Y.:** TAXONOMIC DIVERSITY AND MICROVERTEBRATE FAUNAL ANALYSIS OF THE LATE CRETACEOUS MEETEETSE FORMATION, NORTHERN WYOMING
16. **Shimada, K., Parkin, J.A., Palermo, J.M., and Schumacher, B.A.:** LATE CRETACEOUS MARINE VERTEBRATES FROM THE BASAL GREENHORN LIMESTONE IN SOUTHEASTERN COLORADO
17. **Bennett, G., and Main, D.J.:** FISH FAUNA OF THE HELL CREEK FORMATION, GARFIELD COUNTY, MONTANA: NEW DATA FROM MICROVERTEBRATE LOCALITIES
18. **Trapani, J.:** LATE QUATERNARY ICHTHYOFAUNA FROM THE KIBISH FORMATION, LOWER OMO VALLEY, SOUTHWESTERN ETHIOPIA
19. **Tsuji, L., and Reisz, R.:** AN ARTICULATED SKELETON OF *VARANOPS* (SYNAPSIDA; VARANOPIDAE) WITH EVIDENCE OF SCAVENGING
20. **Shinya, A., Reisz, R., and Kissel, R.:** THE ASTRAGALUS-CALCANEUM COMPLEX OF *MYCTEROSAURUS* AND *VARANOPS* (SYNAPSIDA: VARANOPIDAE): MORPHOLOGY, LOCOMOTION, AND PHYLOGENY
21. **Rushforth, R., and Small, B.:** ANALYSIS OF WICHITA GROUP (REVISED) "SERIES A" *DIMETRODON* SPECIES USING BETA PROBABILITY PLOTS AND HOTELLING'S T^2 STATISTIC
22. **Maddin, H., and Reisz, R.:** THE MORPHOLOGY AND EVOLUTION OF THE TERMINAL PHALANGES IN PALEOZOIC NON-THERAPSID SYNAPSIDS
23. **Wilborn, B., and Cifelli, R.L.:** PHYLOGENETIC RELATIONSHIPS AND BIOGEOGRAPHY OF TRICONODONTIDAE (MAMMALIA)
24. **Pignataro, F., Weil, A., and Williamson, T.:** NEW MULTITUBERCULATE MAMMALS FROM THE LATE CRETACEOUS KIRTLAND FORMATION, SAN JUAN BASIN, NM
25. **Minjin, B.:** THE TARSUS OF A NEW DJADOCHTATHERIAN MULTITUBERCULATE FROM MONGOLIA
26. **Winkler, D., and Jacobs, L.:** REVIEW OF EARLY CRETACEOUS (APTIAN/ALBIAN) BOREOSPHENIDAN MAMMALS FROM TEXAS
27. **Wood, C.B., Rougier, G.W., and Werth, A.J.:** NEW DATA ON ENAMEL MICROSTRUCTURE IN MESOZOIC MAMMALS: PATTERNS AND UPDATES
28. **Szalay, F.S., Sargis, E.J., Archibald, J.D., and Averianov, A.O.: LATE** CRETACEOUS THERIAN POSTCRANIALS FROM THE KYZYLKUM DESERT, UZBEKISTAN: A PRELIMINARY ASSESSMENT OF TAXONOMIC PROPERTIES
29. **Davis, B.:** SYSTEMATICS AND RELATIONSHIPS OF "PEDIOMYID" MARSUPIALS (LATE CRETACEOUS, NORTH AMERICA)
30. **McAfee, R.:** CONFIRMATION OF THE SLOTH GENUS *MEGALONYX* (XENARTHRA: MAMMALIA) FROM THE JOHN DAY REGION AND ITS IMPLICATIONS
31. **Cristin-Ponciano, A., and Montellano-Ballasteros, M.:** LATE PLEISTOCENE MYLODONTIDAE (XENARTHRA) FROM THE VALLEY OF MÉXICO.
32. **Gromny, J., and Rowland, S.:** SEXUAL DIMORPHISM IN THE PELVIS OF SHASTA GROUND SLOTHS (*NOTHROTHERIOPS SHASTENSIS*)
33. **Czaplewski, N.:** A GLYPTODONT (MAMMALIA: XENARTHRA) FROM NORTHERN OKLAHOMA
34. **Salton, J., and Szalay, F.S.:** ECOMORPHOLOGY OF THE TARSAL COMPLEX IN AFRO-MALAGASY TENRECOIDEA
35. **Schumaker, K.:** SORICIDS FROM THE MEDICINE POLE HILLS LOCAL FAUNA (LATEST EOCENE) OF NORTH DAKOTA
36. **Lopatin, A.V., and Kondrashov, P.:** THE SKULL STRUCTURE OF *SINOMYLUS* (MIXODONTIA)
37. **Kondrashov, P., and Lopatin, A.V.:** LATE PALEOCENE MIXODONTS FROM THE TSAGAN-KHUSHU LOCALITY, MONGOLIA
38. **Boyer, D., and Bloch, J.I.:** COMPARATIVE ANATOMY OF THE PENTACODONTID *APHRONORUS ORIELI* (MAMMALIA: PANTOLESTA) FROM THE PALEOCENE OF THE WESTERN CRAZY MOUNTAINS BASIN, MONTANA
39. **Morlo, M., and Gunnell, G.F.:** NEW SPECIES OF *LIMNOCYON* (LIMNOCYONINAE, HYAENODONTIDAE, MAMMALIA) FROM THE MIDDLE BRIDGERIAN (MIDDLE EOCENE) OF SOUTHWESTERN WYOMING
40. **Egi, N., Tsubamoto, T., Shigehara, N., and Takai, M.:** DISCOVERY OF *"PTERODON" DAHKOENSIS* (CREODONTA) FROM THE EOCENE PONDAUNG FORMATION, MYANMAR
41. **Camara, A., Chang, K., and Adam, P.:** VERTEBRAL MORPHOLOGY VERSUS LOCOMOTION AND HABITAT USE IN CARNIVORA: TESTING CORRELATION AND PHYLOGENETIC CONSTRAINT

42. **Person, J.:** POSTCRANIAL ANALYSIS AND FUNCTIONAL MORPHOLOGY OF LATE HEMPHILLIAN CARNIVORA FROM NORTH CENTRAL OREGON
43. **Wallace, S.:** NEW MUSTELID FROM THE GRAY FOSSIL SITE (MIOCENE), WASHINGTON CO., TENNESSEE: A NEW SPECIES AMONG MANY?
44. **O'Connor, J., Prothero, D.R., and Wang, X.:** NEW SPECIMEN OF THE MIOCENE MUSTELID *STHENICTIS* FROM THE MIOCENE OF INNER MONGOLIA, CHINA
45. **Naples, V., Barbiarz, J., and Martin, L.D.: W**HY DOES *XENOSMILUS* LOOK LIKE A PANDA?
46. **Anton, M., Salesa, M., Morales, J., Peigne, S., Pelaez-Campomanes, P., and Fraile, S.:** A EARLY RADIATION OF FELID SABERTOOTHS DOCUMENTED IN CARNIVORE-TRAP FOSSIL SITE IN THE LATE MIOCENE OF SPAIN
47. **Cuozzo, F., Inman, K., and Cummins, E.:** NEW SPECIMENS OF *ARAPAHOVIUS GAZINI* (MAMMALIA, PRIMATES), WITH COMMENTS ON THE EARLY EOCENE (LYSITEAN, BIOCHRON WA6) PRIMATE COMMUNITY OF THE WASHAKIE BASIN, WY
48. **Nakaya, H., Saegusa, H., Pickford, M., Kunimatsu, Y., Nagaoka, S., and Ratanasthien, B.:** LATE CENOZOIC MAMMALIAN FAUNAS AND AGE OF HOMINOIDS FROM THAILAND
49. **Gaboardi, M., Deng, T., and Wang, Y.:** PALEOCLIMATE OF ZHOUKOUDIAN: A GLIMPSE INTO THE ENVIRONMENT OF PEKING MAN
50. **Armstrong-Hall, J.G.:** A NEW THEORY OF HUMAN SPECIATION
51. **Lancaster, T., Kielan-Jaworowska, Z., and Thewissen, J.G.M.:** BODY AND BRAIN SIZE ESTIMATES FROM LONG BONES IN RODENTS: IMPLICATIONS FOR MULTITUBERCULATES
52. **Bell, S., Meyer, T., and Bryant, H.: "**FLYING SQUIRREL" (MAMMALIA; RODENTIA) DIVERSITY IN THE OLIGOCENE OF THE CYPRESS HILLS FORMATION (SOUTHWEST SASKATCHEWAN, CANADA)
53. **Jass, C., and Bell, C.:** MORPHOLOGIC VARIATION IN THE DENTARY OF POCKET GOPHERS (*GEOMYS*) FROM HALL'S CAVE, KERR COUNTY, TEXAS
54. **Goodwin, H.T., and Ryckman, E.:** HIBERNATION IS RECORDED IN PRAIRIE DOG INCISORS
55. **Winkler, A.:** NEW SMALL MAMMAL RECORDS FROM THE EARLY MIOCENE OF UGANDA
56. **Tsubamoto, T., Takai, M., and Egi, N.:** REEVALUATION OF THE ANTHRACOTHERIIDAE (MAMMALIA; ARTIODACTYLA) FROM THE EOCENE PONDAUNG FORMATION, MYANMAR
57. **Meachen, J.:** A NEW SPECIES OF LLAMA (CAMELINAE, LAMINI) FROM THE BLANCAN AND IRVINGTONIAN OF FLORIDA
58. **Thompson, M., and White, R., Jr.:** LATE CENOZOIC CAMELIDS (MAMMALIA: ARTIODACTYLA) FROM GRAHAM COUNTY, SOUTHEASTERN ARIZONA
59. **Ludtke, J., and Prothero, D.R.:** SYSTEMATICS OF THE MIDDLE EOCENE (UINTAN) PROTOCERATID *LEPTOREODON*
60. **Liter, M., and Prothero, D.R.:** NEW DROMOMERYCIDS (MAMMALIA: ARTIODACTYLA) FROM THE MIDDLE MIOCENE SHARKTOOTH HILL BONEBED, CALIFORNIA, AND THE SYSTEMATICS OF THE CRANIOCERATINES
61. **Wheatley, P.V., and Ruez, D.R., Jr.:** PLIOCENE *ODOCOILEUS* FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO, AND COMMENTS ON THE TAXONOMIC STATUS OF *ODOCOILEUS BRACHYODONTUS*
62. **Claeson, K., Godinot, M., and O'Leary, M.:** NEW SPECIMENS OF *DISSACUS* (MAMMALIA, MESONYCHIA) FROM PALETTE, SOUTHERN FRANCE, AND A CLADISTIC ANALYSIS OF *DISSACUS* SPECIES
63. **Mnieckowski, J., and Geisler, J.:** A NEW SPECIES OF PROTOCETID CETACEAN FROM THE EOCENE OF SOUTH CAROLINA
64. **Mannering, J., and Geisler, J.:** A NEW *XENOROPHUS*-LIKE ODONTOCETE FROM THE CHANDLER BRIDGE FORMATION OF SOUTH CAROLINA
65. **McGowen, M., Berta, A., and Deméré, T.:** THE EVOLUTION AND COMPARATIVE FUNCTIONAL MORPHOLOGY OF FILTER-FEEDING IN THE MYSTICETI (MAMMALIA: CETACEA)
66. **Zalmout, I., Gingerich, P.D., Mustafa, H., Smadi, A., and Khammash, A.:** CETACEA AND SIRENIA FROM THE EOCENE WADI ESH-SHALLALA FORMATION OF JORDAN
67. **Uno, H.:** REINTERPRETATION OF THE AUDITORY STRUCTURE IN *DESMOSTYLUS HESPERUS* (MAMMALIA: DESMOSTYLIA): NEW EVIDENCE FROM THE MIDDLE MIOCENE TACHIKARAUSHINAI FORMATION, HOKKAIDO, JAPAN

68. **Roosenberg, A., and Goodwin, H.T.:** DESCRIPTION AND INTERPRETATION OF THE PRILLWITZ MAMMOTH FROM SOUTHWESTERN MICHIGAN
69. **Chew, A.:** EARLY EOCENE PERISSODACTYLS FROM THE CENTRAL BIGHORN BASIN, WYOMING
70. **Miyata, K., and Tomida, Y.:** FIRST DISCOVERY OF BRONTOTHERES FROM THE EOCENE OF JAPAN
71. **Sanchez, I.M., Salesa, M.J., Manuel, H.-F., and Morale, J.:** SYSTEMATICS AND PALEOECOLOGY OF THE SPANISH ANCHITHERIINAE (PERISSODACTYLA; EQUIDAE)
72. **Pagnac, D.:** IDENTIFICATION OF HYPSODONT HORSES FROM THE MIDDLE MIOCENE BARSTOW FORMATION BASED ON ISOLATED CHEEK TEETH
73. **Voorhies, M.:** ANAGENESIS VS. CLADOGENESIS IN THE ORIGIN OF *EQUUS* FROM *DINOHIPPUS*: NEW PERSPECTIVES FROM THE RECORD OF PLIOCENE HORSES IN NEBRASKA
74. **George, C.:** THE ANALYSIS OF WEAR IN HORSE TEETH USING GIS
75. **Scott, E., Graham, R.W., Stafford, T.W., Jr., and Martin, L.D.:** ON THE VALIDITY OF *EQUUS LAURENTIUS* HAY, 1913
76. **Hieronymus, T., and Witmer, L.:** RHINOCEROS HORN ATTACHMENT: ANATOMY AND HISTOLOGY
77. **Emry, R.J., and Lucas, S.G.:** NEW CERATOMORPHS (MAMMALIA, PERISSODACTYLA) FROM THE EOCENE OF THE ILY BASIN, KAZAKSTAN
78. **Bayshashov, B., Lucas, S.G., and Emry, R.J.:** THE GIANT RHINOCEROS *PARACERATHERIUM* IN KAZAKSTAN
79. **Skulan, J., and Kuchta, M.:** A TALE FROM THE CRYPT: STRUVITE MINERALIZATION IN A ROTTING RHINOCEROS
80. **Burger, B.:** STACKING CLADOGRAMS: A NEW METHOD TO MODEL TEMPORAL AND SISTER-GROUP RELATIONSHIPS OF FOSSILS
81. **Silcox, M.T., and Bloch, J.I.:** RECONSTRUCTION OF EAR OSSICLES IN EXTANT AND EXTINCT MAMMALS USING ULTRA HIGH RESOLUTION X-RAY COMPUTED TOMOGRAPHY
82. **Kaye, T.:** LASER SPECTROSCOPY FOR COMPARATIVE ANALYSIS OF FOSSIL MATERIAL
83. **Echizenya, H., Kawamura, M., Okayama, M., and Minoura, N.:** 3-D ANALYSIS AND RETRODEFORMATION OF DEFORMED FOSSILS
84. **Kaiser, T.:** THE DIETARY SPECTRUM OF HERBIVOROUS UNGULATE SPECIES AS A TOOL OF HABITAT RECONSTRUCTION
85. **Dewar, E.W.:** MULTIVARIATE ANALYSIS OF MAMMALIAN COMMUNITIES: MEMBERSHIP AND SPECIES LINEAGE RANGES IN THE TERTIARY OF NORTH AMERICA
86. **McCrea, R., Pemberton, S.G., and Currie, P.J.:** MAMMAL AND REPTILE TRACKS FROM THE UPPER PALEOCENE OF ALBERTA
87. **Strait, S.G.:** NEW MAMMALIAN FOSSILS FROM THE EARLIEST EOCENE (WA-0), BIGHORN BASIN, WYOMING
88. **Holroyd, P., and Strait, S.G.:** AN INTERBASIN COMPARISON OF SMALL-MAMMAL COMMUNITY DIVERSITY FROM THE EARLY EOCENE (WASATCHIAN) OF WYOMING
89. **Bowen, G., Koch, P., Meng, J., and Ye, J.:** NEW EARLY PALEOGENE FAUNAS AND MAGNETOSTRATIGRAPHY FROM INNER MONGOLIA: IMPROVED CONSTRAINTS ON INTERCONTINENTAL BIOCHRONOLOGIC CORRELATION
90. **Draus, E., and Prothero, D.R.:** MAGNETIC STRATIGRAPHY OF EOCENE-OLIGOCENE MARINE -MAMMAL-BEARING FORMATIONS IN NORTHWEST WASHINGTON AND SOUTHERN BRITISH COLUMBIA
91. **Taylor, W., and Mead, A.:** CENOGRAM ANALYSIS OF THE MAMMALIAN FAUNAS FROM THE WHITE RIVER GROUP WITHIN BADLANDS NATIONAL PARK, SOUTH DAKOTA
92. **McCullough, G., Knell, M., Roberts, J., and Herbel, C.:** USING SYNTHETIC MAPPING DATA TO ANALYZE A HYPOTHESIZED ORELLAN CARNIVORE DEN IN BADLANDS NATIONAL PARK, SOUTH DAKOTA
93. **Lien, D., McCullough, G., Herbel, C., Cavin, J., Strauss, J., and Van Daele, K.:** 3-D ANALYST AND ARCVIEW APPLICATIONS FOR SPATIAL ANALYSIS OF THE BIG PIG DIG FOSSIL QUARRY, BADLANDS NATIONAL PARK, SOUTH DAKOTA
94. **Burdick, K.:** GIS DATABASE DEVELOPMENT AT THE MIOCENE FOSSIL SITE IN GRAY, TENNESSEE
95. **Sanchez, F., and Prothero, D.R.:** MAGNETIC STRATIGRAPHY OF THE LOWER-MIDDLE MIOCENE OLCESE SAND AND ROUND MOUNTAIN SILT, KERN COUNTY, CALIFORNIA
96. **Dold, P.E., and Prothero, D.R.:** MAGNETIC STRATIGRAPHY OF THE LOWER-MIDDLE MIOCENE PAWNEE CREEK AND MARTIN CANYON FORMATIONS, NORTHEASTERN COLORADO

97. **Kissell-Jones, M., and Rowland, S.:** TRACKWAYS OF THE MIOCENE HORSE SPRING FORMATION AND A SYNTHESIS OF MIOCENE TRACKSITES IN THE WESTERN U.S.
98. **Fremd, T., McDonald, G., Szarvas, I., and Rickabaugh, S.:** OBSERVATIONS ON THE MIOCENE TERRESTRIAL AND MARINE LOCALITIES OF THE IPOLYTARNOC REGION, NORTHERN HUNGARY
99. **Williams, M., Boardman, G., Schiebout, J.A., Kilbourne, B., and Nguyen, H.:** MIOCENE OF FORT POLK, WESTERN LOUISIANA, 2002-2003
100. **Tucker, S.:** CARNIVORES AND MICROTINE-LIKE RODENTS FROM A NEW LATE MIOCENE (HEMPHILLIAN) LOCALITY IN NORTH-CENTRAL NEBRASKA
101. **Hulbert, R., Webb, S.D., and Morgan, G.S.:** HEMPHILLIAN TERRESTRIAL MAMMALIAN FAUNAS FROM THE SOUTH-CENTRAL FLORIDA PHOSPHATE MINING DISTRICT
102. **Lambert, W.D.:** FUNCTIONAL CONVERGENCE OF ECOSYSTEMS: EVIDENCE FROM BODY MASS DISTRIBUTIONS OF NORTH AMERICAN LATE MIOCENE MAMMAL FAUNAS
103. **Honey, J., Pelaez-Campomanes, P., and Martin, R.:** STRATIGRAPHIC FRAMEWORK OF EARLY PLIOCENE LOCALITIES ALONG THE NORTH BANK OF THE CIMARRON RIVER, MEADE CO., KS
104. **Harington, C.R.:** LIFE AT AN EARLY PLIOCENE BEAVER POND IN THE CANADIAN HIGH ARCTIC
105. **Storer, J.E., Froese, D.G., and Westgate, J.A.:** ICE AGE BIOSTRATIGRAPHY IN EASTERN BERINGIA
106. **Miller, W., Delgado de Jesus, R., Gomez Nunez, R.., Vallejo Gonzalez, J., and Lopez Espinosa, J.:** INITIAL REPORT ON PLEISTOCENE VERTEBRATES OF COAHUILA, MEXICO
107. **Torres-Martinez, A.:** PRELIMINARY REPORT OF A OCCURRENCE OF THE LATE PLEISTOCENE MAMMALS FROM THE CUEVA ENCANTADA NEAR OF CHIMALACATLÁN MORELOS STATE, MÉXICO
108. **Johnson, S., Albright, S.S., and Parris, D.C.:** QUATERNARY FAUNA OF THE DUNGANNON SITE, SCOTT COUNTY, VIRGINIA
109. **Roberts, E., Rogers, R.R., and Foreman, B.Z.:** AN EXPERIMENTAL APPROACH TO IDENTIFYING AND INTERPRETING DERMESTID (INSECTA, COLEOPTERA) BONE MODIFICATION
110 . **Gates, T., Roberts, E., and Rogers, R.R.:** DROUGHT IN THE VERTEBRATE FOSSIL RECORD: A REVIEW OF FOSSIL AND MODERN DROUGHT-RELATED ASSEMBLAGES
111. **Patrick, D., and Grandstaff, D.:** USE OF RARE EARTH ELEMENT SIGNATURES AND TRACE ELEMENTS IN VERTEBRATE FOSSILS TO DETERMINE PALEOENVIRONMENTAL CONDITIONS
112. **Lofgren, D., Hanlon, W., and Clark, C.:** RAYMOND ALF MUSEUM OF PALEONTOLOGY: A 70-YEAR LEGACY OF FIELDWORK AND RESEARCH INVOLVING HIGH SCHOOL STUDENTS FROM THE WEBB SCHOOLS

POSTERS ASSOCIATED WITH THE BIOMINERALIZATION SYMPOSIUM

114. **Adams, J., and Organ, C.:** ONTOGENETIC DEVELOPMENT OF OSSIFIED TENDONS IN HADROSAURIAN DINOSAURS
115. **Biasatti, D.:** ANALYSES OF MODERN SEA TURTLE HUMERI SUGGEST RESPIRATORY EFFECTS ON CARBON ISOTOPE COMPOSITIONS OF BIOGENIC STRUCTURAL CARBONATE
116. **Bergeron, M., and Schweitzer, M.:** THE EXTENT OF PRESERVATION OF BRACHYLOPHOSAUR BONES FROM THE JUDITH RIVER FORMATION, MALTA, MONTANA
117. **Clementz, M., and Koch, P.L.:** BONE CARBONATE, COLLAGEN, AND CHOLESTEROL: THREE TEMPORALLY DISTINCT BIOGENIC RECORDS OF ECOLOGICAL INFORMATION FOR ANCIENT MARINE MAMMALS
118. **Coulson, A., Bartlett, J., and Straight, W.:** EFFECTS OF GRAIN SIZE, MORPHOLOGY, AND PRESERVATION ON TRANSPORT-INDUCED ABRASION OF FOSSIL TEETH
119. **Lindenau, C., and Von Koenigswald, W.:** ENAMEL DIFFERENTIATION IN NOTOUNGULATES
120. **Lyson, T., Hanks, H.D., and Tremain, E.:** NEW SKIN STRUCTURES FROM A JUVENILE EDMONTOSAURUS FROM THE LATE CRETACEOUS OF NORTH DAKOTA
121. **Elliott, J., Wilson, R., and Dowker, S.:** STRUCTURE OF BIOLOGICAL APATITES

SATURDAY MORNING, OCTOBER 18, 2003

TECHNICAL SESSION X
MINNESOTA BALLROOM
MODERATORS: LARRY WITMER AND MIKE PARRISH

8:00 **Wright, J.:** THE EFFECTS OF STRIDE LENGTH AND GAIT ON QUADRUPEDAL VERTEBRATE TRACKWAY PATTERNS

8:15 **Witmer, L.:** NARIAL ANATOMY OF ANKYLOSAURIAN DINOSAURS: OSTEOLOGY AND SOFT-TISSUE RECONSTRUCTION

8:30 **Tsuihiji, T:** EVOLUTIONARY CHANGES IN ATTACHMENTS OF THE AXIAL MUSCULATURE IN THE OCCIPITAL REGION IN MARGINOCEPHALIA (DINOSAURIA)

8:45 **Noriega, K., Sumida, S.S., Eberth, D.A., Brinkman, D., and Skrepnick, M.W.:** THE PES OF CENTROSAURINE CERATOPSID DINOSAURS: NEW INFORMATION FROM A COMPLETELY ARTICULATED SPECIMEN

9:00 **Sullivan, C., Jenkins, F.A., Jr., Gatesy, S.M., and Shubin, N.H.:** A FUNCTIONAL ASSESSMENT OF HIND FOOT POSTURE IN THE PROSAUROPOD DINOSAUR *PLATEOSAURUS*

9:15 **Barrett, P., Upchurch, P., Zhou, X.-D., and Wang, X.-L.:** PROSAUROPOD DINOSAURS FROM THE LOWER LUFENG FORMATION (LOWER JURASSIC) OF CHINA

9:30 **Henderson, D.:** SAUROPOD DINOSAURS WERE THE COLOSSAL CORKS OF THE MESOZOIC

9:45 **Rothschild, B., Molnar, R.E., and Helbling, M.:** BEHAVIORAL IMPLICATIONS OF SAUROPOD STRESS FRACTURES

10:00 BREAK

10:15 **Wilson, J., and Fisher, D.C.:** ARE MANUS-ONLY SAUROPOD TRACKWAYS EVIDENCE OF SWIMMING, SINKING, OR WADING?

10:30 **Parrish, J.M.:** MAPPING ECOMORPHS ONTO SAUROPOD PHYLOGENY

10:45 **Harris, J., and Dodson, P.:** A NEW DIPLODOCOID (DINOSAURIA: SAUROPODA) FROM THE MORRISON FORMATION OF MONTANA

11:00 **Heathcote, J., and Upchurch, P.:** THE RELATIONSHIPS OF *CETIOSAURISCUS STEWARTI* (DINOSAURIA; SAUROPODA): IMPLICATIONS FOR SAUROPOD PHYLOGENY

11:15 **Carrano, M., and Sampson, S.D.:** THE EVOLUTIONARY HISTORY OF BASAL THEROPOD DINOSAURS

11:30 **Therrien, F., Henderson, D.M., and Ruff, C.B.:** BIOMECHANICAL MODELS OF THEROPOD MANDIBLES AND IMPLICATIONS FOR FEEDING BEHAVIOR

11:45 **Sampson, S.D., Loewen, M.A., Farlow, J.O., and Carrano, M.T.:** ECOLOGICAL AND EVOLUTIONARY IMPLICATIONS OF GIGANTISM IN THEROPOD DINOSAURS

12:00 **Peyer, K.:** A COMPLETE REDESCRIPTION OF THE FRENCH *COMPSOGNATHUS* WITH SPECIAL CONSIDERATION OF THE ANATOMY OF THE HAND

12:15 **Smith, J., and Krause, D.W.:** ON THE OCCURRENCE OF *MAJUNGATHOLUS ATOPUS* IN INDIA: IMPLICATIONS FOR ABELISAUROID PALEOBIOGEOGRAPHY

TECHNICAL SESSION XI
GREAT RIVER BALLROOM 1/4
MODERATORS: OLIVIER RIEPPEL, HANS-DIETER SUES, AND CATHY FORSTER

8:00 **Joyce, W.:** THE PRESENCE OF CLEITHRA IN THE PRIMITIVE TURTLE *KAYENTACHELYS APRIX*

8:15 **Bever, G.S., Bell, C.J., and Hutchison, J.H.:** HINGED EMYDINE TURTLES IN NORTH AMERICA: READING THE RECORD

8:30 **Rieppel, O.:** THE PALEOBIOGEOGRAPHY OF TRIASSIC SAUROPTERYGIA

8:45 **O'Keefe, R., and Carrano, M.:** SCALING AND ECOMORPHOLOGICAL TRENDS IN THE EVOLUTION OF THE PLESIOSAUR LOCOMOTOR SYSTEM

9:00 **Müller, J.:** A REVISION OF THE EUROPEAN THALATTOSAURS AND ITS IMPLICATIONS FOR THE EVOLUTION AND BIOGEOGRAPHY OF THE CLADE (REPTILIA, DIAPSIDA)
9:15 **Budney, L.:** A BITE OF SQUAMATE DENTAL HISTOLOGY: TOOTH ATTACHMENT CATEGORIES AND CHARACTERS
9:30 **Head, J.:** SNAKING THROUGH SHAPE-SPACE: GEOMETRIC MORPHOMETRIC APPROACHES TO TAXONOMY AND PHYLOGENY IN ERYCINE SNAKES
9:45 **Stayton, C.T.:** FUNCTIONAL AND MORPHOLOGICAL EVOLUTION OF THE LIZARD SKULL
10:00 BREAK
10:15 **Sedlmayr, J., Rehorek, S., Legenzoff, E., and Sanjur, J.:** THE HARDERIAN-PINEAL-HYPOTHALAMIC AXIS IN EXTANT AND EXTINCT AMNIOTA, WITH SPECIAL ATTENTION TO ARCHOSAURIA
10:30 **Whatley, R.:** RHYNCHOSAURS, TEETH, AND TIME: NEW AND REVISED CHARACTER STATES FROM COMPARATIVE MORPHOLOGY
10:45 **Wilhite, R.:** A REASSESSMENT OF THE ORIGIN OF *M. CAUDOFEMORALIS LONGUS* IN CROCODILIANS AND IMPLICATIONS FOR ITS INTERPRETATION IN EXTINCT ARCHOSAURS
11:00 **Holliday, C.:** A SIMILARITY TEST OF EXTANT ARCHOSAUR JAW MUSCLES: CEPHALIC SOFT TISSUES AND THEIR OSTEOLOGICAL CORRELATES
11:15 **Nesbitt, S.:** A NEW SPECIMEN OF *ARIZONASAURUS* FROM THE MOENKOPI FORMATION (LOWER MIDDLE TRIASSIC) AND ITS IMPORTANCE TO PSEUDOSUCHIAN DIVERGENCE
11:30 **Novak, S.E.:** THE POSTCRANIAL SKELETON OF THE GHOST RANCH *POSTOSUCHUS* WITH SPECIAL CONSIDERATION OF THE MANUS
11:45 **Modesto, S., and Sues, H.-D.:** RE-APPRAISAL OF THE SKULL OF THE EARLY TRIASSIC ARCHOSAUROMORPH REPTILE *PROLACERTA BROOMI*
12:00 **Parker, W.:** REVISED TAXONOMY OF THE LATE TRIASSIC AETOSAUR *DESMATOSUCHUS* (ARCHOSAURIA: CRUROTARSI) FROM THE SOUTHWESTERN UNITED STATES
12:15 **Martz, J., Mueller, B., and Small, B.:** TWO NEW AETOSAURS (ARCHOSAURIA, STAGONOLEPIDIDAE) FROM THE UPPER TRIASSIC OF TEXAS AND COLORADO, AND PROBLEMS IN AETOSAUR IDENTIFICATION AND TAXONOMY

TECHNICAL SESSION XII
GREAT RIVER BALLROOM 2/3
MODERATORS: MATT MIHLBACHLER AND SAMANTHA HOPKINS

8:00 **Mihlbachler, M.:** PRELIMINARY CLADISTIC PHYLOGENY OF THE EOCENE BRONTOTHERIIDAE (MAMMALIA, PERISSODACTYLA)
8:15 **Holbrook, L.:** CRANIAL AND POSTCRANIAL CHARACTERS AND THE PHYLOGENY OF PALAEOTHERIIDS (MAMMALIA, PERISSODACTYLA)
8:30 **Nelson, S.:** MIOCENE PALEOSEASONALITY INFERRED FROM EQUID TEETH AND INTRA-TOOTH ISOTOPIC PROFILES
8:45 **Colbert, M.:** HRXCT ANALYSIS OF THE SKULL OF *COLODON* (PERISSODACTYLA: TAPIROIDEA)
9:00 **Prothero, D.R.:** BIOGEOGRAPHY AND DIVERSITY PATTERNS OF NORTH AMERICAN RHINOCEROSES
9:15 **Bajpai, S., and Thewissen, J.G.M.:** EOCENE AND OLIGOCENE SIRENIA (MAMMALIA) FROM WESTERN INDIA
9:30 **Fisher, D.:** COMBAT-INDUCED INJURIES IN ADULT MALE *MAMMUT AMERICANUM*
9:45 **Todd, N.**: WAS THERE A PROBOSCIDEAN GUILD IN THE AFRICAN CENOZOIC?
10:00 BREAK
10:15 **Green, J., Semprebon, G., and Solounias, N.:** RECONSTRUCTING THE DIETARY HABITS OF FLORIDA MASTODONS VIA LOW-MAGNIFICATION STEREOMICROSCOPY
10:30 **Marcolini, F., and Martin, R.:** PHYLETIC EVOLUTION IN *OGMODONTOMYS* (RODENTIA: ARVICOLIDAE) FIRST LOWER MOLARS FROM THE MEADE BASIN OF SOUTHWESTERN KANSAS
10:45 **Davis, E.:** PHYLOGENETIC ANALYSIS OF CLIMATE TOLERANCES INDICATES CLIMATE-DRIVEN SPECIATION WITHIN *MARMOTA* (RODENTIA: SCIURIDAE)
11:00 **Hopkins, S.:** HYPSODONTY AND NICHE PARTITIONING IN APLODONTOID RODENTS: DO SMALL HERBIVORES PARALLEL UNGULATES DURING MIOCENE DIVERSIFICATIONS?

11:15 **Sundell, C.:** *PARADJIDAUMO*: FIRST DESCRIPTION OF POSTCRANIAL ANATOMY, FOSSORIAL BEHAVIOR AND PALEOECOLOGICAL IMPLICATIONS

11:30 **Trujillo, K.:** RADIOMETRIC EVIDENCE FOR DIACHRONY OF MAMMALIAN FAUNAS FROM THE MORRISON FORMATION AND PURBECK GROUP AND IMPLICATIONS FOR CORRELATION IN THE MIDDLE MESOZOIC

11:45 **Wilson, G.:** AN ASSESSMENT OF CHANGE IN MAMMALIAN DISPARITY ACROSS THE CRETACEOUS-TERTIARY BOUNDARY USING DENTAL MORPHOSPACE

12:00 **Hunter, J., Pearson, D., and Hartman, J.:** ADDITIONS TO THE PUERCAN MAMMALS OF NORTH DAKOTA AND A FRAMEWORK FOR STUDY OF POST-K/T VERTEBRATE RECOVERY

12:15 **Shockey, B., Salas, R., Sargis, E.J., Quispe, R., Flores, A., and Acosta, J.:** MOQUEGUA: THE FIRST DESEADAN SALMA (LATE OLIGOCENE) LOCAL FAUNA OF PERU

SATURDAY AFTERNOON

TECHNICAL SESSION XIII
MINNESOTA BALLROOM
MODERATORS: JOHN HUTCHINSON AND ANGELA MILNER

1:30 **Kobayashi, Y., and Barsbold, R.:** RE-EXAMINATION OF *HARPYMIMUS OKLADNIKOVI* (DINOSAURIA: THEROPODA) OF MONGOLIA AND PHYLOGENY OF ORNITHOMIMOSAURIA

1:45 **Britt, B., Scheetz, R., Stadtman, K., and Chure, D.:** RELICTS OF SOFT TISSUE AND OSTEOPHAGOUS FUNGI IN PARTIALLY OSSIFIED TENDONS OF *CERATOSAURUS* (THEROPODA, DINOSAURIA)

2:00 **Sanders, R.K., and Smith, D.K.:** A THREE-DIMENSIONAL RECONSTRUCTION OF THE ENDOCRANIUM OF *CERATOSAURUS* BASED ON CT-SCAN DATA

2:15 **Loewen, M., Sampson, S.D., Carrano, M.T., and Chure, D.J.:** MORPHOLOGY, TAXONOMY AND STRATIGRAPHY OF *ALLOSAURUS* FROM THE UPPER JURASSIC MORRISON FORMATION

2:30 **Hutchinson, J., Anderson, F.C., and Delp, S.L.:** A 3-D DYNAMIC ANALYSIS OF MUSCULOSKELETAL CONTRIBUTIONS TO BODY SUPPORT DURING BIPEDAL LOCOMOTION

2:45 **Snively, E.:** A THEORETICAL MODEL OF NECK MUSCULOSKELETAL FUNCTION IN THE TYRANNOSAURIDAE

3:00 **Gishlick, A., and Carney, R.:** USING DIGITAL SCANNING AND MODELING TO RECONSTRUCT AND TEST THE FORELIMB FUNCTION OF *DEINONYCHUS ANTIRRHOPUS*

3:15 BREAK

3:30 **Parsons, W., and Parsons, K.:** DESCRIPTION OF A NEW IMMATURE SPECIMEN OF *DEINONYCHUS ANTIRRHOPUS*, (SAURISCHIA, THEROPODA)

3:45 **Baier, D.:** 3D FORCE BALANCE MODEL OF THE AVIAN SHOULDER AND THE ROLE OF THE ACROCORACOID PROCESS

4:00 **Jasinoski, S., Russell, A.P., and Currie, P.J.:** THE EVOLUTION OF THE THEROPOD SHOULDER APPARATUS LEADING UP TO BIRDS: AN INTEGRATED APPROACH

4:15 **Claessens, L.:** THE SKELETAL KINEMATICS OF LUNG VENTILATION IN BIRDS

4:30 **Sipla, J., Georgi, J., and Forster, C.:** THE SEMICIRCULAR CANAL DIMENSIONS OF BIRDS AND CROCODILIANS: IMPLICATIONS FOR THE ORIGIN OF FLIGHT

4:45 **Milner, A.C., Dominguez Alonso, P., Cookson, M.J., and Rowe, T.:** A BIRD-LIKE BRAIN IN *ARCHAEOPTERYX*—EVIDENCE FROM HIGH RESOLUTION TOMOGRAPHY OF THE BRAINCASE

5:00 **Longrich, N.:** *ARCHAEOPTERYX*: TWO WINGS OR FOUR?

5:15 **Galton, P.M., and Martin, L.D.:** *ENALIORNIS* SEELEY, 1876, THE EARLIEST FOOT-PROPELLED DIVING BIRD (AVES, ORNITHURAE, HESPERORNITHIFORMES, ENALIORNITHIDAE), AND OTHER BIRD BONES FROM THE CAMBRIDGE GREENSAND (EARLY CRETACEOUS, ALBIAN, ~100 MA) NEAR CAMBRIDGE, SOUTHERN ENGLAND

5:30 **Dyke, G., and Waterhouse, D.:** FOSSILS AND THE EVOLUTIONARY RELATIONSHIPS OF CHARADRIIFORMES: A TREE AND A TIMESCALE FOR SHOREBIRDS

TECHNICAL SESSION XIV
GREAT RIVER BALLROOM 1/4
MODERATORS: JONATHAN BLOCH AND XIAOMING WANG

1:30 **Hungerbühler, A., Chatterjee, S., and Cunningham, D.P.:** A NEW PHYTOSAUR SPECIES FROM THE TRIASSIC OF WEST TEXAS: NEW INFORMATION ON CRANIAL ANATOMY, TAXONOMY, AND SEXUAL DIMORPHISM IN PSEUDOPALATINAE

1:45 **Clark, J., and Xu, X.:** A LATE MIDDLE JURASSIC CROCODYLOMORPH WITH CURSORIAL ADAPTATIONS

2:00 **Pol, D., and Norell, M.A.:** A NEW GOBIOSUCHID CROCODYLIFORM TAXON FROM THE CRETACEOUS OF MONGOLIA

2:15 **Aumont, A.:** EUROPEAN PAROMOMYIDS (PLESIADAPIFORMES: MAMMALIA): A REAPPRAISAL

2:30 **Walker, A., Silcox, M.T., Bloch, J.I., Spoor, F.S., and Krovitz, G.E.:** THE SEMICIRCULAR CANALS OF PLESIADAPIFORM PRIMATES AND THEIR FUNCTIONAL SIGNIFICANCE.

2:45 **Bloch, J.I., Boyer, D., and Houde, P.:** NEW SKELETONS OF PALEOCENE-EOCENE MICROMOMYIDS (MAMMALIA, PRIMATES): FUNCTIONAL MORPHOLOGY AND IMPLICATIONS FOR EUARCHONTAN RELATIONSHIPS

3:00 **Perry, J., Wall, C.E., and Williams, B.A.:** THE ANATOMY OF THE MASTICATORY MUSCLES IN TWO STREPSIRRHINE PRIMATES AND INFERENCE OF MUSCLE ATTACHMENT AREAS FROM OSTEOLOGICAL MATERIAL

3:15 BREAK

3:30 **Sanders, W.:** THE RELATIONSHIP BETWEEN LUMBOSACRAL STRUCTURE, FUNCTION, AND POSITIONAL BEHAVIOR IN AUSTRALOPITHECINES (MAMMALIA, HOMINIDAE)

3:45 **Koretsky, I., and Barnes, L.G.:** ORIGINS AND RELATIONSHIPS OF PINNIPEDS, AND THE CONCEPTS OF MONOPHYLY VERSUS DIPHYLY

4:00 **Newsome, S., Etnier, M., Koch, P., and Gifford-Gonzalez, D.:** THE HOLOCENE ECOLOGY AND DISTRIBUTION OF NORTHERN FUR SEALS

4:15 **Goswami, A.:** PRELIMINARY ANALYSES OF THE INFLUENCES OF ONTOGENY, PHYLOGENY, AND FUNCTION ON MORPHOLOGICAL INTEGRATION IN THE CARNIVORAN SKULL

4:30 **Van Valkenburgh, B.:** ITERATIVE EVOLUTION OF LARGE SIZE AND HYPERCARNIVORY IN CARNIVORES AND THE MACROEVOLUTIONARY RATCHET

4:45 **Wang, X., Qiu, Z., and Wang, B.:** A PRIMITIVE LEPTARCTINE (CARNIVORA: MUSTELIDAE) FROM THE EARLY MIOCENE OF WESTERN GANSU, CHINA AND ZOOGEOGRAPHY OF EARLY MUSTELIDS

5:00 **Wheeler, H.T., and Jefferson, G.:** FOSSIL EVIDENCE OF SOCIAL BEHAVIOR AT RANCHO LA BREA BY *PANTHERA ATROX* BETWEEN 14 AND 11 KYR BP

5:15 **Fox-Dobbs, K., Koch, P.L., and Clementz, M.T.:** LUNCHTIME AT LA BREA: ISOTOPIC RECONSTRUCTION OF *SMILODON FATALIS* AND *CANIS DIRUS* DIETARY PATTERNS THROUGH TIME

5:30 **Anyonge, W., Meyer, J., Baker, A., Alberico, P., and Roman, C.:** BODY MASS AND FEEDING BEHAVIOR IN THE EXTINCT PLEISTOCENE DIRE WOLF (*CANIS DIRUS*)

TECHNICAL SESSION XV
GREAT RIVER BALLROOM 2/3
MODERATORS: ANDY WYSS AND JOHN HARRIS

1:30 **Flynn, J.J., Charrier, R., Croft, D.A., Hitz, R.B., and Wyss, A.R.:** THE ABANICO FORMATION OF THE CHILEAN ANDES: AN EXCEPTIONAL EOCENE-MIOCENE RECORD OF SOUTH AMERICAN MAMMAL EVOLUTION

1:45 **Wyss, A.R., Charrier, R., Croft, D.A., Flynn, J.J., and Wertheim, J.:** NEW MIDDLE CENOZOIC MAMMALS FROM THE LAGUNA DEL LAJA REGION (CURA MALLÍN FORMATION, SOUTH CENTRAL CHILE)

2:00 **MacFadden, B.J., and Higgins, P.:** MIDDLE MIOCENE LAND MAMMALS FROM PANAMA: EVIDENCE FOR THE AGE OF THE NEOTROPICAL RAINFOREST

2:15 **Jaffri, A., and Murphey, P.:** A BIOSTRATIGRAPHIC REVISION OF THE PLIO-PLEISTOCENE UPPER SIWALIK DEPOSITS OF THE POTOHAR PLATEAU, PAKISTAN

2:30 **Feranec, R.:** DETERMINATION OF RESOURCE PARTITIONING IN A PREDOMINANTLY C3 ENVIRONMENT BY THE ANALYSIS OF STABLE ISOTOPE VALUES FROM HERBIVORES IN YELLOWSTONE NATIONAL PARK

2:45 **Ruez, D.:** RELEVANCE OF MODERN ECOSYSTEMS TO PLIO-PLEISTOCENE MAMMALIAN PALEOECOLOGY

3:00 **Koch, P.L., Diffenbaugh, N.S., and Hoppe, K.A.:** ISOTOPIC RECORDS OF LATE QUATERNARY ECOSYSTEM CHANGE IN TEXAS

3:15 BREAK

3:30 **Harris, J., Coltrain, J., Cerling, T., and Ehleringer, J.:** TROPHIC RELATIONSHIPS OF LATE PLEISTOCENE MAMMALS FROM RANCHO LA BREA

3:45 **Barnosky, A.D.:** A BALANCED LOOK AT PLEISTOCENE EXTINCTIONS

4:00 **Behrensmeyer, A.K., Harmon, E.H., and Kimbel, W.H.:** ENVIRONMENTAL CONTEXT AND TAPHONOMY OF THE FIRST FAMILY HOMINID LOCALITY, HADAR, ETHIOPIA

4:15 **Badgley, C., and Smith, G.R.:** ENVIRONMENT AND EVOLUTION OF MAMMALS AND FRESHWATER FISHES

4:30 **Wagner, H.M., Randall, K., Riney, B.O., and Roeder, M.A.:** A LATE PLEISTOCENE (RANCHOLABREAN) VERTEBRATE FAUNA FROM THE WANIS VIEW ESTATES HOUSING PROJECT, OCEANSIDE, NORTHWESTERN SAN DIEGO COUNTY, CALIFORNIA

4:45 **Nave, J., and Wallace, S.:** NEW TECHNOLOGY FOR AN OLD SITE: USING SURVEY GRADE GPS AND TOTAL STATIONS TO ESTABLISH A PERMANENT CONTROL NETWORK AND A TOPOGRAPHIC MAP OF THE PLEISTOCENE-AGE SITE IN SALTVILLE, VIRGINIA

5:00 **Spaeth, P., Conroy, C.J., Chan, Y., and Hadly, E.A.:** BIOGEOGRAPHIC AND GENETIC ORIGINS OF THE GREATER YELLOWSTONE ECOSYSTEM MAMMALIAN FAUNA

5:15 **Steele, T., and Hadly, E.A.:** PALEOECOLOGY OF SMALL MAMMALS FROM WATERFALL LOCALITY, YELLOWSTONE NATIONAL PARK, WYOMING, USA

5:30 **Moore, J.:** ANALYSING DOMINANCE IN VERTEBRATE PALEOECOSYSTEMS: A QUANTITATIVE METHOD

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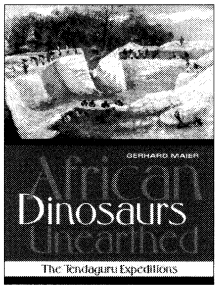

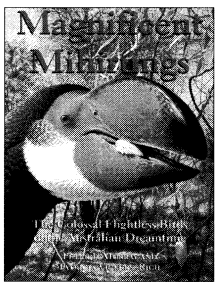

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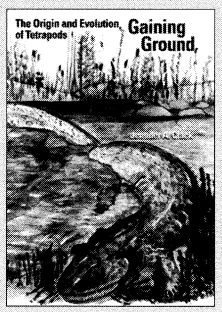

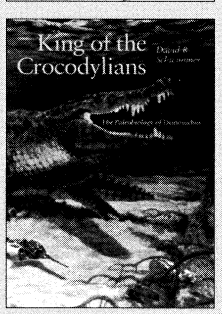

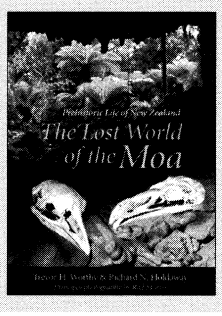

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ONTOGENETIC DEVELOPMENT OF OSSIFIED TENDONS IN HADROSAURIAN DINOSAURS

ADAMS, Jason, ORGAN, Chris, Montana State University, Bozeman, MT.

Ossified tendons are commonly preserved along the axial column of most ornithischian dinosaurs. Historically, these structures have been considered to be important for the reconstruction of hadrosaurian biomechanics because they represent fossilized portions of muscle-tendon units. Because the metaplastic alteration of tendon can occur as a response to various types of stress, disease, injury, and aging, as well as through normal developmental processes, knowledge of tendon development is a prerequisite to understanding their presence and function. Tendons ossify as part of the normal growth process of many avian groups, and their development is well understood. Samples of ossified tendons from birds and hadrosaurs were derived from different growth stages. Histologic examination has resulted in the recognition of numerous similarities between normally ossifying avian and dinosaur tendons. Evidence supports the conclusion that tendons in hadrosaurian dinosaurs ossified as part of their normal developmental process and not as a response to abnormal stress. Furthermore, the onset of intratendinous ossification begins much earlier in hadrosaurs than in birds. Tendon ossification in hadrosaurs appears to proceed in a similar fashion to that of avian tendon metaplasia, but ossifies more extensively at younger growth stages. Knowing when and how the axial column is affected by increased rigidity due to tendon ossification may be instrumental in determining the changes in locomotor strategies throughout the hadrosaur life span.

A LEATHERBACK SEA TURTLE FROM THE EOCENE OF ANTARCTICA: IMPLICATIONS FOR THE ANTIQUITY OF GIGANTOTHERMY IN DERMOCHELYIDAE

ALBRIGHT, Barry, Museum of Northern Arizona, Flagstaff, AZ; WOODBURNE, Michael O., University of California, Riverside, Riverside, CA; CASE, Judd A., St. Mary's College, Moraga, CA; CHANEY, Dan S., Smithsonian Institution, Washington, DC.

The mainly pelagic extant leatherback sea turtle, *Dermochelys coriacea*, is primarily distributed in tropical to warm temperate regions of the world's oceans, but is known to occur as far north as Newfoundland, British Columbia, and the British Isles to as far south as the Cape of Good Hope. *Dermochelys* is evidently able to tolerate higher latitude colder waters due to its ability to maintain a body temperature as great as 18° to 21° C above that of the surrounding water through a combination of large body size, insulative tissue, low metabolic rate, and changes in blood flow – a condition of temperature regulation known as gigantothermy. Remains of leatherback sea turtles in late middle Eocene estuarine deposits of Seymour Island, Antarctica, indicate their presence in high southerly latitudes well after the Early Eocene Climatic Optimum and during an interval of time over which climatic deterioration was well underway as confirmed by planktonic, oxygen isotopic, molluscan, palynomorph, and plant megafossil data from Seymour Island and the surrounding James Ross Basin. Southern ocean sea surface temperatures (SSTs) during this time are estimated to have been between 6° and 10° C. Therefore, the Seymour Island dermochelyid taxon must have had some physiological means of maintaining a body temperature conducive to a relatively active metabolism in cold waters, in turn implying that gigantothermy in the Dermochelyidae can be traced back at least to the middle Eocene.

WHEN *TERRESTRISUCHUS GRACILIS* REACHES PUBERTY IT BECOMES *SALTOPOSUCHUS CONNECTENS*!

ALLEN, David, Northern Illinois University, DeKalb, IL.

Sphenosuchian crocodylomorphs were ecologically important terrestrial carnivores that persisted from the Late Triassic until the Middle Jurassic. They were among the first crocodylomorphs to evolve and, at just 80 cm in length, *Terrestrisuchus gracilis* has long been considered the smallest of the sphenosuchian lineage. Significantly, all material referred to this monospecific genus is derived from the Norian and Rhaetian fissure-fill lagerstatten of south-west Britain. Adult specimens are notably absent from these deposits and this has inspired controversy regarding the validity of this genus. Some workers argue that *Terrestrisuchus* represents a genuinely small genus while others believe these specimens represent a collection of juveniles from another genus. The genus most closely associated with the British specimens is *Saltoposuchus*. *Saltoposuchus* was temporally coincident, although it is known exclusively from fluvial deposits of south-west Germany. All specimens of *Saltoposuchus* are larger than any specimen assigned to *Terrestrisuchus*, and all appear to have been mature in age. A newly confirmed juvenile specimen from southwest Britain provides information that shows the *Terrestrisuchus* holotype to also be at a juvenile stage of growth. Comparison of British specimens with those from Germany highlighted trends regarding relative sizes of the maxillae, skull element sculpture and proportional length of the hindlimb. These trends suggest that these, and a number of published cladistic characters, are strongly influenced by ontogeny. When characters relating to absolute size, and those associated with ontogenetic change, are removed from an analysis there is often an associated reduction in resolution. Omission of such characters from recognized cladistic studies results in *Saltoposuchus* and *Terrestrisuchus* becoming cladistically indistinguishable. *Terrestrisuchus* is considered a juvenile synonym of *Saltoposuchus*. The paleogeographic range of *Saltoposuchus* is expanded to include Britain.

THE 5% PROJECT: JUST HOW GOOD IS THE FOSSIL RECORD OF TETRAPODS?

ALROY, John; BEHRENSMEYER, Kay; CARRANO, Matt; CLYDE, Will; FARA, Emmanuel; FORTELIUS Mikael; HEAD, Jason; HUNTER, John, UHEN, Mark; WANG, Xiaoming.

The Paleobiology Database (PBDB) has organized a working group to study large-scale patterns in the vertebrate fossil record. Its first goal is to estimate the relative amount of sampling in different parts of the record by databasing a randomly chosen 5% subsample of the scientific literature. 2628 references were identified by querying GeoRef with the keyword "Tetrapoda." Abstracts, guidebooks, theses, popular literature were excluded. The list was split between dinosaurs (Carrano), diapsids (Fara, Head), marine mammals (Uhen), and terrestrial mammals from Africa (Behrensmeyer), Asia (Clyde, Wang), Australia (everyone), Europe (Fortelius, Hunter), and North and South America (Alroy). A web-based Perl/MySQL system was used to track progress, preventing duplication of effort. References, collection data, and occurrences were entered into the PBDB. To date, 1234 references have failed to yield useable data, 492 have been entered, and 902 are still in process

The distribution of collections and occurrences demonstrates several key patterns. (1) There is a dramatic, virtually exponential increase in sampling through time, with Cenozoic sampling levels being easily an order of magnitude greater than Cretaceous levels. This pattern is likely to hold up because a large majority of the in-process references concern Cenozoic mammals. (2) There is a very strong latitudinal gradient favoring northern regions. Much of the gradient tracks the latitudinal distribution of continental area, but a belt between 30°-50° shows an anomalous spike. (3) The record is dominated by sandstones and clay/mud/siltstones, with conglomerates, carbonates, organics, and phosphatics being rare. Fluvial and overbank contexts are most common. (4) A large majority of collections include macrofossils (>10 mm), which even are present in most screenwashed microfossil assemblages. We conclude that strong sampling effects dominate the tetrapod record, including collector bias (latitude, fossil size), taphonomy (lithology, environment), and outcrop availability (evolutionary time). Large-scale studies should address these effects carefully.

THE ORIGIN OF LISSAMPHIBIA

ANDERSON, Jason, Dept of Biology, Mississauga, ON, Canada.

The origin of frogs, salamanders, and caecilians (Lissamphibia) remains one of the most vexing problems in lower tetrapod phylogeny. Modern amphibians are highly divergent and share few unambiguous synapomorphies with Paleozoic species. The controversy is exemplified by the three suggested hypotheses: lissamphibians are monophyletic with origins in temnospondyls, they are monophyletic with origins in lepospondyls, or they are polyphyletic with origins in both groups. Most recent large scale phylogenetic analyses support monophyly, but diverge on the question of origins. As a result, various research groups have been investigating new sources of evidence, including the description of new taxa, patterns of development, and the effect of adding ever-increasing numbers of taxa and characters to already large data sets, to try and resolve the issue.

These new lines of evidence will be evaluated and their implications for the question of lissamphibian origins will be tested. Specifically, I will compare the pattern of cranial ossification described in some temnospondyls and lissamphibians with that seen in the only lepospondyl that preserves this information, the aistopod *Phlegethontia*. I will present preliminary results from several ongoing anatomical investigations and examine tooth anatomy in detail. Finally, all of these data will be incorporated for the first time into a phylogenetic analysis that will include both the temnospondyl and lepospondyl transformational series that have been suggested as ancestral for lissamphibians.

TWO NEW PTEROSAUR SPECIES FROM LIAONING, CHINA, AND THE RELATIONSHIPS OF THE PTERODACTYLOIDEA

ANDRES, Brian, Yale University, New Haven, CT; JI, Chiang, Chinese Academy of Geological Sciences, Beijing, China.

Two new species of pterodactyloid pterosaurs from the Yixian Formation of Liaoning, People's Republic of China, are described on the basis of an articulated partial postcranium and a nearly complete skeleton. A phylogenetic analysis of the Pterodactyloidea places the first species in the Gnathosaurinae, a group of ctenochasmatid pterosaurs with elongate cervical vertebrae and between 100 and 200 teeth. Characters present in the cervical vertebrae of this new species suggest that the isolated cervical vertebrae from the Purbeck Limestone belong to the gnathosaurines from the same formation. The second species is placed in the Istiodactylidae, a previously monospecific family of pteranodontoid pterosaurs with lancet-shaped teeth and a depressed rostrum. This family was formerly known only from the Vectis Formation of the Isle of Wight, England. This analysis establishes a more robust hypothesis of the relationships of the Archaeopterodactyloidea, a Late Jurassic to Early Cretaceous pterodactyloid radiation. The previously described pterodactyloids from the Yixian Formation, *Eosipterus yangi* and *Haopterus gracilis*, are classified with respect to the rest of the Pterodactyloidea with *E. yangi* placed as the sister group to *Pterodaustro guinazui* within the Ctenochasmatidae and *H. gracilis* placed as the sister group to the Archaeopterodactyloidea. In this analysis, the genus *Pterodactylus* is recovered as paraphyletic. *Pterodactylus elegans* and *Pterodactylus micronyx* are placed in the Ctenochasmatidae while *Pterodactylus longicollom* and a sister group of *Pterodactylus antiquus* and *Pterodactylus kochi* are placed as successive sister groups to a group comprising the Cycnorhamphidae and the Ctenochasmatidae. This phylogeny also implies that the distribution of cranial crests in pterosaurs has a wider distribution than is preserved in the fossil record.

DICYNODONT EXTINCTIONS IN THE PERMIAN: ONE, MANY OR NONE?

ANGIELCZYK, Kenneth, Univ.of California, Berkeley, CA; RUBIDGE, Bruce, Bernard Price Institute for Palaeontology, Johannesburg, South Africa.

Dicynodont therapsids were the most successful vertebrate herbivores during the Late Permian and Early Triassic. Thus, accurately reconstructing changes in dicynodont diversity is an important step in understanding the rate and magnitude of the Permo-Triassic extinction in the terrestrial realm. Recent work in the *Dicynodon* Assemblage Zone of South Africa shows that dicynodonts were strongly affected by the end-Permian extinction, and one taxon is known to cross the Permo-Triassic boundary. Data from phylogenetic studies show that two to three additional dicynodont lineages must have survived the extinction elsewhere. Besides

the end-Permian event, a second major drop in tetrapod diversity has been inferred at the end of the early Late Permian *Tapinocephalus* Assemblage Zone. Because there is much stratigraphic and phylogenetic uncertainty regarding the *Tapinocephalus* Zone and its fauna, it is difficult to determine if this episode is real or an artifact. Recently, several new dicynodonts have been discovered in the lower *Tapinocephalus* Zone, and we present an additional new form here. Phylogenetic analysis suggests that some of the new taxa are basal members of known clades, whereas others represent new lineages, increasing the known dicynodont diversity of this time. However, we do not know whether the new taxa occur only in the lower *Tapinocephalus* Zone or if they persist through most of the zone. If they are restricted to the base of the zone, then the rate of turnover must have been low throughout *Tapinocephalus* Zone times as the basal forms disappeared and more derived taxa originated. Alternatively, if these taxa occur through much of the *Tapinocephalus* Zone, then dicynodont diversity generally increased during this time, but was sharply culled at the end of the zone. Additional collecting as well as comparisons to other clades clearly are needed to test these hypotheses. However, determining what, if anything, happened to dicynodonts at the end of the *Tapinocephalus* Zone is necessary to fully assess whether one or more serious extinction events affected Late Permian terrestrial ecosystems.

EARLY RADIATION OF FELID SABERTOOTHS DOCUMENTED IN CARNIVORE-TRAP FOSSIL SITE IN THE LATE MIOCENE OF SPAIN

ANTON, Mauricio, SALESA, Manuel, MORALES, Jorge, Museo Nacional de Ciencias Naturales-CSIC, Madrid, Spain; PEIGNE, Stephane, Museum National d'Histoire Naturelle, Paris, France; PELAEZ-CAMPOMANES, Pablo, FRAILE, Susana, Museo Nacional de Ciencias Naturales-CSIC, Madrid, Spain

The Upper Vallesian (late Miocene, MN 10 Zone) site of Batallones-1 (Madrid, Spain) has yielded an exceptional sample of fossils of two species of sabertooths, the leopard-sized *Paramachairodus ogygia* (MNI=24) and the tiger-sized *Machairodus aphanistus* (MNI=18). These hitherto poorly known species are found in association in several Vallesian age sites in Western Europe, constituting one of the earliest radiations of felid sabertooths. The Batallones-1 sample, which includes several specimens of every bone of the skeleton, allows us to assess for the first time the functional anatomy of these machairodontines, while the characteristics of the accumulation provide insights into their ecology and territorial behavior. Both species display primitive postcranial anatomy, functionally similar to modern pantherine cats of similar size, lacking the typical adaptations of later, derived machairodontines (powerful forelimbs, shortening of lumbars, etc.). The dentition of both taxa shows early adaptations to a type of bite that caused bleeding in large-sized prey rather than a crushing or throttling bite as in modern cats, although precise cranial adaptations for the canine shear-bite (typical of derived sabertooths) were only incipient. *M. aphanistus* displays a great sexual dimorphism, similar to that of lions and leopards, which suggests a breeding system with high competition between males for access to the females. *P. ogygia*, in contrast, shows a lower dimorphism, as in jaguars and pumas, suggesting much less aggressive interactions between males. The near-absence of juveniles of either species is interpreted as evidence of solitary behavior, while social behavior would have resulted in more abundant preservation of individuals of all ages. The presence of *M. aphanistus* and *P. ogygia* in the trap and the greater abundance of the latter suggest that vegetation cover was important enough to allow the smaller species to avoid the larger one. The faunal association, which includes some forest dwellers, such as *Steneofiber* sp. and *Martes* sp., also supports the presence of a highly structured habitat.

BODY MASS AND FEEDING BEHAVIOR IN THE EXTINCT PLEISTOCENE DIRE WOLF (*CANIS DIRUS*)

ANYONGE, William, MEYER, Jessica, BAKER, Andrew, ALBERICO, Paul, ROMAN, Chris, Xavier Univ., Cincinnati, OH.

The dire wolf, *Canis dirus*, is an extinct species of canid that inhabited North and South America during the Late Pleistocene. An abundance of fossil remains have been recovered from both regions with the best preserved specimens being those from the Rancho La Brea deposits in Los Angeles, California. Records indicate that it was the most common fossil wolf during the Late Pleistocene. Many questions still abound regarding the body size, locomotor and dietary behavior in this species. Many authors agree that the dire wolves were more powerful predators than the modern gray wolves, *Canis lupus*, and some studies have suggested that they may have used their postcarnassial molars to crush substantial amounts of bone.

In our study, we used several linear and cross-sectional geometric properties of the femur and humerus to estimate body mass in the dire wolf. We also applied a biomechanical analysis to infer biting strength at various positions along the upper tooth row. In addition, we estimated relative moment-arms of jaw-closing muscles (temporalis and masseter) and compared them to those in the living gray wolf and the spotted hyena.

Our results indicate that adult dire wolves averaged over 50 kg in body weight and had relatively greater biting strength at the upper molar, carnassial, and canine tooth positions compared to the gray wolves. Dire wolves did not differ significantly from gray wolves in the length of the moment-arms of the temporalis and masseter. Both canids, however, have relatively shorter moment-arms, and relatively smaller jaw-closing muscles than those in the spotted hyena. We concluded that the dire wolves resembled the gray wolves in overall musculoskeletal morphology of the skull but differed in biting strength at various tooth positions mainly due to differences in lever-arm lengths. We suggest that these differences are not necessarily indicative of specialized bone-cracking ability in the dire wolves.

A NEW THEORY OF HUMAN SPECIATION

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Analysis using a MANOVA on statewide standardized science-testing results yielded surprising and significant data. This information pointed towards a dichotomous evolution of inherited neural networks that correspond to opposing spatial abilities between males and females as a result of hunting and gathering over thousands of years. Eight spatial abilities (four male and four female) are outlined. Abstract thought may be directly linked with the process of hunting. Further studies with neurological, paleontological, biological and sociological sources have suggested a possible set of mechanisms for brain expansion and reorganization in humans. This theory involves an isolated, extreme and expansive environment that early humans (*Homo erectus*) tried to navigate. For survival, it was necessary to remember details of the environment and to be able to verbally label every object in that environment. Singing has been shown by neurologists to put information directly into long-term memory and dreaming has been linked to imagination. The Australian Aboriginal with their songlines and dreamtimes may hold the key to understanding the evolutionary leap from primitive to modern man.

EUROPEAN PAROMOMYIDS (PLESIADAPIFORMES: MAMMALIA): A REAPPRAISAL

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North American paromomyids have been the subject of many studies since some paleontologists proposed them as sister-group of Dermoptera. In Europe, they have not been as intensely studied. Their first discovery in the Old World was in 1967 when Russell and collaborators described the two endemic species *Arcius lapparenti* and *A. fuscus*, based on scarce teeth. Today, the larger collections of European localities allow a reappraisal of these paromomyids.

The high morphological variation and size range described for each locality are interpreted as the co-occurrence of two species. These two species keep their original names, *A. lapparenti* and *A. fuscus*, however emended diagnoses are proposed. In some loci (Mutigny and Avenay; Marne, France), these two species are difficult to differentiate, and in some other younger places (Condé-en-Brie, Saint Agnan, Sézanne; Aisne, Marne, France) they can be clearly recognized. This pattern is interpreted as a cladogenesis.

Morphological and biometrical variations through time are used for biochronology. Early Eocene fossil localities from Europe are isolated and the geological deposits show discontinuities and diachronisms. In this context, mammalian biochronology is one of the best way to date localities. Hence the biochronological meaning of the paromomyid fossil record is important and it appears to confirm previous biochronological hypotheses.

The link between Northern European species (*A. fuscus* and *A. lapparenti*), the Southern European species (*A. rougieri* and *A. zbyszweskii*) and the North American species has always been extremely vague because the European specimens were very fragmentary. Newly identified teeth as lower and upper incisors and also (for the first time in Europe) deciduous lower and upper incisors allow new considerations about the whole family. The four European species can clearly be recognised as members of one and the same genus (*Arcius*), and cladistic analysis is performed to clarify the link between the endemic European genus and its North American relatives.

THE LOCAL FLORA AND FAUNA OF A SITE IN THE UPPER MORRISON FORMATION (UPPER JURASSIC) OF NORTHEASTERN WYOMING

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Over the summer of 2002 the University of Kansas returned to a dinosaur quarry previously worked in 1997 and 1998 in the Black Hills of northeastern Wyoming. The site consists of fluvial quartz sandstones and mudstones shallowly dipping to the southwest. The most common dinosaurs are sauropods. Three *Camarasaurus* were recovered, varying in age from juvenile to adult. The skeleton of a diplodocid and the pes of a large brachiosaur were collected in 1998. Excavation in the past year produced a fourth subadult *Camarasaurus* and a probable brachiosaur skeleton. Associated with the sauropod skeletons are large and small theropod teeth, crocodile teeth, and shell fragments from the freshwater turtle, *Glyptops plicatalus*. The microfauna occurs in two distinct zones. Underlying the dinosaur specimens in a thin layer of laminated mudstone, where fish scales and bones prove to be abundant. A bone-pebble conglomerate contains some of the more complete skeletons of the microfauna. In 1997 and 1998 partial skeletons of a coelurosaur and a juvenile *Othneilia* were found in the conglomerate. An isoloated *Glyptops* skull and the metatarsals of a juvenile *Allosaurus* were also collected in 2002. Leaf fossils are rare at the locality, although two gymnosperms are well represented by reproductive structures. The most common are *Araucaria* seeds found in the laminated mudstone. Numerous male cycad cones and an (?) *Araucaria* cone were found in the mudstone surrounding the *Camarasaurus*.

ENVIRONMENT AND EVOLUTION OF MAMMALS AND FRESHWATER FISHES

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The geographic distribution of extant terrestrial mammals and freshwater fishes over North America suggests a hypothesis for the causes of species diversity at the regional scale. Over most of North America, mammals exhibit greater species density in western landscapes of high physiographic and climatic complexity than in geologically older areas at low elevation in eastern North America at the same latitude. Fishes show the opposite pattern. For each group, similar geographic patterns occur on other continents. Both patterns depart significantly from the null model of the mid-domain effect on species density.

We propose that geologic history (tectonics and climate) determines the areas, shapes, and connectivity of suitable habitats for members of each group. Reticulated landscapes with intermediate levels of connectivity promote species metapopulations in the short term and speciation in the long term. For mammals, geologically young or active landscapes offer a patch-

work of heterogeneous habitats suited to recurrent isolation and genetic differentiation of populations. For freshwater fishes, passive margins with large, dendritic river systems offer numerous opportunities for headwater colonization followed by allopatric speciation. For both groups, climatically-driven range shifts may cause expansion of species ranges across the landscape or extinction from loss of habitat area. Thus, tectonics and climate play a dominant role in controlling speciation, extinction, and species accommodation. We test this hypothesis with paleontological, phylogenetic, and population-genetic data for both mammals and fishes.

3D FORCE BALANCE MODEL OF THE AVIAN SHOULDER AND THE ROLE OF THE ACROCORACOID PROCESS

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In extant birds, the acrocoracoid process projects from the dorsal end of the coracoid. The raised position of this process is derived in Avialae, but its functional significance remains controversial. The role of the acrocoracoid process can be better understood by considering how forces are transmitted across the shoulder joint in extant flying birds. In gliding flight, the pectoralis depresses the humerus to counter upward rotation produced by the aerodynamic forces on the wing. However, the glenoid lacks ventral support and requires an additional component to prevent dislocation. A 2d force balance model predicts that the acrocoracohumeral ligament (AHL) performs this role. In a 3d model, the pectoralis also pronates and retracts the humerus, both of which are countered by the AHL. The pectoralis and AHL combine to medially compress the humeral head into the glenoid. In flapping flight, the pectoralis produces force during most of the downstroke. If the AHL is made taut by the pectoralis, then it will limit the movement of the humeral head on the glenoid. The avian glenoid allows elevation/depression, protraction/retraction, pronation/supination, and dorso-ventral gliding of the humeral head, yet only small subsets of all the possible combinations are used during wingbeat cycles. I propose that the AHL restricts the range of possible combinations, thereby constraining humeral motion. The AHL spans from the acrocoracoid process to the transverse sulcus of the humerus. The position of the acrocoracoid process permits the AHL to counter the massive pectoralis during flight. Hence, the elevated position of the avialan acrocoracoid process may be related to an increasingly important role of the AHL.

NEW FOSSIL SHREW REMAINS FROM WESTERN NEBRASKA AND A SUGGESTED SUBFAMILIAL REVISION OF THE SORICIDAE (MAMMALIA; INSECTIVORA)

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Soricid remains discovered in early Arikareean through early Barstovian deposits in western Nebraska shed new light on the phylogeny of the Soricidae. The two principal characters that define subfamilial relationships in this monophyletic group, morphology of the mandibular condyle and p/4, are well preserved in each new taxon discussed.

The earliest North American member of the Limnoecinae (= Crocidosoricinae), n. gen. A from the early Arikareean Ridgeview l.f. (ca. 28 Ma), has a crescentic labial emargination of the mandibular condyle and a pocketed internal temporal fossa, both considered synapomorphies of the Soricidae. Additional plesiomorphic characters of the Limnoecinae include: double rooted, tetrahedron-shaped p/4 with V-shaped wear facet; m/1 with protoconid and metaconid closely appressed, isolated entoconid, and a strong labial cingulum interrupted by the protoconid as in the Heterosoricidae; talonid of m/3 is greatly reduced but basined. The autochthonous clade *Limnoecus* first appears in the late Arikareean and remains dentally conservative through the early Hemingfordian *L.* (= *Antesorex*) *compressus*, the late Hemingfordian *L.* n. sp., and the late Barstovian *L. niobrarensis*. A second small limnoecine (n. gen. B) from the early Barstovian and two large Hemingfordian forms, *Angustidens vireti* and cf. *Adeloblarina* n. sp. (Companion Quarry l.f.), show variations of the V-shaped wear facet on p/4 and more extensive labial emargination, separating well defined condylar facets in the latter genus.

The characteristic, complete dorso-ventral separation of condylar facets, apomorphic for the Soricinae, was achieved by subsequent lingual emargination of the limnoecine condyle reducing the interarticular list to a narrow lingual attachment of the facets in cf. *Adeloblarina* n. sp. The synapomorphic labial emargination unites the Limnoecinae, Crocidurinae and Soricinae (evident in the lingual tilt of the upper condylar facet) within the Soricidae.

A GEOMETRIC MODEL OF ONTOGENETIC TOOTH WEAR IN MAMMALS: STRUCTURE, FUNCTION, AND EVOLUTION OF HYPSODONT MORPHOLOGIES

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A two-dimensional model of ontogenetic wear of mammal teeth was developed to explore geometric controls on occlusal surface topography and occlusal dimensions of hypsodont teeth. A tooth is modeled as part of the area between two perfect circles, and is characterized by four geometric parameters: 1) radius of the outside circle, 2) radius of the inside circle, 3) linear displacement between circle centers, and 4) angle of occlusion in relation to the displacement direction. Ontogenetic wear is modeled as the rotation of the occlusal surface around the center of the outside circle, while the angle of occlusion is held constant and growth rate is assumed to equal wear rate. A set of potential morphologies was generated by varying values for each of the parameters using an interactive geometry computer program. Model morphologies were categorized into four major types based on changes to the length of the dimension across the occlusal surface and topography of the occlusal surface. The model was tested with measured parameters from samples of *Ondatra* upper incisors and central upper cheek teeth of *Lepus* and *Russellagus*. In each case, the model generated occlusal topography and occlusal dimension changes comparable to patterns observed in ontogenetic series.

Results from this analysis support the idea that tooth geometry can strongly influence the expression of ontogenetic wear on the occlusal surface. This model suggests that some hypsodont morphologies are structurally "preadapted" to hypselodonty, while others have a limited ontogenetic lifespan and cannot attain full hypselodonty but may have other structural or functional advantages in certain circumstances.

EOCENE AND OLIGOCENE SIRENIA (MAMMALIA) FROM WESTERN INDIA

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The District Kachchh in western Gujarat is well known for its Eocene cetaceans. However, Eocene sirenians are also known from Kachchh. Our recent field work in the Harudi Formation yielded material for two families of sirenians, Protosirenidae and halitheriine Dugongidae. Several fossils, including two fragmentary skulls, represent *Protosiren*. Two mandibles pertaining to sirenians are much smaller than *Protosiren*: a well-preserved mandible with several teeth is *Eotheroides* and an edentulous mandible is similar to *Eosiren*.

The five richest localities in Eocene Kachchh yield approximately 90% of all mammal fossils. However, the distribution of mammalian taxa at these sites differs greatly. At Rato Nala, more than half the recovered fossils pertain to the cetacean genus *Remingtonocetus*, and sirenians make up less than 5% of the mammals. At Babia Hill, half of the mammal fauna consists of the cetacean *Andrewsiphius*, and sirenians make up 10% of the fauna. At Vaghapadar, in contrast, sirenians make up two-thirds of the assemblage, and cetaceans are a minority. We suggest that different localities sampled different depositional environments, and that the differences in abundance reflect habitat differences.

In addition to Eocene sirenians, Kachchh also yielded Miocene sirenians and a few fragments of Oligocene sirenians. This year, we improved the Oligocene collection when we recovered several sirenian specimens in the Chattian Mariyana Fort Formation. These include a mandible and well-preserved skull of a sirenian. Overall, these specimens resemble the common Oligocene genus *Halitherium*. However, the Indian material shows several pecularities, such as the presence of a large tusk-like first incisor, the presence of two double- or triple-rooted upper (deciduous?) premolars, and the anterior position of the ventral jugal process.

Based on these fossils, it is clear that Kachchh supported a diversity of sirenians throughout the Paleogene.

SKELETAL DEVELOPMENT OF THE VERTEBRAL COLUMN IN *ASCAPHUS TRUEI* (AMPHIBIA: ANURA)

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The historic importance of the tailed frog *Ascaphus truei* lies in its purported phylogenetic position as a basally diverging member of crown-clade Anura. The notochordal state of the centra contributes to the systematic placement of this taxon; however, few studies examine the development of the vertebral column of *A. truei* within a phylogenetic context. In this study, the vertebral development of *A. truei* was examined using a growth series of cleared and stained specimens (Gosner stages 36 to 45), as well as high-resolution x-ray CT images of an adult. Timing and sequence of ossification in the various vertebral elements were noted and compared to published data for the other major anuran clades.

The first elements to ossify in *A. truei* are the neural arches (stage 36), followed by the transverse processes (stage 42) and the urostyle (stage 45). Development of the centra is delayed considerably with initial ossification not appearing until the subadult stage. This delay in centrum development represents a deviation from the pattern found in other anuran groups in which the neural arches ossify first, followed by the centra, the transverse processes, and finally the urostyle. Interestingly, the sequence of ossification of the vertebral elements traditionally is thought to be conservative across Anura. Although this shift in developmental timing suggests a heterochronic event, the direction of this event is not clear. The addition of outgroups such as stem-group frogs, caudates, and gymnophionans should help to determine if this delayed ossification is a derived or plesiomorphic condition.

DENTITION OF *BARAPASAURUS TAGOREI* FROM THE KOTA FORMATION (UPPER JURASSIC) OF INDIA

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The Early Jurassic sauropods *Barapasaurus tagorei* and *Kotasaurus yamanpalliensis* from the lower Kota Formation (Hettangian to Pliensbachian) of eastern India and *Vulcanodon karibaensis* from Zimbabwe are among the earliest known sauropod dinosaurs. The dentition of early sauropods is poorly known, but may provide important phylogenetic data. *Barapasaurus* teeth are spoon-shaped; some have coarse denticles on the posterior carina. The largest tooth, probably a right upper, is typical. It is slightly curved in anterior aspect, and straight in lingual/labial aspect with slight asymmetrical bulge of the crown. The tapered root is elliptical in cross-sectional aspect, and is slightly constricted at its junction with the crown, which is also constricted and subcircular at its base. Most of the enamel of the crown is weakly crenulated. The labial surface of the crown is convex; the lingual surface weakly sigmoid, producing a spatulate profile in lateral or medial aspect. Three coarse tubercles on the posterior carina produce a scalloped, asymmetrical outline, proximal profile shallow, apical profile steep. Three other teeth are similar in overall anatomy; one has two tubercles on the posterior carina, while the other two lack tubercles. A smaller tooth, with elongate root and reduced crown, resembles a mammalian incisor. The bulbous crown is truncated by a beveled surface,

apparently a wear facet that is inclined lingually. This is probably the tooth of a juvenile individual. These teeth resemble descriptions of the dentition of *Vulcanodon*, but not the teeth of *Kotasaurus*, which are short and have a curved apex.

NEW POLYCOTYLID PLESIOSAUR FROM THE LATE CRETACEOUS OF MOROCCO

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We report on a new short-necked plesiosaur from the Late Cretaceous (Turonian) of southern Morocco. The specimen consists of a nearly complete skull and lower jaw, and 37 associated vertebrae (including the entire cervical and pectoral series and the anteriormost dorsals) from the Goulmima region (Er- Rachidia Province) and was collected in the southern slope of the High Atlas Mountains. The Lower Turonian beds of this area have yielded a rich fauna of marine vertebrates, including actinopterygians, a basal mosasauroid, a turtle, and three plesiosaurs: an elasmosaurid, a pliosaurid and a polycotylid. The latter has a long-snouted skull (length 66 cm) and exhibits a large maxilla-squamosal contact, as is typical in polycotylids. It is referred to a new genus and species on the basis of the following autapomorphies: orbits regularly oval without supraorbital processes; premaxillae with swollen lateral processes between the external nares and the frontal foramina; dental formula consisting of 5 premaxillary, at least 22 maxillary, and 29 dentary teeth; mandibular symphysis bearing 15 pairs of teeth; relatively long neck consisting of 30 cervical vertebrae; cervical centra nearly as long as high, and bearing longitudinal ridges. Polycotylidae are well known in North America (*Polycotylus*, *Dolichorhynchops*, *Trinacromerum*, *Edgarosaurus*) and their remains have also been described in Asia (*Georgiasaurus*), South America (*Sulcusuchus*), Australia and New-Zealand. This is the first polycotylid found in Africa at subtropical palaeolatitudes.

THE MOST PRIMITIVE KNOWN PLATANISTID (CETACEA; ODONTOCETI), A NEW EARLY MIOCENE SPECIES FROM SOUTHERN CALIFORNIA

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The cetacean family Platanistidae includes rare fossil Miocene species from the North Atlantic and North Pacific realms, but today is restricted to the strange little highly derived dolphins of the genus *Platanista* that live only in the Ganges and Indus river systems of southern Asia. In contrast to the living species, all known fossil platanistids were much larger (approaching 4 m in body length) and more primitive. A fossil platanistid dolphin skeleton, apparently representing a new species of *Allodelphis*, discovered in the lowest Miocene Vaqueros Formation near Irvine, southern California, is the first discovery of a fossil platanistid reported from southern California. It differs from the most primitive named platanistid, early Miocene *Allodelphis pratti*, from north of Bakersfield in central California, by having smaller nasal openings that are positioned more anteriorly on the cranium, more anteroposteriorly elongate nasal bones, larger temporal fossae, and more prominent nuchal and lambdoidal crests. Its smaller occipital condyles and cervical vertebrae suggest that enlargement of cervical vertebrae is a synapomorphy of later *Allodelphis pratti*, middle Miocene *Zarhachis flagellator* from the western North Atlantic, and other Miocene Northern Hemisphere marine platanistids. The new platanistid from southern California has apically extended crowns on its anterior teeth, and relatively large vertebrae, which in the dorsal vertebral region have exceptionally wide transverse and dorsal processes. These apomorphic characters, which are shared with *Zarhachis flagellator* and Recent *Platanista*, are probably additional diagnostic characters of the family Platanistidae.

A BALANCED LOOK AT PLEISTOCENE EXTINCTIONS

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One of the great extinction debates of all time, which has raged for four decades, is what caused the demise of the Pleistocene megafauna—humans or climate? Confounding the issue are political ramifications: paleontology meets conservation biology where humans potentially affect ecosystems. This makes it all the more important to resolve the debate with sound scientific reasoning and data. Since Paul Martin first proposed the human overkill hypothesis, most treatments of the question have focused on presenting evidence in one of six arenas: (1) subjective assessments of what late Pleistocene humans were or were not capable of or inclined towards; (2) association (or lack thereof) of archaeological data that links human activities with extinct megafauna; (3) simulations that examine whether or not expanding predator populations are capable of wiping out prey; (4) correlations between human arrival and megafaunal extinctions; (5) evidence of how humans (usually) or climate (rarely) affect island ecosystems; (6) ideas and evidence about the ecological effects of climate change or deletion of keystone species. Most studies use the evidence from one arena to argue the point but fail to integrate (or even to mention) what may be contradictory evidence from the other arenas. Almost completely lacking has been a key piece of evidence: (7) how do ecosystems respond to Pleistocene climate changes in the absence of humans? Here this new evidence is added and integrated with current information from the other six arenas. The result is a model that differentiates expectations of climatic versus human impacts on ecosystems and is consistent with the hard evidence that bears on Pleistocene extinctions.

THE EVOLUTIONARY SIGNIFICANCE OF THE GROWTH PLATE

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Biomineralization is a crucial phenomenon due to adaptive properties it imparts to tissues and organs. Moreover, mineralized tissues have the greatest potential to become part of the fossil record. In the long bones of vertebrates, growth plate cartilage is responsible for bone elongation. The life cycle and architecture of growth plate cells is distinctive. These cells exert forces that extend the length of a bone while at the same time serving as a template for longitudinal extension of the bone shaft. Towards the end of their life cycle, growth plate cells mineralize their extracellular matrix and those cells that will be replaced by bone undergo programmed cell death. The growth plate modulates differential growth rates. Rapid determinant bone growth is adaptive in that it minimizes the vulnerable juvenile and adolescent periods of vertebrate life. Examination of growth plates of diverse taxa reveals that this strategy has arisen independently in birds and mammals. By studying the mineralized portion of the growth plates of fossil vertebrates, we gain insight into development, physiology and systematics.

PROSAUROPOD DINOSAURS FROM THE LOWER LUFENG FORMATION (LOWER JURASSIC) OF CHINA

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The Lower Lufeng Formation (Yunnan Province, China) has yielded a rich fauna of Early Jurassic terrestrial vertebrates. Remains of prosauropod dinosaurs are the most abundant elements in this fauna and several genera have been erected on the basis of this material, including *Lufengosaurus*, *Yunnanosaurus* and *Gyposaurus*. Some genera encompass more than one species. Many of these taxa are based on almost complete skeletons: nevertheless, they have been neglected for almost 60 years and have not been subject to detailed analyses since their initial description. The age, provenance and completeness of the material suggest that it will be of great significance to sauropodomorph phylogeny, prosauropod taxonomy, palaeobiology and palaeobiogeography, and Early Jurassic palaeoecology. We have been engaged in a project to redescribe this material and use these new data to address some of these issues. Re-examination of the genotype specimens of *Lufengosaurus* and *Yunnanosaurus* confirms that they are generically distinct. Revised diagnoses are presented for each genus: in both cases the majority of autapomorphies are cranial. The genotype specimens of *Gyposaurus* are fragmentary and non-diagnostic, but may represent juvenile material of *Lufengosaurus*. However, an almost complete individual referred to *Gyposaurus* can be characterised by various postcranial autapomorphies and probably represents a new taxon. First-hand examination of this material has permitted us to correct many errors in the original descriptions of these taxa and has provided the first accurate character-codings for these animals. These data have been incorporated into a new phylogenetic analysis of basal sauropodomorphs, which confirms prosauropod monophyly and addresses the relationships of these previously enigmatic taxa.

THE GIANT RHINOCEROS *PARACERATHERIUM* IN KAZAKSTAN

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Indricotheres are Eocene-Oligocene rhinoceroses of the family Hyracodontidae assigned to the subfamily Indricotheriinae Borissiak, 1923 divided into two tribes, Forstercooperiini Kretzoi, 1940 (*Forstercooperia* Wood, 1938) and Indricotheriini Borissiak, 1923 (*Juxia* Chow & Chiu, 1974,*Urtinotherium* Chow & Chiu, 1963, and *Paraceratherium* Cooper, 1911). The giant indricothere *Paraceratherium* was the largest known land mammal and was distributed from eastern Europe to eastern Asia during the Oligocene. Its most extensive fossil record comes from Kazakstan, where fossils of *Paraceratherium* are known from these localities: 1, Shalkar-Teniz, 2, Torgai River, 3, Kara Torgai River, 4, Shyntuzsai, 5, Kyzyl-Kak, 6, Myneskysuek. 7, Donyztau, 8, Bolattam, 9, Atambaschink, 10, Kyzyl-Kyya, 11, Zhayrem, 12, Sarysu River, 13, Beleuty River, 14, Kutantas, 15, Boktykaryn River, 16, Saryoi, 17, Aktau, 18, Kyzylzhar, 19, Sary ozek, 20, Akespe and 21, Kumbulak. These are localities in the Central Kazakstan region (1-13), Betpakdala region (14-16), Ily basin (17-19) and along the north shore of the Aral Sea (20-21). Localities 1-9 are early Oligocene (Shandgolian), 10-19 are late Oligocene (Tabenbulukian) and two sites (20-21) are possibly of earliest Miocene age. At least three species of *Paraceratherium* are present in Kazakstan: *P. transouralicum*, *P. prohorovi* and *P. zhajremensis*, though most occurrences are of fragmentary specimens that can only be identified as *Paraceratherium* sp.

ANTHROPOID ORIGINS: MOSAIC EVOLUTION, BIOGEOGRAPHY, AND THE GENESIS OF THEIR PALEOECOLOGICAL DOMINANCE

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Prior to a decade ago, the fossil record provided little insight into the nature of the evolutionary transition between the most primitive known primates and undoubted anthropoids. The earliest anthropoids known at that time, from early Oligocene strata in the Fayum region of Egypt, possessed the full arsenal of modern anthropoid anatomy, including: fused mandibular symphysis, postorbital septum, auditory region with perbullar carotid pathway and anterior accessory cavity, loss of lower molar paraconids, and diagnostic changes in the postcranial skeleton.

Recent additions to our knowledge of middle Eocene Asian Eosimiidae emphasize their transitional status between the earliest and most primitive primates and undoubted anthropoids from the early Oligocene. Eosimiids retain such primitive primate features as an unfused mandibular symphysis and large molar paraconids. On the other hand, their derived mode of lower premolar compaction and details of their ankle morphology reveal them to be stem anthropoids. Unpublished maxillary specimens show that eosimiids differ strongly from liv-

ing and fossil tarsiiform primates in possessing relatively small orbits, suggesting a diurnal activity pattern.

In the middle Eocene Shanghuang fauna of Jiangsu Province, China, eosimiids and other basal anthropoids already dominate the primate component of the mammalian assemblage, both in terms of alpha-level diversity and individual abundance. In Africa, early Cenozoic anthropoids rapidly achieved an even greater level of paleoecological dominance. Historical biogeography offers a potential explanation for these paleoecological patterns, which continue to exert a pervasive influence on global primate communities today.

A SPECIMEN OF *CLIDASTES PROPYTHON* WITH AN ARTICULATED FOREPADDLE

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A specimen of *Clidastes propython* was collected from the Smoky Hill Chalk Member of the Niobrara Formation in Logan County, Kansas, in June, 1991. Upon preparation, the specimen was discovered to have an articulated cervical and dorsal series of vertebrae, as well as several caudals, ribs, and a nearly complete front flipper. The left forepaddle was damaged during collecting, but the right forepaddle should have remained intact. Many of the cranial elements are also present but were disarticulated. This specimen provides valuable information about the structure of the forepaddle in *Clidastes propython*, and the phalangeal formula of the genus. As of this time, models of this formula have only been suggested by paleontologists based on incomplete forepaddles. The phalangeal formula appears to be confirmed by our articulated specimen.

ENVIRONMENTAL CONTEXT AND TAPHONOMY OF THE FIRST FAMILY HOMINID LOCALITY, HADAR, ETHIOPIA

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The A.L. 333 locality in the Denen Dora Member of the Hadar Formation is one of the most enigmatic concentrations of early hominid remains ever found. At least 271 specimens representing at least 17 individuals have been recovered, and excavation and surface screening indicate that most if not all are derived from a single stratum within a restricted area of outcrop, dated at about 3.2 Ma. Microstratigraphic study of well-exposed strata surrounding the site revealed that the bone concentration was preserved in the uppermost fill of a channel system that can be traced across an area of paleolandscape approximately 2.0 by 0.8 km. When active, the channel was up to 3 m deep, 40 m wide and flowed north, with smaller and shallower tributaries feeding in from the south and southwest. At the time of burial of the hominids, the abandoned channel formed a shallow swale that carried only low-energy, silt-bearing flow during flood events. The hominid zone at the excavation site is heavily bioturbated with carbonate nodules and root casts, indicating pedogenesis superimposed on the channel-fill silts. Other faunal remains from the excavations include only fragments of rodent, amphibian, snake, fish, bird, mollusk, eggshells, and a few crocodile and large mammal teeth. Throughout the area examined, the channel has relatively few fossils, highlighting the uniqueness of the hominid concentration. Overall sedimentary context, skeletal part preservation, lack of abrasion on the remains and their spatial concentration indicate that the hominids died near where they were buried in a slight depression formed by an abandoned channel. Bone modification features suggest that scavenging and weathering affected some remains prior to final burial. The evidence argues against death caused by an unusual flood or miring and leaves open the possibility of predation or another cause of sudden mass mortality.

"FLYING SQUIRREL" (MAMMALIA; RODENTIA) DIVERSITY IN THE OLIGOCENE OF THE CYPRESS HILLS FORMATION (SOUTHWEST SASKATCHEWAN, CANADA)

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Modern flying squirrels (Sciuridae, Pteromyinae) are found in North America, Europe and Asia. The earliest described pteromyine *Oligopetes* is known from the early Oligocene of Europe and Southwest Asia. Purported "flying squirrel" fossils have previously been recovered in North American faunas from Hemingfordian (early middle Miocene) and later sites. The earliest described North American species is *Sciurion campestre*, from the Hemingfordian Topham Locality in the Cypress Hills Formation. At least three species referable to *Sciurion* have recently been recognized from Cypress Hills sites that are Orellan, Whitneyan and early Arikareean. The Cypress Hills *Sciurion*, and most other fossil pteromyine material, consist of isolated dental remains. The recognition of *Sciurion* in early Oligocene deposits places the initial appearance of the Pteromyinae in North America at roughly the same time as their appearance in Europe.

The contemporaneous presence of pteromyines with different morphologies in the early Oligocene of the Old and New World may indicate an earlier origin and subsequent radiation of pteromyine taxa than current fossil evidence would suggest. Alternatively, this circumstance could imply separate origins of the *Sciurion* and Old World pteromyines, necessitating the removal of the former from the Pteromyinae. The phylogeny of the Pteromyinae remains uncertain due to ambiguities in the identification of flying squirrels based on dentition alone. Recent studies of molecular data regarding flying squirrels do not support such an early divergence of flying squirrels from tree squirrels, but do indicate monophyly of the modern Pteromyinae. If these results are upheld, it might suggest that *Sciurion* is not associated with the modern flying squirrel radiation and evolved a pteromyine-like dentition independently.

FISH FAUNA OF THE HELL CREEK FORMATION, GARFIELD COUNTY, MONTANA: NEW DATA FROM MICROVERTEBRATE LOCALITIES

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The late Maastrichtian Hell Creek Formation of eastern Montana is found to have a more diverse fish fauna than previously reported. A series of nearly three dozen vertebrate microsites have been screened and/or surface collected to produce well over one thousand identifiable fish elements. Taxa have been identified primarily utilizing vertebral morphology following recent studies in the Campanian Dinosaur Park Formation of Alberta. A varied fauna is also present in Hell Creek time, as evidenced by vertebral centra of a hiodontid, at least two types of acanthomorphs, two distinct but unidentified teleosts, likely representatives of the Salmoniformes, Esocoidea, and Osteoglossomorpha, and a possible ichthyodectiform.

The vast majority of taxa and specimens continue to support the established interpretation of the Hell Creek environment as a low energy, fresh-water fluvial system; amiids and lepisosteids remain the two most common fish by a significant margin. Exceptions include phyllodontid elopomorphs, salmoniforms, and ichthyodectiforms, which may have periodically penetrated rivers from adjacent brackish and marine realms. Modern dasyatids, hiodontids, and salmoniforms typically require swift, cold or well-circulated waters, and were also likely rare visitors to the lowland Hell Creek waterways. Recovered elements from these rare taxa were likely washed in from upland areas. Evidence of hiodontids and salmoniformes in the Maastrichtian verifies their continued presence in the Western Interior of North America. Several other distinct but presently unidentifiable teleosts hint at further fish diversity within the Hell Creek Formation.

NEW INFORMATION ON THE GENERA *PTERODACTYLUS* AND *GERMANODACTYLUS* FROM THE SOLNHOFEN LIMESTONE OF SOUTHERN GERMANY

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Seven years ago, I showed that the Solnhofen Limestone's pterosaur fauna was biased toward preservation of juveniles, and that juvenile pterodactyloids were classed in various species of *Pterodactylus*, whereas most adults were classed in other genera. I suggested that *P. antiquus*, *P. kochi*, *P. longicollum*, *Germanodactylus cristatus*, and *G. rhamphastinus* represented juveniles and adults of 2 or 3 biological species: a long-necked species consisting of *P. longicollum* and some or all juveniles assigned to *P. antiquus* and *P. kochi*; and 1 or 2 short-necked species consisting of *G. cristatus* and/or *G. rhamphastinus* and perhaps some juveniles assigned to *P. kochi*. However, measurement data suggesting that *P. antiquus* and *P. kochi* differed significantly in growth trajectories, differences in dentition, and the edentulous jaw tips of *G. cristatus* argued against such lumping. Recent work on Solnhofen pterodactyloids has led to the identification of: 1) a mature specimen of *P. antiquus* with a premaxillary crest and many more teeth than *P. longicollum*; 2) measurement errors that produced the apparent differences in growth trajectory between *P. antiquus* and *P. kochi*; and 3) juvenile specimens of *G. cristatus* with edentulous jaw tips that had been referred to *Pterodactylus* species. It is now clear that adults of *P. antiquus* had a premaxillary crest, and that most specimens assigned to *P. kochi* pertain to *P. antiquus*. *Pterodactylus longicollum* is distinct from *P. antiquus* because of differences in dentition and proportions, and present taxonomic usage would place it in a separate genus. Juveniles and adults of *G. cristatus* had edentulous jaw tips and differ from *P. antiquus* in proportions. *Germanodactylus rhamphastinus* is distinct from *G. cristatus* because it lacks edentulous jaw tips, but the two species have similar dentition and proportions and seem to be congeneric. No juveniles of either *G. rhamphastinus* or *P. longicollum* have been identified.

THE EXTENT OF PRESERVATION OF BRACHYLOPHOSAUR BONES FROM THE JUDITH RIVER FORMATION, MALTA, MONTANA

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A bonebed consisting of 1000+ *Brachylophosaur* elements was deposited in a distributary channel in the Judith River Formation near Malta, Montana. The exterior of the bones is unusually well-preserved; and exhibit little or no sediment infilling. Previous taphonomic data suggest transport and burial of these elements within 5 years of death.

The quality and extent of preservation of bone is primarily controlled by the biological, chemical, and physical environment of deposition and diagenesis of the bone and surrounding sandstones. Petrographic analysis of the sandstone surrounding the bones has revealed varying geochemical environments that affect the quality of preservation. Early calcite cemented concretions contain floating grains, spherulitic and euhedral calcite, and surround bones demonstrating exceptional preservation. Clay and iron oxide cemented sandstones with long grain contacts encase bones that are less well preserved. The varying geochemical environments have resulted in differential preservation of the bones.

SYSTEMATICS AND EVOLUTION OF THE MYSTICETI

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Although mysticetes are the largest animals on earth they are among the least understood in terms of their phylogenetic interrelationships. Preliminary results of a collaborative study of mysticete phylogeny are presented. Our species level "total evidence" phylogenetic analysis of the Mysticeti, using a combination of over 60 morphological characters together with more than 600 phylogenetically informative molecular characters (mitochrondrial, nuclear, and amino acid sequences) supports a monophyletic Mysticeti, sister group to Odontoceti. Toothed mysticetes include the stem taxon Mammalodon and the aetiocetids. The earliest known baleen bearing eomysticetids are sister taxon to later mysticetes. Some resolu-

tion among the paraphyletic 'cetotheres' is indicated. Extant mysticetes are divided into two clades: Eschrichtiidae + Balaenopteridae and Balaenidae + Neobalaenidae. In several equally parsimonious trees based on molecular data *Eschrictius* is placed within the balaenopterids. *Caperea* is positioned as sister taxon to balaenids, an arrangement that is supported by some molecular data.

This phylogenetic framework is then used to optimize two key functional morphologic adaptations of mysticetes important in their ecological diversification. Evolution of the forelimb involves transition from a fully mobile propulsive limb to a rigid limb used for steering. Important events include loss of elbow mobility (e.g., division between radial and ulnar surfaces of distal humerus) at the time of divergence of mysticetes and odontocetes from basilosaurid archaeocetes. Loss of manus mobility (e.g., absence of bony phalangeal epiphyses) likely occurred at the base of mysticete evolution and reduction in number of digits even later among balaenopterids, neobalaenids and eschrichtiids. Evolution of the unique filter-feeding specialization in mysticetes involves a transition from toothed to baleen bearing species. Among the major feeding types in baleen bearing taxa (skimming, engulfment, and benthic suction) an intermediate filter feeding stage, 'gulping', is the most likely ancestral feeding mode inferred for some 'cetotheres'.

HINGED EMYDINE TURTLES IN NORTH AMERICA: READING THE RECORD

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Interest in the fossil record of hinged emydines recently increased following the publication of molecular-based phylogenies suggesting the distribution of plastral hinges among living emydine turtles are the result of multiple, independent evolutionary transformations. A turtle collected from the Miocene June Quarry, Brown County, Nebraska is one of the earliest known emydines exhibiting plastral kinesis. The specimen includes approximately the anterior three-quarters of an articulated carapace and a poorly-hinged plastron. A partially articulated skull is visible within the shell. The specimen was CT scanned and prepared digitally. Digital removal of the shell reveals that most of the cranial elements are present, as are the rarely recovered hyoid apparatus and portions of the pectoral girdle and forelimbs. The preservation of the skull presents a unique opportunity to assess cranial and shell characters simultaneously for a mid-Tertiary hinged emydine, and to place these data in a broader phylogenetic context. The systematic and taxonomic position of our specimen is problematic and illustrates the need for a reappraisal of emydid morphological characters in light of competing phylogenetic hypotheses.

More importantly, our efforts to place this specimen into a broader context of emydid evolution emphasize a renewed concern about the disparity between historical and modern approaches to the taxonomic allocation of fossils. In many modern studies, taxonomic allocations are based on synapomorphy, independent of temporal and geographic assumptions about past distributions of taxa. This is a relatively new approach in our discipline, and in some cases, little effort is being made to critically reevaluate prior taxonomic designations made under different methodological and philosophical approaches. The resulting complications include 1) inappropriate comparisons of distantly related forms whose only shared feature is their generic allocation; 2) a false perception of clarity; 3) perpetuation of misleading data regarding the distribution of taxa through space and time; 4) an inadequate understanding of evolutionary dynamics.

ANALYSES OF MODERN SEA TURTLE HUMERI SUGGEST RESPIRATORY EFFECTS ON CARBON ISOTOPE COMPOSITIONS OF BIOGENIC STRUCTURAL CARBONATE

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Analyses of extant marine turtle humeri indicate that diet is the primary influence on the carbon isotopic composition of sea turtle bone carbonate. However, secondary physiological and geographical factors, such as foraging locality, migratory range, and respiratory physiology also influence carbon isotope values of biogenic structural carbonate. The difference in carbon isotope compositions between diet and bone structural carbonate is consistently smaller in the deep-diving leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys olivacea*) turtles than in the shallow-diving green turtle (*Chelonia mydas*). During breath-hold dives by sea turtles, CO_2 accumulates in the body as oxygen is consumed and intracardiac shunting favors greater accumulation of CO_2 in body fluids than in lung gas. The predominant form of CO_2 in blood is bicarbonate (HCO_3^-. It has been suggested that as blood circulates, blood bicarbonate exchanges slowly with bone carbonate, although rapid exchange may occur during metabolic acidosis. Because respired CO_2 is ^{13}C-depleted, the more respired CO_2 accumulated in the blood, and therefore, the more respired CO_2 incorporated into an animals bone carbonate, the lower the bone carbonate $\delta^{13}C$ values should be. The data supports the hypothesis that respiratory effects are evident in delta ^{13}C values because deep-divers incorporate more respired CO_2 into their bone carbonate during extended dives, which should reduce the offset between diet $\delta^{13}C$ and bone carbonate $\delta^{13}C$. Preliminary analyses of collagen and muscle tissue do not show evidence of respiratory effects on their carbon isotope compositions.

THE RECONSTRUCTION OF THREE ANKYLOSARIDS FROM THE CEDAR MOUNTAIN FORMATION OF EASTERN UTAH

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Three ankylosaurid skulls were reconstructed at the College of Eastern Utah in Price. Missing bones were mirror-imaged when possible. Papers and replicas of other nodosaurs and ankylosaurs were studied to determine how the missing bones should look and fit. The three reconstructed skulls are: *Animantarx ramaljonsi*, *Cedarpelta bilbeyhalorum*, and a new nodosaur.

The *Animantarx* skull was crushed. The posterior half from the ectopterygoid back was recovered. The length of the missing snout was determined by using the left mandible that was recovered at the same site. A mirror-image was made of the mandible to complete the lower jaw. The total length of the skull is 28 cm.

Cedarpelta was reconstructed using two skulls from the C.E.M. site. Skull 1 was recovered with the left side intact from the occipital condyle to the ectopterygoid including the brain case and the vomer. Both paraoccipital processes were missing. The right side was very fragmented. The right maxilla was recovered. The teeth were all broken off but the mandible contained two unerupted teeth and a single complete tooth was dicovered. Skull 2 was disarticulated over a two square meter area. Mirror-images of the mandible, premax, quadrate, and surangular were made to aid in the reconstruction. The skull bones of both skulls showed sutures indicating they were not fully mature. The total length of the reconstructed skull is 50 cm.

The new nodosaur skull was disarticulated but the bones were close together with the exception of the premax and the left surangular. The posterior half of the skull was complete with the exception of the right pterygoid and both paraoccipital processes. Some crushing had occurred during the fossilization process. One small section of the maxilla was recovered with one complete tooth. We estimated the maxillae to have 14 teeth each, and the total length of the reconstructed skull to be 60 cm.

NESTING TRACES OF SEA TURTLES: A RETROSPECTIVE PERSPECTIVE

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Body fossils of sea turtles are present in rocks dating back through the Cretaceous; traces of nesting activities of sea turtles ought to have a similar range. Recent loggerhead sea-turtle nests have been extensively studied on St. Catherines Island, GA. Study and documentation of over 1450 nests and associated crawlways, and detailed trenching of more than 50 of these, has led to a three-dimensional model of modern sea-turtle nests and the description of the sedimentary structures associated with nesting of the species *Caretta caretta* Linnaeus, 1758. The sedimentary structures studied present a recognizable spectrum of preservable traces dictated by a nesting ethogram consisting of nine described steps; 1) approach to the beach, 2) ascent of the beach, 3) wandering the beach, 4) wallowing to damp sand, 5) digging an egg chamber, 6) depositing eggs, 7) backfilling egg chamber, 8) covering activity, and 9) crawling to the sea. Loggerhead nest structures are elliptical with surface bioturbation masking underlying nest structures consisting of a body pit and egg chamber. Crawlways made during entering and leaving the nest, the thin veneer of bioturbated sand produced in the covering activity, and the underlying body pit and egg chamber are capable of preservation in ancient rocks. Successful incubation of sea turtle eggs could result in hatchling stopes, emergence craters, and fan-shaped patterns of hatchling crawlways; depredation of nests should result in recognizable sedimentary structures.

The lack of recognition of ancient sea-turtle nests may be partly due to the lack of description of Recent nests. The spectrum of potential nesting structures is obfuscated by the spatial constraints of differing viewpoints of biologists and geologists; the horizontal view of beach structures normally observed by biologists must be set in contrast to the vertical orientation of geologic information of geologists.

This spectrum of potential sedimentary structures and disparate viewpoints has been partly validated, and is illustrated by the Cretaceous sea-turtle nest described from the Fox Hills Formation of Colorado.

PHYLOGENETIC AUTOCORRELATION IN BODY WEIGHT OF THEROPOD DINOSAURS

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Recent developments in the analysis of comparative data in evolutionary biology indicate that it is possible to partition the total variance of a quantitative character into a phylogenetic component, containing the part of the variation attributed to common ancestry, and a specific component, resulting from independent evolution after cladogenesis. In this study, the variation in body mass across 31 genera of theropod dinosaurs was analyzed using phylogenetic autocorrelation and autoregressive models to evaluate evolutionary constraints and test adaptive effects on morphology. The phylogenetic autocorrelation analysis was performed with the Moran's I coefficient, and a phylogenetic correlogram with five distance classes were constructed, using the COMPARE v4.4 software. The resultant coefficients indicate positive autocorrelation in the former distance classes, with monotonic decreasing from the second class until the last and negatively correlated one. The estimated autoregressive coefficient (rho) was equal to 0.11, indicating that less than 2 per cent of the variation in body mass can be attributed to inertial phylogenetic effects. This low value of rho supports the hypothesis of few evolutionary constraints in diversification of theropod body weight and reveals the importance of adaptive trends in the phylogenetic history of this group.

NEW SKELETONS OF PALEOCENE-EOCENE MICROMOMYIDS (MAMMALIA, PRIMATES): FUNCTIONAL MORPHOLOGY AND IMPLICATIONS FOR EUARCHONTAN RELATIONSHIPS

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New skeletons of two micromomyids from late Clarkforkian (Cf3) and early Wasatchian (Wa1) limestones from the Clarks Fork Basin, Wyoming, have recently been discovered. They are the most complete micromomyid skeletons known and have well-documented associations that allow for a better understanding of micromomyid morphology and positional behavior than previously possible. While micromomyids are notably smaller than most other plesiadapiforms (ca. 30-40 g), they have many postcranial similarities to plesiadapids, carpolestids, and paromomyids that suggest that they were committed arborealists adapted for locomotion on large diameter supports, similar to extant claw-climbing callitrichids. They differ from all other plesiadapiforms in having a radius with a strong dorsal ridge on the distal end, and a large area for insertion of the pronator teres at the midshaft; a fibula with a wide proximal end; and an astragalus with a large groove for the tendon of mm. flexor fibularis. This suggests that micromomyids were capable of suspensory behaviors associated with locomotion on the undersides of small diameter branches, similar to those of extant arboreal tree shrews, dermopterans, and bats. Micromomyids differ from dermopterans in having shorter manual than pedal phalanges, shorter metacarpals than metatarsals, and intermediate phalanges shorter than proximal phalanges. These features, together with comparative morphometric analyses of long bones and vertebrae, indicate that micromomyids were not mitten gliders, as previously suggested. Phylogenetic analyses indicate that micromomyids are the sister group to a clade that includes paromomyids, plesiadapoids, and Euprimates and are the most primitive known plesiadapiform primates for which the postcranial skeleton is known. Postcranial similarities between the Paleocene nyctitheriid insectivore *Leptacodon*, the extant tree shrew *Ptilocercus*, and micromomyids indicate that the ancestral euarchontan might be best characterized as a small-bodied arborealist most similar to *Ptilocercus* in its foraging ecology, perhaps derived from a more primitive *Leptacodon*-like scansorial form.

PATTERNS OF DIVERSITY IN PLIOCENE AND PLEISTOCENE BOVIDS FROM THE TURKANA BASIN, KENYA AND ETHIOPIA

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The Turkana Basin of Kenya and Ethiopia provides one of the most continuous and abundant records of Pliocene and Pleistocene fossil mammals in the world. Separate field projects in various parts of the Turkana Basin over the last few decades have produced distinct and often independent samples of the fossil fauna. Here we present new results based on an integration of the data from all Plio-Pleistocene localities in the basin. The newly created Turkana Basin Paleontology Database documents each fossil mammal from the basin, and now has 22,363 fossil bovid specimens. We present abundance data on the family Bovidae, and analyze patterns of biodiversity and turnover from 4 to 1 million years ago. Our results indicate that bovid tribes show distinct patterns of abundance over time in different parts of the basin (Omo, West Turkana, East Turkana). The abundance of bovids indicative of open and seasonally arid environments (Alcelaphini, Antilopini, and Hippotragini) is consistently and significantly higher in West Turkana localities than in the Omo localities. These differences indicate environmental differentiation between marginal and axial regions of the basin. The first and last occurrence data show multiple peaks of turnover; the most significant peak takes place after 2 million years ago, and coincides with a climax in species richness. The Turkana Basin fossil bovids illustrate intrabasin variability in faunal change and overall trends in relation to global climate and regional tectonics.

THE IMPLICATIONS OF PLEISTOCENE (RANCHOLABREAN) PLUVIAL LAKE SYSTEMS ON THE PALEOECOLOGY AND PALEOBIOGEOGRAPHY OF *CANIS DIRUS* (MAMMALIA: CARNIVORA) IN THE GREAT BASIN, UNITED STATES

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The absence of *Canis dirus* in the paleontological record for the hydrologic Great Basin has to this point been an enigma. One hypothesis to explain their absense is the spatial limitations of habitat in the Great Basin during the Rancholabrean. The pluvial lakes Lahontan and Bonneville drastically minimized the available terrestrial habitat. *Canis dirus* is believed to have occupied a similar ecological niche to that currenty held by the hyenas of Africa. Therefore, they would have required a large home territory to provide sufficient primary and scavengeable prey. Evidence of insufficient resources would be supported by a lack of, or reduction in, other obligate carnivores, as well as their prey. There have been *Smilodon* and *Panthera atrox* occurrences in the Basin but their occurrences are rare and tend to be from the latest Rancholabrean. The available terrestrial habitat could have provided a seasonal home for migrating ungulates and proboscideans. This very well could have sustained felid populations that would have followed the herds. The presence of *C. lupus* and *C. latrans* from the Great Basin are consistent with a year round prey population of small-bodied ungulates, rodents, and lagomorphs.

Two assumptions will be addressed in this study. First, the Sierra Nevada and the Wasatch limited migration of carnivore populations from outside of the Great Basin. Second, *Canis dirus* conformed to modern carnivore ecological requirements. If these assumptions are confirmed, the primary hypothesis that the Great Basin did not have sufficient resources to maintain a population of *Canis dirus* would be supported.

GIANTS TIE IN ARMS RACE: GEOMETRIC SIMILARITY IN SAUROPOD DINOSAUR AND WHALE HUMERUS GROWTH

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It has long been recognized that the limb bones of sauropod dinosaurs and cetaceans have spongy but solid interiors with roughened epiphyseal surfaces presumably capped by thick cartilage. However, the presence of "cetacean" features in sauropod long bones contradicts trends in other large terrestrial dinosaurs and mammals. Remarkably, the humerus of sauropods and cetaceans retains a simplified, "dumb-bell" profile in juveniles and adults. Retention of a "dumb-bell" humerus in cetaceans appears to be correlated with reduced endochondral bone remodeling and the predominance of appositional, periosteal growth. This pattern of growth may also be correlated with the rugose surfaces of cetacean epiphyses: because the humerus is not significantly remodeled during development, the epiphyses are never completely smooth. Could a similar growth mechanism have been present in sauropod dinosaur humeri as well?

Linear regression of humeral dimensions against maximum humerus length should result in an isometric or near-isometric slope if geometric similarity is retained throughout ontogeny. Cetacean and sauropod humeri were measured and their slopes compared to a null hypothesis of isometry (i.e., slope = 1.0; error = 0.05). Results of linear regression show that the humeri of three neosauropods (*Apatosaurus*, *Diplodocus*, *Camarasaurus*) and cetaceans have isometric (or near-isometric) ontogeny, in contrast to positive allometric trends in *Alligator* or other dinosaur humeri. By comparison with cetaceans, the isometric ontogeny reported for sauropod humeri would correlate with predominantly appositional, periosteal growth. Such a growth pattern has significant implications for the physiological and functional interpretation of sauropod long bone histology. These results would explain the geometric similarity of juvenile and adult sauropod humeri, the predominance of primary fibrolamellar bone throughout ontogeny in sauropods, and suggest that the roughened epiphyses of sauropod humeri resulted from reduced remodeling during ontogeny.

NEW EARLY PALEOGENE FAUNAS AND MAGNETOSTRATIGRAPHY FROM INNER MONGOLIA: IMPROVED CONSTRAINTS ON INTERCONTINENTAL BIOCHRONOLOGIC CORRELATION

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Early Paleogene fossil localities in Inner Mongolia, China, provide the framework for several Early Paleogene biostratigraphic units recognized throughout Asia, and as such are key to understanding the evolution of Asian mammal faunas through time. In turn, the temporal relationships between the Asian faunal sequence and those on other continents provide a critical constraint on models for the origination and dispersal of major mammalian taxonomic groups in the Early Paleogene. To improve our understanding of the temporal correlation of the record from Inner Mongolia relative to other records from Asia and beyond, we sampled 4 fossil-bearing stratigraphic sections in the Erlian Basin for magnetostratigraphic analysis.

Lacustrine and pedogenic mudstones, siltstones, and sandy siltstones from the Erlian Basin exhibit moderately stable demagnetization behavior and carry multiple components of magnetization. A characteristic component, removed between 250 and 540° C, exhibits two, antipodal directions, and is interpreted as depositional remanent magnetization. At 3 localities, our pilot data suggest that strata bearing fossils characteristic of the Gashatan Asian Land Mammal Age (ALMA) were deposited during a reversed-polarity interval. At one locality, Huheboerhe, new specimens of *Gomphos elkema*, indicative of the Bumbanian ALMA, were found ca. 15 m above the Gashatan level. Within the resolution of our sampling, these Bumbanian fossils occur within the same reversed-polarity interval as the Gashatan fossils. Gashatan-age fossils have previously been observed in association with the Chron C25N/24R reversal, ca. 700 ky before the Paleocene/Eocene boundary. Our new findings suggest that the Gashatan extends into Chron C24R, perhaps to within several hundred thousand years of the Paleocene-Eocene boundary. This implies that many Gashatan faunas are correlative with North American Clarkforkian and European Thanetian-age faunas, with which they share compositional affinities.

THE HOLE TRUTH: INVESTIGATING THE PRESENCE OF OBTURATOR FORAMINA IN THE ISCHIA OF *EDMONTOSAURUS ANNECTENS*

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The presence of a completely enclosed obturator foramen as opposed to an open obturator notch in the ischia of hadrosaurids is believed by many to be an indicator of advanced age . To test this hypothesis, twenty-eight ischia collected from a single locality and belonging to the hadrosaurine *Edmontosaurus annectens* were examined. The presence of a complete obturator foramen was only observed in five of these specimens, but two of these belonged to individuals of juvenile to sub-adult size. One of these ischia exhibited two obturator foramina, one of average size and location and a second, smaller obturator foramen directly anterior to it. The other twenty-three ischia exhibited the more common obturator notch. The area surrounding the obturator notch on these ischia was carefully cleaned and studied. Exposed internal bone structure was found on the tops of the elevated knobs on either side of each obturator notch, indicating this area had been damaged prior to burial. The size, shape and common occurance of this internal bone structure indicates that most if not all of these specimens had once displayed a completely enclosed obturator foramen. It was also noted that the area surrounding the obturator foramen was statistically the most likely area of the ischium to be damaged prior to deposition. However, larger specimens had thicker boarders enclosing the obtu-

rator foramen and these larger specimens usually displayed less damage to this area, allowing the obturator foramen to be recognized more easily. This thickening with age and the ensuing preservational bias is most likely the reason that obturator foramina are only thought to be present in individuals of advanced age. In summary, it is the observation of the authors that obturator foramina cannot be used to determine the relative age of a specimen. Also, the presence of an enclosed obturator foramen in a juvenile specimen of a lambeosaurine and a hadrosaurine, along with the high statistical probability of the area around the obturator foramen to be damaged, disqualifies its use as a taxonomic indicator.

COMPARATIVE ANATOMY OF THE PENTACODONTID *APHRONORUS ORIELI* (MAMMALIA: PANTOLESTA) FROM THE PALEOCENE OF THE WESTERN CRAZY MOUNTAINS BASIN, MONTANA

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Newly discovered, semi-articulated specimens of early Tiffanian *Aphronorus orieli*, recovered from limestone nodules of the Fort Union Fm., represent a new skull and the first postcrania known for the Pentacodontidae. Interpretations of new morphology are consistent with the hypothesis, based on dental features, that pentacodontids are closely related to the Pantolestidae. Postcranial similarities to the primitive palaeanodont, *Escavadodon zygus*, and cranial similarities to the metacheiromyid palaeanodont, *Palaeanodon*, may indicate affinities to these taxa as well.

A. orieli is similar to pantolestids in having a humerus with a deltopectoral crest that has a sharp distal end and a supinator crest that lacks a prominent proximal projection. It is similar to both pantolestids and *E. zygus* in having a humerus with a broad distal end and a shelf-like deltopectoral crest; an ulna that has a deep shaft with a strong lateral groove along its entire length; a tibia that is fused distally to the fibula, has a reduced medial malleolus, an anteriorly curved, mediolaterally flattened shaft, and a strong cnemial crest; and an astragalus with a grooved body and no astragalar foramen. Similarities to *E. zygus* include a humerus with a deltopectoral crest that ends at mid-shaft; a radius with an elliptical head and a distally flattened shaft with an arcuate line on the anteromedial aspect; and an astragalus with distinctly separate navicular and sustentacular facets. Cranial similarities to *Palaeanodon* include a petrosal with grooves for two lateral branches of the internal carotid artery on the promontorium and a completely ossified bulla including an entotympanic element but no basisphenoid component.

Additionally, *A. orieli* appears to share traits with lepticids, palaeoryctids and various carnivorans. We use cladistic analysis to evaluate the phylogenetic significance of these traits and address the hypothesis that pentacodontids are closely related to pantolestids and palaeanodonts.

A NON-MARINE VERTEBRATE ASSEMBLAGE FROM THE LATE CRETACEOUS (TURONIAN-CONIACIAN) CANADIAN HIGH ARCTIC

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An assemblage of non-marine vertebrates has been recovered from sedimentary rocks at the base of the Kanguk Shale on Axel Heiberg Island. $^{40}Ar/^{39}Ar$ radiometric age data on underlying basalts, magnetostratigraphic data, and ammonites and inoceramids from overlying sediments constrain the fossil assemblage to the Turonian-Coniacian interval. Sedimentology of the unit indicates deposition in a bay or estuary, although the vertebrate fauna suggests a fully fresh-water environment. New paleomagnetic data indicate that the fossil locality was at a paleolatitude of 71°N.

The assemblage includes fishes, turtles, champsosaurs, a plesiosaur, and a volant bird. Fish are represented by well-preserved but isolated elements of lepisosteids, amiids, and teleosts. Additional holostean-grade fish are indicated by isolated scales, although the identity and relationships of these fishes remain unknown. The turtle assemblage includes a trionychid and two primitive eucryptodires (one of unknown relationships and one of macrobaenid affinities). Champsosaurs are abundantly represented by isolated elements and articulated remains. Plesiosaurs are represented by isolated teeth, and an incomplete humerus indicates the presence of a bird.

Both a high abundance and diversity of ectothermic mesoreptiles and an ichthyofauna reminiscent of those found at lower latitude localities and are consistent with mounting evidence for extremely warm climates in the Arctic during Turonian-Coniacian times. The presence of a macrobaenid turtle indicates a connection to Asia.

DARWIN'S CONVERSION RECONSIDERED: THE *BEAGLE* VOYAGE AND FOSSIL VERTEBRATE SUCCESSION

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The prevailing view among historians of science holds that Charles Darwin only became a convinced transmutationist in the early spring of 1837, after his *Beagle* collections had been examined by Richard Owen and other British naturalists. With respect to the fossil vertebrate evidence, some historians believe that Darwin was incapable of seeing or understanding the transmutationist implications of his specimens without the help of expert naturalists. In contrast, I argue that Darwin clearly recognized the similarities between several of the fossil vertebrates he collected and some of the extant fauna of South America before he returned to Britain. These comparisons, recorded in his correspondence, his diary and his notebooks during the voyage, were the first instances of the phenomenon that Darwin later called the "law of the succession of types." Moreover, on the *Beagle*, Darwin was following a geological research agenda outlined in the second volume of Charles Lyell's *Principles of Geology*, which implies that paleontological data could provide an insight into the laws that govern the appearance of new species. Since Darwin claims in the *Origin of Species* that fossil vertebrate succession was one of the key lines of evidence that led him to question the permanence of species, it is likely that he was contemplating transmutation during the *Beagle* voyage. If so, historians of science need to reconsider both the role of Britain's expert naturalists and the importance of the fossil vertebrate evidence in the development of Darwin's ideas on transmutation.

RELICTS OF SOFT TISSUE AND OSTEOPHAGOUS FUNGI IN PARTIALLY OSSIFIED TENDONS OF *CERATOSAURUS* (THEROPODA, DINOSAURIA)

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Broad bands of osseous tissue are preserved along the lateral surfaces of the sacral neural spines of new specimens of *Ceratosaurus*. The bands are ossified tendons of epaxial muscles. Tendon fascia originate low on the spine and extend cranially and slightly dorsally before merging with the main tendon bundle which extends caudocranially as a band alongside the spines. This contrasts with the crisscrossed pattern of ossified rod-shaped tendons in ornithischians. Unusual muscle/tendon scars spines of dorsal vertebrae suggest that ossified tendons may have attached to dorsal, not just sacral vertebrae.

Thin sections of the tendon bundles in BYU 17550, a nearly complete pelvis, show dark fibrous bands that grade into immature haversian bone. Longitudinal sections of the dark bands reveal pinnate structures with parallel rows of lacunae. The lacunae represent tendonoblasts, which increase in size towards fully ossified tissue, as in modern ossified tendons, and mark the area of active tendon mineralization. A waveform or crimp pattern is exhibited in one fascicle indicating it was relaxed (unloaded) at the time of fossilization. Transverse sections of the same dark bands show nested bundles that may represent collagen fibers. Ossification of the tendon in this genus occurs relatively late in ontogeny as there is no evidence of ossified tendons in a three-quarters grown individual, NAMAL 2002-02-28. In a subadult, BYU 17550, the tendon was in the process of being replaced by haversian bone at the time of death whereas in a large individual, BYU 12893, the tendon is fully ossified.

In addition to tendons, well-preserved fungi with hyphae penetrating the bone are preserved in calcite-filled nutrient canals of the haversian bone. Fungal mycelia apparently follow the canals and obtain nutrients from organic components of the bone. Fungal fragments also occur in the unossified tendon.

CALIBRATION SENSITIVITY AND QUARTET DATING: SYSTEMATIC UNDER- AND OVERESTIMATION OF DIVERGENCE TIMES FROM MOLECULAR DATA

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Nucleotide sequence-based methods for estimating divergence time can be misled by problems with individual fossil data points used to calibrate molecular clocks. Several techniques have been developed to overcome one such problem: multiple substitutions per site will accumulate over time, leading to underestimates of rates of molecular evolution from increasingly old fossil calibration points. We applied one of these methods, quartet dating, to vertebrate clades with well-sampled fossil records in a phylogenetic framework. The method uses calibration points from two pairs of ingroup taxa to estimate evolutionary rates leading back to their last common ancestor. Application of a wide temporal range of calibration points for the same evolutionary event reveals extreme sensitivity to calibration choice—younger calibrations support young divergences, sometimes with confidence intervals that exclude known fossils older than the divergence estimate. Very young calibrations have to be at least doubled in age to "correct" this problem. Divergence time estimates grow progressively older as calibration point age increases, and the oldest calibrations support divergence estimates much older than the fossil record would predict. These can be as much as 800 percent older than estimates derived with younger calibration points, and some can be unreasonably old—for example, possibly extending the alligatorid-crocodylid split into the Ordovician. Similar patterns have been observed before and are usually explained away as the result of fossil calibration error; the generality of the phenomenon suggests that quartet dating does not overcome calibration choice sensitivity, and that the method may be overcompensating for silent substitutions when older calibration points are used. This may help explain the discrepancy between fossil and molecular estimates of divergence timing between extant mammal and bird orders—some molecular methods may systematically overestimate divergence times.

THE SEAMY SIDE OF MOLD MAKING: DESIGN CONSIDERATIONS FOR SMALL MULTI-PART MOLDS

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When creating multi-part molds, extreme care must be exercised in designing the mold and determining the nature and placement of seams. Important factors dictating mold design include casting material properties and casting technique, critical specimen morphology, specimen integrity and size. Different combinations of these factors require slight modifications to the basic mold-making technique. The goal of proper mold design is to produce dimensionally accurate and detailed casts efficiently while exposing the specimen to as little jeopardy as possible.

Small, simple two-part molds intended for the production of solid resin casts should have a planar parting surface with continuous or dual-function registrations (mold alignment plus resin confinement) and usually do not require a mother or shell mold. Somewhat larger

molds intended for producing laid-up hollow resin casts do not need planar parting surfaces, but do require especially strong part-to-part and mold-to-mother registrations. Trapezohedral or orthogonal registration marks provide better alignment than rounded ones. Special internal-part molds require interlocking registrations. Thick molds assure dimensional accuracy, but they are less flexible and fragile specimens can easily be damaged during demolding. Use of a low-durometer molding compound should be considered for very fragile specimens, however these soft mold compounds require more robust registrations. A well-executed cast should have a very thin flash or visible seam line. Excess flash should be removed, but the seam line should not be obscured or "smoothed" away.

Examples from UNSM's extensive mold collection, produced over a 25+ year period, illustrate the evolution of mold design in our laboratory. Some designs have been elegantly successful. Some designs are, mercifully, now extinct. All are instructive.

A NEW SLENDER-SNOUTED CROCODYLIFORM FROM THE UPPER CRETACEOUS MAEVARANO FORMATION, MADAGASCAR

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Several crocodyliforms from the Upper Cretaceous Maevarano Formation in the Mahajanga Basin of northwest Madagascar have been described and discussed in the 10 years since work began in the area as part of several joint SUNY Stony Brook/University of Antananarivo expeditions. The crocodyliform fauna is currently known to contain 7 taxa, including the bizarre, pug-nosed *Simosuchus* and the large, broad-snouted *Mahajangasuchus*.

We describe and discuss here the anatomy, phylogenetic relationships and biogeographic implications of a taxon that until recently was known only from fragmentary material. This presently unnamed form is best represented by the posterior portion of a skull and a complete mandible found in association with postcranial elements. The skull possesses a long, narrow snout, large antorbital and supratemporal fenestrae and a squamosal that extends far posteriorly as an elongated process.

The postcranial material consists of five anterior dorsal vertebrae, a scapula and a coracoid, two humeri, and assorted rib fragments. The vertebrae are procoelous and are fused with the neural arches. The humeri both exhibit typical sigmoidal curvature and well-developed deltopectoral crests. The scapula is less complete than the coracoid and only a central portion of a gracile blade is preserved, whereas the coracoid has a well-preserved region for articulation with the scapula and a less well-preserved contribution to the glenoid. Like the scapula, the remainder of the coracoid is gracile with little further lateral expansion.

The biogeographic implications, resulting from the analysis of the phylogenetic relationship of this taxon to other crocodyliforms, are considered along with previously proposed hypotheses using other Malagasy vertebrates.

ADDRESSING THE POTENTIAL FOR CRANIAL KINESIS IN *TYRANNOSAURUS REX*: A COMPARISON OF THE PALATE COMPLEXES OF *TYRANNOSAURUS REX* TO *VARANUS*

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Cranial kinesis, the movement of the skull elements relative to one another, is known in many taxa of Lepidosaura and Aves. Cranial kinesis has been proposed in *Tyrannosaurus rex*, but much of the discussion has been speculative, and without comparison to extant taxa with kinetic skulls.

The possibility of kinesis in the skull of *T. rex* may be examined via the articulations of the bones of the palate, which is involved in many forms of cranial kinesis. The individual palate bones of the *T. rex* skull BHI-3033 and their points of articulation are directly compared to the corresponding palate bones in a *Varanus* skull, as the monitor displays a high degree of cranial kinesis. Based on preliminary observations, the loose nature of the articulations of the vomer, palatine, ectopterygoid, and epipterygoid to the pterygoid, and the similarity of these articulations in *Varanus,* suggests that the possibility for cranial kinesis exists in *T. rex*.

It has been previously interpreted that the skull of *T. rex* is stable as an akinetic unit. Kinesis may have been used for shock absorption to compensate for the large bite force in *T. rex*. As the degree of kinesis is not yet known in *T. rex*, the question remains whether kinesis was used in feeding, as in extant taxa. These preliminary results are part of a ongoing investigation into the kinetic potential of the skull of *T. rex*.

A BITE OF SQUAMATE DENTAL HISTOLOGY: TOOTH ATTACHMENT CATEGORIES AND CHARACTERS

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Most squamates are considered acrodont, where teeth are attached by bone of attachment to the crest of the tooth-bearing bone, or pleurodont, where teeth are attached by bone of attachment to the pleura of the tooth-bearing bone. The discovery of "thecodont" tooth attachment tissues in "acrodont" and "pleurodont" squamates necessitated a review of the conventional tooth attachment categories and their usage as characters in phylogenetic analyses of Squamata; thecodonty is the condition where teeth are attached by ligaments to the walls of bony sockets in the tooth-bearing bone. Tooth attachment tissues were identified for 34 extant and 2 extinct squamate species. The extant specimens were processed, sliced and stained (Gabe's Gomori's Trichrome) using conventional histologic methods. The fossil material was sliced, mounted and ground manually to produce sections for transmitted light microscopy. The examined squamate dentitions were attached to the tooth bearing bone by various amounts of cement, periodontal ligament and alveolar bone. An evaluation of tooth attachment characters in published cladistic analyses of Squamata was conducted and new tooth attachment characters generated in light of the histologic data.

REVISIONS TO THE SYSTEMATICS OF TYLOSAURINE MOSASAURS (REPTILIA: SQUAMATA)

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The Late Cretaceous mosasaur *Hainosaurus* is united with the genus *Tylosaurus* in the Subfamily Tylosaurinae based primarily on the presence of an elongate, toothless rostrum on the premaxilla. Two species of *Hainosaurus* are currently recognised: *H. bernardi* from the Maastrichtian of Belgium and *H. pembinensis* from the Campanian of Manitoba, Canada. While the anatomy of *Tylosaurus* species has been established from a number of exceptionally complete specimens, the anatomy of *Hainosaurus* species is relatively obscure, and their relationships within and without the Tylosaurinae are unclear.

An undescribed mosasaur from the Upper Campanian Bearpaw Formation of Saskatchewan presents new data relevant to this investigation. A toothless premaxillary rostrum clearly identifies this specimen as a tylosaurine, and the specimen's overall size suggests placement in *Hainosaurus*. A quadrate with robust processes and a large, concave tympanic ala, a prefrontal which does not contact the narial margin, and other skull features suggest placement in *Tylosaurus*. Examination of the type material of *H. bernardi* and *H. pembinensis* shows that several features previously used to classify *Hainosaurus* are held in common with *Tylosaurus*. The characters used to distinguish tylosaurines are reviewed in light of this new information, and a preliminary phylogeny of these mosasaurs is proposed.

GIS DATABASE DEVELOPMENT AT THE MIOCENE FOSSIL SITE IN GRAY, TENNESSEE

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A Geographic Information System (GIS) provides a powerful tool for the mapping, analysis, and display of spatial data. As a result, GIS is becoming more prevalent in the discipline of paleontology with respect to the mapping and recording of fossils. In particular, a GIS database allows for the digital recording of any spatial information that may be useful for taphonomic analyses. Therefore, it is important to decide from the beginning just how the database will be developed, specifically what fields (categories) will be created.

Because GIS is relatively new to the paleontological discipline, a complete recipe for database development is at this time unavailable. The following are simply examples of categories that should be considered significant and it is expected that modifications will occur as work at the site progresses: Taxon(various divisions), element, side (left or right), age(juvenile or adult), weathering prior to fossilization, association (alone or part of a skeleton), location (X,Y,Z coordinates), and azimuth (orientation of long bones), etc. Initial studies such as this are vital to developing standardized methods of analyses.

STACKING CLADOGRAMS: A NEW METHOD TO MODEL TEMPORAL AND SISTER-GROUP RELATIONSHIPS OF FOSSILS

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The difficulty of modeling both temporal and sister-group relationships in phylogenetic studies has resulted in a clash between cladistic and biostratigraphic methologies in the study of paleontology. Methods of combining temporal and character data are of two fundamental types. Methods either convert temporal data into character data or compare the statistical fit of character data phylogenies with the observed temporal data. Although both methods are useful, I here describe a simple third way to model phylogenies by using multidimensional character matrixes. A case study was carried out on 20 species of *Hyopsodus* from North America in order to compare this method's reconstructed phylogeny to that of the the well documented stratigraphic record of the genus. The results of the analysis indicate a phylogeny that is very similar to previous studies that have relied on the stratigraphic record. Differences include the position of *H. minor* (which is debated stratigraphically), *H. wortmani*, *H. marshi* (a rare species with little stratigraphic range) and whether late Eocene species descended from *H. paulus* or from a common ancestor of *H. paulus* and *H. minusculus*. This study represents the first published cladogram of *Hyopsodus* species that was mathematically calculated from a matrix illustrating a similar stratigraphic pattern observed in the rock record. However, the new approach did not differ from results obtained by simple cladistic analysis using Wagner Optimization. This is believed to be the result of having only one time period where rapid diversification took place and long periods of sequential transitions between species (i.e the *Hyopsodus paulus* lineage). Superficially, a consequence of the inability to statistically verify ancestral-descendant relationships results in lineages depicted as sister-group relationships even when the resulting cladograms are temporally stacked. One way to illustrate ancestral-descendant relationships would be to drop branches that have zero branch length if the taxon matching the predicted morphology of the node is found to occur in older layers.

UNUSUAL PRESERVATION EVEN FOR A LIAONING BIRD

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Preservation of feathers and body outlines are well known in Early Cretaceous birds from Liaoning Province in China. The development of transfer preparation techniques for specimens from these deposits have revealed a new and unexpected type of preservation. The skeleton of a long-billed enantiornithine bird is shown to be surrounded by a body mold. This is reminiscent of the body molds surrounding human skeletons in the Pompeii ash fall. The bird specimen lay within a layer of white volcanic ash several millimeters thick overlain and underlain by dark, gray non-volcanic lake sediments. At the time of burial, the bird was com-

pletely embedded in volcanic ash. The inhalation of very fine ash may have contributed to the death of the bird by suffocation. Conceivably, ashfalls were deleterious to birds and may have caused the mass death assemblages found in the same deposits.

FOSSIL AND RECENT CENTRA OF CARCHARHINIFORM SHARKS: MORPHOLOGY AND PHYLOGENY

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Studies of Mesozoic and Cenozoic sharks have relied heavily on isolated fossil teeth. While abundant, teeth present well-documented difficulties that have led to many taxonomic problems, and these in turn cloud phylogenetic interpretations. Shark vertebral centra are well-calcified, regularly found as fossils, and character-rich, and show great potential as an additional and potentially more objective basis of generating data that can be used to compare fossil and extant taxa.

The external morphology and internal calcification patterns of fossil and recent shark centra of the Order Carcharhiniformes have been studied in detail in order to establish which features are most useful for systematic purposes. Carcharhiniform sharks were selected as a study group because they are a monophyletic clade with reasonably well understood intraordinal relationships, a rich fossil record, and readily available Recent comparative skeletal material.

External characteristics that are being evaluated and scored include centrum proportions (including positional and taxonomical variations), and the size, shape, and spacing of the foramina for the basidorsal and basiventral arch components. The internal calcification characteristics evaluated include the morphology and spacing of the four intermedialia, the four noncalcified areas, and the four diagonal calcifications, and also the degree of calcification of the intermedialia and diagonal calcifications.

This research enhances our understanding of the morphology and the taxonomic and phylogenetic utility of both Recent and fossil carcharhiniform shark centra, and it will allow for a more objective means of determining the interrelationships of fossil and extant carcharhiniform sharks. The data gathered will also be important for future studies to interpret the relationship between centrum morphology and swimming characteristics in extant and, ultimately, extinct taxa.

ON THE ORIGIN OF SNAKES

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The origin of snakes from within squamate reptiles is an excellent example of a major evolutionary transition. Investigating the origins of a major lineage, such as snakes, is problematic for the simple reason that the processes of macrevolutionary change produce major morphological differences between the studied lineage and its closest relative or sister clade. Snakes possess a number of squamate synapomorphies that strongly support their inclusion, and thus origin, within Squamata. However, snakes are also anatomically very distinct from lizards and within their own lineage have evolved a number of specialized/ autapomorphic anatomies; this degree of distinctiveness and specialization makes it difficult to interpret characters and hypothesize character states for use in subsequent phylogenetic analysis. In the absence of robust phylogenetic hypotheses the induction of origins scenarios is even more problematic. Despite the inherent difficulties of studying the evolutionary transitions leading to the origins of a major vertebrate lineage, there has been a resurgence of interest on the problem of snake phylogeny and origins. Anatomical features present in a variety of new fossil snakes and lizards have invigorated the debate and are reviewed here alongside new data obtained from the analysis of the anatomy and molecules of extant snakes and lizards. Recent hypotheses of snake ingroup and sistergroup relationships, and the origins scenarios they implicitly or explicitly support, are reviewed and contrasted. A first-level problem concerns the sister-group relationship of scolecophidian snakes. Are they a distinct clade of basal snakes, or are they derived snakes nested within a clade of higher snakes? All other sister-group relationships and origins hypotheses for snakes are dependent on the answer to this problem.

VERTEBRAL MORPHOLOGY VERSUS LOCOMOTION AND HABITAT USE IN CARNIVORA: TESTING CORRELATION AND PHYLOGENETIC CONSTRAINT

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Although predictions of fossil mammal locomotion and habitat often rely on craniodental and limb morphometrics, many workers advocate use of vertebral morphology as additional evidence. Others believe that at least some locomotor strategies can be predicted from vertebral morphology alone. In 1946, a landmark paper by E.J. Slijper summarized much of our knowledge of vertebral morphology and how it correlates with locomotion in select, often distantly related and highly specialized species. With the exception of primates, Slijper's hypotheses have not been tested within a phylogenetic paradigm to explore whether or not vertebral morphology can be used to accurately predict locomotion or habitat use among closely related forms that have different locomotor strategies. The Carnivora represents a clade of ca. 270 species that display wide variation and many examples of convergence with respect to locomotion and habitat use (e.g. phocid and lutrine hind limb swimming, binturong and red panda arboreality). We present preliminary results from a survey of 82 carnivoran species in an attempt to further evaluate the use of vertebral characteristics to predict locomotion and habitat. Standard measurements (centrum width, length, and height; spinous process and total vertebral heights; width across transverse processes) were taken from vertebrae of species with well documented life histories and subjected to principal component and discriminant function analyses. Our results indicate that although some locomotor strategies and habitats can clearly be predicted from vertebrae (e.g. hind- and forelimb swimming, semifossoriality), others appear to be less predictable and are not always reflected by consistent trends in vertebral morphology (e.g., among scansorial, arboreal, and terrestrial species). Moreover, additional data from a literature survey of vertebral formulae in a larger sample of carnivore species indicates that vertebral counts cannot be used to reliably predict locomotor strategies or habitat.

AN INEXPENSIVE MOLD/CAST PROCEDURE SUITABLE FOR ELEMENTARY STUDENTS

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St. Louis Community College, Meramec Campus, offers a two-week summer program ("College for Kids") to gifted elementary age students. Two 1.5 hour daily sessions called "Diggin' Dinosaurs" are offered as part of the program. One session is for grades 2 and 3 and the other for grades 4 and 5.

Students "find" their own dinosaur bone fragments and casts of dinosaur bones and teeth in a simple on-campus "dig" site. They then return to the lab to clean and prepare their specimens. Part of the session is devoted to simple molding and casting techniques using inexpensive materials available in local hardware stores. Casts of T-rex teeth and claws are very popular and the students embellish them with imaginative paint jobs.

PHYLOGENETICALLY TESTING THE HYPOTHESIS OF SECONDARY FLIGHTLESSNESS IN MANIRAPTORIFORMES

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Recently, some authors have hypothesized that certain clades within Maniraptoriformes are secondarily flightless, and thus may be more related to modern birds than *Archaeopteryx lithographica* is. However, no phylogenetic framework or methodology has yet been applied to this evolutionary scenario. The purpose of this study is to scientifically test the hypothesis of secondary flightlessness in maniraptoriform theropods by analyzing the appearance of characters necessary for flight in a phylogenetic context.

Using a methodological framework for phylogenetically testing functional hypotheses, I structurally and functionally defined the key adaptation central to the origin of avian flight, which is the origin of the flight stroke itself. Relevant flight characters were then described and divided into two tiers: those necessary for active flight (which are present in *Archaeopteryx*), and those necessary for advanced flight, such as an alula and elongate coracoid. After defining the relevant taxa, I analyzed the sequence of appearance of the necessary characters in birds and outgroups using recent theropod phylogenies, and tested this against the original hypothesis.

While recent findings show that many so-called "avian" features—including asymmetrical (aerodynamic) pennaceous feathers—did evolve before *Archaeopteryx*, I found no evidence for secondary flightlessness among non-avian maniraptoriform theropods. Rather, evolutionary convergence and exaptations for flight within this clade of dinosaurs seem to have been previously misinterpreted as evidence for secondary flightlessness due to an "anachronistic" fossil record and an absence of phylogenetic framework and methodology.

NEW INSIGHT INTO THE EVOLUTION OF TYRANNOSAUROID THEROPODS: "EVENT PAIR CRACKING" AND THE INTEGRATION OF ONTOGENETIC AND PHYLOGENETIC DATA IN PALEONTOLOGY

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Paleontologists often neglect the fact that extinct dinosaurs grew; evolutionary studies tend to focus on speciation patterns and extrinsic processes. This is partly because paleontologists face two challenges to comparative ontogenetic studies: 1) the absence of an independent metric of individual age for calibrating growth series and 2) the production of an explicit, phylogenetically constrained method for inferring intrinsic processes (e.g., heterochrony). Recognizing that the sequence of developmental events is unique to each species can solve the first problem. The quantitative method of "event pair cracking" allows identification of shifts in events between plesiomorphic and derived ontogenies. Recognizing that different levels of analysis can be used resolves the second problem. Therefore, fossil species that consist of only developmental extremes are amenable to the inference of intrinsic processes that underlie evolutionary transformations. The first analysis subjects entire growth series to the neontological method of "event pair cracking." The second involves pairwise sister- and outgroup comparison of the growth changes of phylogenetic characters between species.

Growth series of *Albertosaurus libratus* and *Tyrannosaurus rex* were reconstructed by subjecting qualitative morphological characters to cladistic analysis. "Event pair cracking" was used to compare the growth series of *A. libratus* and *T. rex*. Relative to *A. libratus*, the growth series of *T. rex* shows evidence of two events shifted early and two events shifted late. Four tyrannosaurid species (*Albertosaurus libratus*, *Daspletosaurus* sp., *T. bataar*, *T. rex*) share at least six homologous characters for which growth changes can be compared. The evolution of two characters show evidence of peramorphosis, three show paedomorphosis, and one displays isomorphosis.

The present study using tyrannosauroids illustrates the value of employing neontological approaches to propose defensible hypotheses of how evolutionary novelties in fossil taxa were actually produced developmentally, when such data are available.

THE EVOLUTIONARY HISTORY OF BASAL THEROPOD DINOSAURS

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Theropod phylogeny has received intense scrutiny over the past 15 years, but the interrelationships of non-coelurosaur taxa are comparatively poorly understood. Whereas coelurosaur phylogenies often include the most fragmentary forms, those dealing with more basal taxa tend to rely on species that are well known or of specific interest. The result is an

inability to place many incomplete but geographically and temporally important forms. This practice has also hindered attempts to thoroughly analyze patterns of evolution within this diverse dinosaur clade.

A three-year systematic study of basal theropods, involving first-hand examination of nearly all known taxa worldwide, has permitted a detailed analysis of historical relationships. Using a matrix of some 350 characters and nearly 70 taxa, the resultant phylogeny yields a remarkable degree of resolution, despite the inclusion of significantly fragmentary forms. Most major clades (Coelophysoidea, Ceratosauria, Spinosauroidea, Allosauroidea, Coelurosauria) are recovered, although support for some (e.g. Coelophysoidea) is surprisingly poor. Herrerasaurids and *Eoraptor* are supported as primitive theropods, but the latter weakly so. We also resolve over a dozen taxa as spinosauroids (including a clade of megalosaurs) and more than 15 as ceratosaurians.

This phylogenetic pattern clarifies numerous aspects of theropod evolution, many of which deserve further study. These include (1) convergent evolution of several trophic and locomotory features; (2) repeated size increases and decreases throughout the group; (3) complex patterns in the evolution of pneumatic characters; and (4) few robust biogeographic patterns among these basal forms. Finally, our results underscore the importance of including fragmentary taxa (especially for biogeographic hypotheses), verifying published observations, and examining undescribed and/or unnamed materials.

ORIGIN OF TERRESTRIAL LOCOMOTION IN VERTEBRATES

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One of the most important transitions in the history of vertebrates was their emergence onto land. Despite an informative fossil record, the selective advantage for the origin of terrestrial locomotion remains contentious. Evidence from a diversity of footprints from the basal Carboniferous of the Horton Bluff Formation, and from the anatomy of the pectoral and pelvic girdles of Upper Devonian amphibians shows the early achievement of terrestrial locomotion. Numerous trackways from the Tournaisian show that the digits of the fore- and hind limbs faced forward and that the body was raised above the substrate. The pace and stride are comparable to those of previously described Upper Carboniferous and Lower Permian trackways assumed to have been made by large quadrupedal vertebrates.

It has been argued that the Upper Devonian tetrapods *Acanthostega* and *Ichthyostega* were primitively aquatic and that tetrapod limbs evolved in an aquatic environment. This is difficult to reconcile with the large ventral expanse of the endochondral portion of both the pectoral and the pelvic girdles in these genera, which in modern tetrapods serves as the area of origin for the large pectoralis and puboischiofemoralis muscles that adduct and retract the limbs, and so lift the body above the ground and move it foreward. There is no adaptive reason for the presence of such extensive areas of muscle attachment in primitively aquatic vertebrates, whose body would be supported by the water. We suggest that the great expansion of the girdles in Upper Devonian genera and the elaboration of tetrapod limbs was associated with basking behaviour that would have enabled them to attain a high body temperature. Their bodies could have maintained a high metabolic rate while capturing prey in the water, as is the case for modern crocodiles, turtles, and semi-aquatic snakes and lizards. This is demonstrated by the well-documented rates of absorption of radiant heat from the sun and for heat loss in the water in ectotherms the size of early tetrapods.

THE EVOLUTION OF STINGRAYS (CHONDRICHTHYES: MYLIOBATIFORMES), WITH SPECIAL REFERENCE TO THE FRESHWATER STINGRAYS OF THE GREEN RIVER FORMATION OF WYOMING (EARLY EOCENE)

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The freshwater stingrays of Fossil Lake of the late Early Eocene Green River Formation of Wyoming are known from hundreds of specimens, the vast majority of which are of *Heliobatis radians*. A new genus and species of stingray known from 17 specimens is presented here. An extensive anatomical revision of the Green River stingrays has prompted us to examine the anatomy and relationships of stingrays in general. Our phylogenetic analysis of Myliobatiformes is the most comprehensive to date based on morphological characters, and our resulting phylogeny is at odds with previous studies. We present novel patterns of systematic relationships that permit us to discuss the biogeographic history of stingrays in Fossil Lake, re-evaluate the age and origin of the freshwater stingrays of South America (Potamotrygonidae), and discuss other pressing topics in stingray evolution. This research is part of a larger morphological study on the evolution of batoids, based on both living and fossil taxa, which also includes a revision of the Early Eocene rays of the Monte Bolca Formation (northeastern Italy).

LATE CRETACEOUS DINOSAURS FROM THE ANTARCTIC PENINSULA: REMNANT OR IMMIGRANT FAUNA?

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The Upper Cretaceous deposits of the James Ross Basin, Antarctic Peninsula, have grudgingly produced dinosaur specimens, which is not entirely surprising as these deposits a predominantly near shore marine deposits. The chronostratigraphic range of these dinosaurs is from earliest Santonian to the late Maastrichtian (i.e. Senonian). This dinosaur fauna consisted of an early Santonian, megalasaur-like, basal tetanuran theropod (based on a distal tibia), a Campanian, nodosaurid ankylosaur (partial skeleton) and an early Maastrichtian iguanodontid (femur), all from James Ross Island, plus an early Maastrichtian, hypsilophodontid ornithipod (partial skeleton) and a late Maastrichtian hadrosaur with additional late Maastrichtian theropod and possible ankylosaur material from Vega Island.

A prime question about this fauna is what is the origin of this fauna? Does it represent a long lasting remnant of a more cosmopolitan Gondwanan fauna or is it an immigrant fauna from one of the Gondwanan continents?

An examination of similarity values (S= 2xCommon taxa/ taxa in A + taxa in B) between the Antarctic dinosaur fauna and dinosaur faunas from other areas at different times in the Cretaceous (early middle and late = Neocomian, Gallic and Senonian respectively) demonstrates that the greatest similarity to the Antarctic fauna is the Gallic-aged fauna from Australia (S=72.7%). The corresponding Senonian fauna from nearby Argentina is only 36.4% in similarity to the Antarctic fauna, yet this same Argentinean fauna is more similar to the Indo-Madagascar fauna (S=54.5%), which is attached to Antarctica on the other side of the Weddell Sea. Both the Antarctic and the Australian dinosaur faunas share taxa, basal tetanuran theropods, nodosaurid ankylosaurs, iguanodontids an, hypsilophodontids, which are cosmopolitan taxa, that were well represented in Laurasia during the early and mid-Cretaceous. Surprisingly, Antarctica and Australia lack titanosaurid sauropods and abelisauroid theropods present in South America and Indo-Madagascar, while that later two Gondwanan continents lack the nodosaurs and hypsilophodontids recovered in Antarctica and Australia.

MAGNETIC STRATIGRAPHY OF THE UPPER CRETACEOUS MAEVARANO FORMATION (CAMPANIAN(?)-MAASTRICHTIAN), NORTHWESTERN MADAGASCAR

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The Maevarano Formation (Mahajanga Basin, Madagascar) is well known for its assemblage of fossil vertebrates, including fishes, frogs, turtles, snakes, crocodyliforms, dinosaurs, birds, and mammals. The unit is presently considered Campanian(?)-Maastrichtian based on correlation with portions of the marine Berivotra Formation, which yields foraminifera that are Maastrichtian in age. Here we report results of the first paleomagnetic study of the Maevarano Formation. Samples (n=24) were collected from all three members of the formation (Masorobe, Anembalemba, Miadana), and the Berivotra Formation, and analyzed using both AF (alternating field) and thermal demagnetization at the Institute for Rock Magnetism. The average spacing between sampled horizons is 4.4 m. Three analyses were conducted on each sample. The magnetic carrier was identified as magnetite except in the Masorobe Member, which contains both hematite and magnetite.

All samples derived from the Maevarano Formation are normal in polarity. Seven of the nine samples collected from the ~30 m thick Berivotra Formation are also normal in polarity. Only the top two samples in the Berivotra Formation, which are situated within a few meters of the overlying Betsiboka limestone and the Cretaceous-Tertiary boundary (as defined by independent biostratigraphic data), are reversed in polarity. Based on the position of the K-T boundary, the two samples with reversed polarity at the top of the Berivotra Formation are interpreted to represent Chron C29R. Underlying samples in both the Berivotra and Maevarano formations with normal polarity are interpreted to represent Chron C30N. This interpretation, which suggests that much of the section under scrutiny is younger than previously surmised, is consistent with the sedimentology and taphonomy of the study interval in that there are no indications of significant hiatus or erosion, and fossils are exquisitely preserved (indicative of rapid burial). Our results are somewhat contrary to a recent reappraisal of the biostratigraphy of the Berivotra Formation, and thus more sampling is planned, especially in lower parts of the section.

TEN YEARS OF ACCOMPLISHMENT AT THE BIG PIG DIG: AN IMPORTANT OLIGOCENE SITE, BADLANDS NATIONAL PARK, SOUTH DAKOTA

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Badlands National Park is one of the premiere sites of Eocene-Oligocene, White River faunas. The Park, located in southwestern South Dakota, contains extensive deposits of Eocene Chadron and Oligocene Brule Formations. The Orellan Big Pig Dig is located in the Lower Scenic Member, Brule Formation, with an approximate age of 33 Ma. In 1993, two Park visitors, Jim Carney and Steve Gassman, noticed several exposed fossil bones near Conata Road and are credited with discovering this enigmatic fossil site. After receiving a report of the find, two paleontology interns worked to collect the elements (later identified as a vertebral column and two femora of the rhino, *Subhyracodon* and skull and teeth elements of the entelodont *Archaeotherium*). As trenching continued around the exposed bones, they continued to find more specimens. Unable to continue the excavation unaided, the Park developed a partnership with the South Dakota School of Mines and Technology (SDSM&T). Later, test pits reveled the fossiliferous lens to cover an area of approximately 92 by 15 meters.

Since 1993, the research and education partnership between the Park and the SDSM&T has expanded into other areas within the Park. The Pig Dig provides invaluable work experience for SDSM&T students both in the field and the laboratory. Several research projects (including two theses and several senior research projects) have directly resulted from work at the site. The Park, in return, gains a valuable resource by having fossils collected and studied. This site also provides an opportunity for Park visitors to see on-going paleontological fieldwork thus generating much interest in the Parks vertebrate paleontological history. New

information from the large assemblage of animals found in this bone bed continues to present a broader picture of what life was like in the region during the early Oligocene. To date, over 6000 bones have been excavated representing eight species. Badlands National Park and SDSM&T are proud of the work that has been accomplished at this site over the last ten years and expect to continue this partnership far into the future.

RECREATING AN UPPER CRETACEOUS DINOSAUR ASSEMBLAGE WITH GIS SOFTWARE

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Preserving the record and register of fossils as they occur during quarry development is crucial for careful taphonomic studies. Using data from digital photographs and high-resolution GPS coordinates of the bones, we have recreated precise virtual maps of the distribution of all bones, bone fragments, ossified tendons and teeth from quarries in an extensive Upper Cretaceous (Lance Formation) bone bed in eastern Wyoming.

The bones are field prepared and photographed and GPS data are recorded *in situ*. The digital images of the bones are then stripped from their background using a "smart edge" feature in Paintshop Pro and converted to TIF files on a white background. The ArcMap module of ArcGIS 8.2 is used to georeference the TIF file of each bone with the GPS data. When the bones have been rectified, they can be imported into the ArcScene 3-D viewer and examined in three space.

Because of limitations in the number of independent images that can be simultaneously displayed in the ArcScene viewer, we have found it convenient to group the bones in clusters by year or by bone type or elevation in the quarry to develop larger georeferenced assemblages of bones that can be treated as single elements. This grouping allows us to display the data by bone type, species, or by distribution in vertical or horizontal space.

As a consequence of applying these techniques, virtually all of the data on location of the bones are preserved intact, and the assemblage can be visualized as it appeared in the ground. Additional data derived from subsequent and previous research on the site can easily be incorporated in the view. The finished views can be exported as image files for use in publications or for field reference. Further analysis can be facilitated by overlaying the bone assemblages with relevant sedimentological and stratigraphical information, greatly enhancing the reconstruction of events related to the bone deposit.

EARLY EOCENE PERISSODACTYLS FROM THE CENTRAL BIGHORN BASIN, WYOMING

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The Perissodactyla includes the Equidae (horses), Tapiridae (tapirs), Rhinocerotidae (rhinos), and their fossil relatives. Perissodactyls emerged in the early Eocene with the appearance of equids, tapiroids and brontotherioids. The diversity of this radiation has only recently become apparent: in western North America, early Eocene equids are represented by 6 genera (12 species), tapiroids by 3 genera (5 species), and brontotherioids by 1 genus (2 species). Many of these species are of biostratigraphic significance and have been used to define subzones of the Wasatchian (early Eocene) NALMA. This study examined approximately 6700 perissodactyl specimens collected from the lower Eocene strata of the central Bighorn Basin, WY. This dense sample was used to investigate the dispersal, evolution, and paleoecology of a large community of early perissodactyls. The bulk of this sample, collected by the USGS/Johns Hopkins expeditions from 1979 to the present, has not previously been studied in detail.

Equid specimens were assigned to 10 species, tapiroid specimens to 6 species, and brontotherioid specimens to 1 species. The biostratigraphic significance of several of these species is altered by this analysis. For example, *Arenahippus aemulor* and *Homogalax protapirinus* appear earlier in the central Bighorn Basin than elsewhere, while *Cardiolophus radinskyi* makes its first appearance later than expected. Several of the identified species were shown by this analysis to be segments of evolving lineages, including *A. grangeri/A. pernix/Eohippus angustidens* and *A. aemulor/A.* sp. nov. Species turnover is concentrated in a stratigraphic interval previously identified in the central Bighorn Basin as a significant faunal turnover event (Biohorizon B). This interval has been correlated with a sharp warming trend and is coincident with dwarfing in the most abundant equid and tapiroid lineages (*A. pernix* and *Homogalax* sp. nov.). There may also be some correlation between paleosol development and the distribution of specimen sizes within species, although further work is required.

DISTINCTIVE ACCUMULATIONS OF FOSSIL FISH DEBRIS IN THE MOENAVE FORMATION TELL A STORY OF LIFE AND DEATH IN A BIOTICALLY PRODUCTIVE, EARLY JURASSIC LAKE NEAR ST. GEORGE, UTAH

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Very distinctive fossil deposits in exceptional exposures of lacustrine sediments of the Whitmore Point Member of the Moenave Fm. in southern Utah reveal successive episodes of fish mortality. Abundant fish scales and bones from semionotid fishes have been found in highly unusual cylindrical concretions, flattened concretions, and in patchy, concentrated aggregations. These various types of skeletal concentrations indicate different taphonomic histories of fish carcasses in the lake. Most peculiar are the elongate cylindrical concretions (each ~6 cm in diameter and 1 to several m in length). The masses were initially interpreted as large coprolites, but mapping of *in situ* specimens revealed that they are laid out in parallel, equidistant lines. The more typical flat concretions have an irregular distribution, and their size, shape, and flattened profiles indicate that they contain whole or partial fish skeletons. Poorly cemented aggregations of fish debris are also present in the sediments. The concentrated fish debris is confined to specific intervals; 2 m of lake strata contain six layers that have significantly more fish debris than the intervening sediments. These concentrations suggest mass mortality and/or physical conditions that were optimal for fossilization. A layer containing numerous flat concretions records a mass fish kill that probably occurred over a relatively short time span. Rapid sedimentation after the mortality event would have prevented significant scavenging. In contrast, the cylindrical concretions and concentrated debris appear to represent events of mass or attritional fish death, where carcasses were exposed long enough to be disarticulated by scavengers and currents. The parallel arrangement of the cylindrical concretions suggests that they are cemented sedimentary structures that were formed by wave action. The concentrations of fish debris at this site indicate that the ancient Moenave lake was biotically productive and supported a sizable population of fish. The evidence for episodic fish mortality may reflect recurring unfavorable environmental conditions or natural physiological death after spawning.

NEW BASAL NEOCERATOPSIAN FROM THE LOWER TWO MEDICINE FORMATION OF MONTANA PROVIDES A LINK BETWEEN ASIAN AND NORTH AMERICAN TAXA

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The description of a new genus of basal Neoceratopsia (non-ceratopsid Ceratopsia) includes a unique combination of characters, some seen before only in Asian basal neoceratopsian taxa and some known only from North American forms. The referral of United States National Museum specimens formerly described as *Leptoceratops* sp. to the new genus augments the number of mixed characters.

Characters of the new genus include a fenestrated frill and premaxillary teeth, not described for any of the three known North American basal taxa, but found in Asian taxa including *Protoceratops*. Additional characters not found in other North American forms include the absence of a large gap between the basisphenoid processes and the basisphenoid contribution to the basioccipital tubera, and a short, ventrally angled edentulous portion of the maxilla.

The new genus also exhibits characters similar to those of other North American forms including everted basioccipital tubera, crest-shaped epijugals, and most importantly a tooth wear pattern including both vertical shear and a horizontal shelf or notch.

Previous cladistic analyses have not been able to demonstrate monophyly of basal neoceratopsians, but with the addition of this taxon as well as another new North American genus the current cladistic analysis of basal Neoceratopsia includes a strong Protoceratopsidae consisting of all basal taxa except for *Asiaceratops* (most likely due to lack of material) and *Archaeoceratops*. This clade is supported by at least 10 characters. The cladistic analysis indicates that the new genus is the sister group to Leptoceratopsinae, the clade comprised of the three other North American taxa and the Asian *Udanoceratops*.

A LIGHTWEIGHT ALTERNATIVE TO LARGE SILICONE BLOCK MOLDS

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Silicone block molds of large fossils can be very expensive and time consuming to construct. They may also be awkwardly heavy and suffer deformation under their own weight, thereby producing inaccurate casts. I describe a molding method using a putty-like thixotropic silicone for molds and thixotropic plastic for mother molds. Using these materials requires less preparation and de-molding time than the standard practice of pouring silicones. This method also reduces mold volume and mass thereby decreasing cost and risk of injury to personnel.

BULLETS, BOMBS, AND BONES: THE IMPACT OF 20TH CENTURY WARFARE ON FOSSIL VERTEBRATE COLLECTIONS

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The science of vertebrate paleontology is strongly collection-based. During the last century there increasingly emerged professional and technical concerns about the long-term conservation and curation of fossils. But with nearly 50 wars, the 20th century was also a period of unparalleled conflict. Vertebrate fossil collections suffered considerably during this time but the destruction and long-term damage are not well documented and most of what is known is anecdotal. WW II serves as a case study because virtually anything that can happen to a collection did happen during that conflict.

In the face of the human tragedy that war often entails, the preservation of fossil collections is a low societal priority. Through the efforts of individual or small groups of paleontologists, some collections in the theaters of conflict were spared. These actions ranged from individuals taking specimens and notes to their private residences to repeatedly moving entire collections from advancing battlefronts. In many cases, however, other factors played a decisive role in the fate of collections. Among these factors are military planning and objectives, political, social, and racial ideology, weapons technology, intentional destruction, individual and systematic looting, and historical contingencies. Collections also suffered from the loss of facilities and staff, loss of associated museum and research data, and long-term degradation of storage conditions.

Although the wartime looting and destruction of artwork and other cultural resources have been well studied, the loss of natural history collections in general and fossil collections in particular have received scant attention and is a fertile area for research. The reports of SVP members contained in the early issues of the society's *News Bulletin* are a very important account of the impacts of WW II on collections and bear examination by anyone wishing to pursue this topic. They offer chilling descriptions of the losses sustained by some museums

and as well as information on the fate of paleontologists. This contemporaneous historical record may be unique to our discipline.

NEW INSIGHTS INTO THE POSTCRANIAL SKELETON OF *ICHTHYOSTEGA*

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New specimens and examination of earlier-collected material has allowed a reassessment of key parts of the postcranial skeleton of the Devonian tetrapod *Ichthyostega*, including the forearm and carpus and the vertebral column. Humeri from subadult specimens show differences in ossification from the larger, previously figured specimens, including a shorter head, relatively larger pectoral crest and a very large 'canal b'. In these and larger specimens, radial and ulnar facets are widely separated as in *Acanthostega* suggesting a broader arc for the carpus than in earlier restorations. A newly recognised ulna, associated with a humerus, radius and other elements from a partially articulated adult, suggests that earlier reconstructions were based on an incomplete specimen and that the ulna was broader, flatter and more paddle-like than previously figured. The elongate radial facet is anteroventrally positioned in the new specimens. The suggested range of movement of the lower arm is limited but predominantly mesial-lateral. Several associated carpal elements show an ossified carpus as in *Tulerpeton* but unusual among early tetrapods generally. As in *Tulerpeton* it includes a large possible ulnare, an intermedium with a finished anterior edge and a few other probable carpals. However the presence of a metacarpal and its position suggests that as in *Tulerpeton*, the carpus of *Ichthyostega* contained fewer elements than those of later tetrapods. The posterolateral margin of the ulna has a long unfinished edge that together with a closely associated incomplete but cylindrical element suggests the presence of at least one digit associated directly with it as in Tulerpeton. Preliminary analysis of the vertebral column shows differentiation in the neural spines around the sacral region. This and the new forearm data suggest a more specialised form of locomotion than previously envisaged.

NEW SPECIMENS OF *DISSACUS* (MAMMALIA, MESONYCHIA) FROM PALETTE, SOUTHERN FRANCE, AND A CLADISTIC ANALYSIS OF *DISSACUS* SPECIES

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Mammal remains recovered from Palette (southern France) include a number of well-preserved mesonychian specimens. These mammals are Neustrian in age and most likely contemporaneous with mesonychians found in Wasatchian faunas of North America. We report on new specimens of the mesonychian *Dissacus* from Palette including two very complete left dentaries, one right maxillary fragment with several teeth, and more than twenty isolated teeth. One specimen exhibits an extreme size reduction of M^3. Reduction and even loss of M^3 have been observed in other mesonychian genera but this extreme degree of tooth size reduction has not previously been observed in *Dissacus*.

Dissacus, which is known from the Paleocene and Eocene of Europe, Asia and North America, has been considered one of the oldest and most primitive mesonychians. It differs from other mesonychians in retaining a well-developed metaconid on all lower molars. Despite there being more than ten species in this genus, the interrelationships of these species have not been examined in detail until now. Without a phylogenetic hypothesis the biogeographic history of this widespread genus has also remained unclear, including such questions as whether species from the same continent are more closely related to each other than they are to species from other geographic areas.

We conducted a species-level cladistic analysis of *Dissacus*, which included the specimens from Palette as well as previously described specimens, in order to test the phylogenetic relationships within the genus. Differences among species of *Dissacus* are primarily subtle, continuous characters of the dentition and these were the primary source of cladistic characters. Many *Dissacus* species are extremely rare and known from such fragmentary remains, that the issue of missing data becomes central to any attempt to evaluate the evolutionary history of this clade.

THE SKELETAL KINEMATICS OF LUNG VENTILATION IN BIRDS

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The morphology and function of the avian respiratory system provides important comparative information with which to interpret the respiratory anatomy and function of extinct archosaurs. Detailed studies of the skeletal kinematics of bird lung ventilation, however, have not been made previously. As part of a project investigating the evolution of respiratory mechanisms in the Archosauria, the skeletal kinematics of breathing in Guinea fowl (*Numida meleagris*), as well as other birds, was examined by cineradiography.

Avian vertebrocostal joints are bicondylar, and limit the movement of each vertebral rib to a single axis of rotation. The anterior vertebral ribs of the thorax each articulate with a single, well-ossified sternal rib. Articulations between the vertebral and sternal ribs are monocondylar, but the joints with the sternum are bicondylar. Respiratory movement of the vertebral ribs in extant birds results in a relatively uniform lateral widening or narrowing of the thorax. During craniolateral movement of the vertebral ribs, the sternal ribs push the sternum ventrally. Due to the caudad increase in length of the sternal ribs, the largest amount of displacement of the sternum takes place caudoventrally. Uncinate processes on the vertebral ribs may provide a more beneficial moment arm for the intercostal musculature. Suprapubic muscles help ventilate the caudal trunk area by moving the pelvis and uropygium, a mechanism that does not appear to be homologous to crocodylian pubic aspiration.

Together with results obtained from cineradiographic investigation of crocodylian breathing, the information on avian respiratory skeletal kinematics provides an in vivo framework for the reconstruction of breathing mechanisms in extinct archosaurs such as dinosaurs.

A LATE MIDDLE JURASSIC CROCODYLOMORPH WITH CURSORIAL ADAPTATIONS

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Here we report a new basal crocodylomorph from the late Middle Jurassic lower Shishugou Formation of China. The holotype of the new species, comprising the uncrushed anterior half of a skeleton, is the most complete articulated non-marine crocodylomorph of any kind from the poorly known Middle Jurassic and is the youngest known "sphenosuchian." Unique among sphenosuchians the basisphenoid is greatly inflated, similar in extent to the protosuchid crocodyliforms and the therizinosaurid theropod *Erlikosaurus*. Related to this inflation, the distal end of the paroccipital process contacts the distal end of the quadrate and encloses within it the cranioquadrate passage, a feature previously considered diagnostic of the Crocodyliformes. As in other "sphenosuchians" the glenoid fossa of the shoulder girdle faces directly posteroventrally, with no lateral component as in living crocodylians, indicating the forelimb was held directly beneath the body. The forelimb includes two features previously unknown in crocodylomorphs that are also suggestive of cursoriality: a distinct inturned head is developed in the proximal end of the humerus, and the outermost digit is reduced, so that the fourth metacarpal does not contact the carpus. This new species independently evolved two vertebral features diagnostic of living crocodylians and their closest relatives (Eusuchia): procoelous vertebrae and ventral processes (hypapophyses) on cervico-thoracic vertebrae. However, unlike in living crocodylians osteoderms are absent from this small, gracile-limbed form. Procoely without osteodermal constraint suggests much greater axial mobility than in living crocodylians, and the sub-vertical orientation of the zygapophyses of dorsal vertebrae indicate that flexion was mainly in the vertical plane rather than the horizontal plane as in living crocodylians. A preliminary phylogenetic analysis suggests that this form helps resolve relationships among sphenosuchians, resulting in sphenosuchians being paraphyletic relative to crocodyliforms.

THE MORPHOLOGY, TAXONOMY, AND SYSTEMATIC POSITION OF *ICHTHYORNIS*: A CASE STUDY OF ALPHA TAXONOMIC PRACTICE IN A PHYLOGENETIC FRAME

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Ichthyornis, one of the toothed birds from the Late Cretaceous of Kansas, has languished in need of anatomical restudy and taxonomic revision subsequent to its monographic treatment by O.C. Marsh in 1880. This is despite that *Ichthyornis* was broadly recognized as important early support to a theory of evolution and continues to figure prominently in our understanding of the evolution of birds. *Ichthyornis* is one of the closest outgroups to crown clade Aves and remains one of very few Mesozoic avialans known from more than a handful of specimens.

For nearly a century, however, important *Ichthyornis* material, including holotype specimens, was essentially inaccessible, plastered into Yale Peabody Museum (YPM) exhibit mounts. Recently, the entire YPM *Ichthyornis* collection, comprised of 81 specimens including the material freed from the mounts, was restudied with holotype, and referred, specimens from other institutions. This morphological work yielded the following results: (1) there is evidence for only one species of *Ichthyornis*, rather than the eight previously proposed; (2) 78 YPM specimens are part of this species, *Ichthyornis* dispar; (3) two previously-identified species are not part of *Ichthyornis*; and (4) one new species is identified. The analysis provided a case study in developing protocols for increased transparency in alpha taxonomic practice, species identification, and the referral of fragmentary material. The application of a system of phylogenetic nomenclature at the species level was also explored.

Phylogenetic analyses of 202 morphological characters, scored for 24 terminal taxa, evaluated the relationships among basal ornithurines including *Ichthyornis dispar* and the newly identified taxa. Marsh's "Ichthyornithiformes" is not found to be monophyletic: two previously named species of *Ichthyornis* and *Apatornis celer* are placed as more closely related to, or as part of, Aves. Methodological problems posed by extensive missing data for many included taxa were investigated and, with the phylogenetic results, have implications for understanding the timing and pattern of the origin of Aves.

LATE CRETACEOUS MAMMALS FROM THE PRINCE CREEK FORMATION, COLVILLE RIVER, ALASKA

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Mammalian remains have been found in a sample of a local fauna preserved in a series of channel fillings in the Prince Creek Formation exposed at *Pediomys* Point on the Colville River, North Slope, Alaska. The locality currently is at approximately 70° North latitude. Sediments preserving the *Pediomys* Point local fauna were deposited on a low gradient, low relief coastal plain when the area was at a higher paleolatitude. Palynological evidence from the site indicates a late but not latest Cretaceous age—pre-*Wodehouseia spinata* Assemblage Zone. To the south in middle paleolatitudes all Lancian North American Land Mammal Age (NALMA) local faunas for which there are palyonological data are correlatives of the *Wodehouseia spinata* Assemblage Zone. Other paleontological data and radiometric age determinations from ashes within the Prince Creek Formation suggest correlation of the *Pediomys* Point local fauna with local faunas that lived during the ill-defined Edmontonian NALMA.

The available sample of the *Pediomys* Point local fauna was obtained by underwater

screening of channel fillings. Accumulation of vertebrate remains appears to have occurred with a taphonomic bias favoring small teeth and skeletal elements. The site has yielded records of chondrichthyans, osteichthyans, juvenile dinosaurs, and mammals. Remains of amphibians, lizards, turtles, crocodilians, and champsosaurs, common elements of latest Cretaceous local faunas to the south, have yet to be discovered at *Pediomys* Point or other Prince Creek Formation localities. At least two species of cimolodontan multituberculates were present in the local fauna. Most of the specimens collected so far are referable to a small species of pediomyid marsupial, a group well represented to the south but as yet unknown in the Cretaceous of Asia. A few teeth resemble those of the North American and Asian gypsonictopids. These small mammals lived in an environment characterized by winters with more than three months of darkness and frosts or short periods of freezing.

BONE CARBONATE, COLLAGEN, AND CHOLESTEROL: THREE TEMPORALLY DISTINCT BIOGENIC RECORDS OF ECOLOGICAL INFORMATION FOR ANCIENT MARINE MAMMALS

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Effective conservation of marine mammal populations requires establishing baseline ecological knowledge for species prior to human contact or exploitation, which is often difficult to gather from fossil specimens or historical accounts. Stable carbon isotope analysis of biogenic substrates has proven to yield viable estimates of dietary and habitat information for extinct species. Bone carbonate, collagen, and cholesterol are three substrates suitable for $\delta^{13}C$ analysis that can be extracted from a single bone and can potentially be preserved over long time scales (~100 kyrs). Furthermore, the production of each substrate results from the assimilation of different dietary components (e.g., proteins, lipids, and carbohydrates), providing a tool for identifying changes in these dietary resources. Also, the rates of synthesis of these substrates differ, meaning that there are significant disparities in the amount of time averaged within each substrate, ranging from only a few months (cholesterol) to several years (bone carbonate, collagen). In combination, these substrates can yield short-term and long-term information on the use of different dietary components by marine mammals.

To determine the viability of bone carbonate, collagen, and cholesterol for reconstructing ancient marine mammal diets, we analyzed bone samples from extant and fossil specimens spanning a 1 m.y. interval of time. From collected specimens, ~1 g of bone material was sampled and bone carbonate, collagen, and cholesterol $\delta^{13}C$ values were determined. For all substrates, $\delta^{13}C$ values closely tracked those of primary producers, suggesting each substrate could serve as a proxy for marine mammal foraging preferences. For all species, cholesterol $\delta^{13}C$ values yielded the highest degree of variation, confirming that cholesterol carbon isotope analysis was capable of tracking short-term variations in diet that could be missed by sole analysis of bone carbonate or collagen. Thus, dietary interpretations for extinct species could benefit from $\delta^{13}C$ analysis of multiple carbon substrates within fossil bone.

PROBOSCIS EVOLUTION IN MAMMALS: RULES OF CONSTRUCTION AND FUNCTIONAL MORPHOTYPES

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Modern mammals possess a large diversity of narial structures. Almost every major clade of mammals contains one or more taxa that have evolved structures that may loosely be called a proboscis. Despite this diversity, certain fossil mammals with a small set of bony characteristics have been reconstructed with a short, generic "trunk." This study seeks to determine rules or principles of proboscis construction in order to understand better both the diversity found in modern mammals and the potential diversity to be found in the fossil record. A variety of anatomical methods including imaging (using CT, or computed tomography), vascular injection, dissection, and skeletonization were applied to hooded seals, moose, and saiga antelopes. Previous literature was used for other proboscis-bearing species such as elephants, tapirs, and dik-diks. Outgroups (e.g. bearded seals, oxen, sheep, deer, horses, and rhinos) were studied using similar techniques. Particular attention was paid to how the bony support for narial structures changed as a result of elaboration of soft tissues.

This study tests two major hypotheses. First, novel narial structures are phylogenetically constrained, such that components of a proboscis are merely modifications of plesiomorphic conditions found in outgroups rather than entirely new structures. Second, similar modifications evolve convergently in probosces that perform similar functions. Convergent modifications suggest morphogenetic constraints on proboscis evolution that accommodate relatively few "rules of construction" governing the evolution of proboscis morphotypes. Hydrostatic probosces show a reduction in osseocartilaginous support of narial tissues, whereas display structures and nostril specializations generally show an increase in support elements. Primitively inconspicuous muscles gain relative importance in proboscis-bearing taxa, such as lateralis nasi and nasalis. The osteological correlates of novel soft tissues permit more detailed reconstruction of both narial anatomy and potential behavior in fossil taxa.

ARMS, ARMOUR, CONVERGENCE AND CONSERVATISM: A LOWER CARBONIFEROUS HYBODONT SHARK

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New material of *Onychoselache traquairi*, from the Holkerian (Viséan: Lower Carboniferous) of Scotland, shows it to be in most respects a conventional hybodontiform selachian, but with some unusual specialisations. The identification of an undoubted hybodontid from the Viséan is itself noteworthy. The previous earliest representative of this predominantly Mesozoic clade is about 45 million years younger (*Hamiltonichthys*). *O. traquairi* bears an extraordinary set of spined plates, which presumably provided defence for this diminutive (~24 cm) fish. The braincase is characteristically hybodontid: the otic capsules are positioned between the postorbital processes. The jaws and jaw suspension are similarly derived: all traces of primitively amphistylic suspension are absent. Likewise, the shoulder girdle resembles the standard hybodontid pattern, but the detailed form of the articular surfaces differs. Furthermore, the pectoral fin skeleton is disproportionately large, and, unexpectedly for a Palaeozoic chondrichthyan, resembles those of certain modern elasmobranchs.

The combination of features in *Onychoselache traquairi* represents the earliest evidence of a morphological signature that characterised a shark clade, largely unchanged, throughout a subsequent 270 million years. But the pectoral fins are almost cartilage-for-cartilage copies of examples present in extant, specialised, orectolobiforms, and these similarities extend to the unusual profile of the glenoid surfaces. A functional interpretation of these specialisations presents an intriguing addition to current views of early shark biology; it is also noted that this convergence of ancient and modern fins is consistent with suggestions that modern elasmobranches retain a primitive developmental tool-kit. Finally, much of these data are revealed by the discovery of only the third specimen of *Onychoselache traquairi*, found by Mr S. P. Wood at the Mumbie Quarry exposure of the Glencartholm Volcanic Beds, Galloway and Dumfries Region, Scotland.

HRXCT ANALYSIS OF THE SKULL OF *COLODON* (PERISSODACTYLA: TAPIROIDEA)

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Previously undescribed skulls of *Colodon* were scanned at the University of Texas High-Resolution X-ray CT Facility. CT data reveal cranial architectural features that include indicators of proboscis development. These morphologies represent character complexes that are critical to phylogenetic analyses within Tapiroidea. In particular, the degree of nasoincisive incisure retraction, the development of frontal sinuses, and the elaboration of fossae hypothesized to have housed cartilaginous meatal diverticulae, are all considered synapomorphies of a taxon that includes *Tapirus*, but not the early Oligocene *Protapirus*. Traditionally, *Protapirus* has been deemed the 'earliest tapirid' and more closely related to extant tapirs than is *Colodon*. These older interpretations of the evolutionary relationships of *Colodon* were based largely on the assumption that its relatively robust third digit and reduced lateral digits on both fore and hind feet were too 'specialized' to be ancestral to the later tapirs. These derived features are hypothesized here to be autapomorphies of *Colodon*.

A LATE CRETACEOUS (CAMPANIAN) MARINE VERTEBRATE MICROFAUNA FROM THE AGUJA FORMATION OF CHIHUAHUA, MEXICO

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Processing of bulk-sampled sediments from the Los Altares locality of the Aguja Formation in Chihuahua, Mexico has resulted in the discovery of a vertebrate microfauna including the remains of selachians, bony-fishes, and reptiles. The selachian fauna is highly diverse, with representatives from at least a dozen families and over 15 genera, including *Hybodus, Chiloscyllium, Ginglymostoma, Cretorectolobus, Odontaspis, Carcharias, Scapanorhynchus, Cretolamna, Squalicorax, Rhinobatos, Protoplatyrhina, Squatirhina, Ischyrhiza,* and *Ptychotrygon*. Many of these taxa have not previously been reported from the Aguja Formation, which extends northward into the Big Bend region of Texas. The fauna also includes *Squalicorax* cf. *S. bassanii*, a North African species here first reported from the Western Interior of North America. The bony fish fauna is dominated by isolated teeth from several species of phyllodont fishes and also includes remains of *Enchodus, "Stephanodus,"* an amiid, and other taxa.

TRITYLODONTIDS FROM AN EARLY JURASSIC FISSURE FILL, GLAMORGANSHIRE AND A RE-EVALUATION OF THE GENUS *OLIGOKYPHUS*

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Remains of an Early Jurassic vertebrate fauna have been discovered in a fissure fill within the Carboniferous limestone of Glamorganshire, South Wales. Pant 4 fissure (the fourth discovered fissure in Pant quarry) formed on a Late Triassic/Early Jurassic island named St. Bride's, now a plateau near the South Wales coast. Similar fissures elsewhere on St. Bride's Island have produced a typical vertebrate fauna, comprising three main species, and named the *Hirmeriella* fauna after associated remains of the fossil conifer *Hirmeriella muensteri*. Pant 4 fissure has an atypical fauna with numerous taxa in addition to the *Hirmeriella* components. Up to 21 species have been proposed, making the fissure more speciose than neighbouring sites.

Based on the characteristic morphology of the cheek teeth, the tritylodontid *Oligokyphus* is identified from Pant 4. It is a herbivorous non-mammalian synapsid, or mammal-like reptile, phylogenetically close to the origin of mammals, with a worldwide distribution (England, Germany, U.S.A., China). A re-analysis of *Oligokyphus* teeth from Pant 4 places all specimens in a single species. Comparison of this species with remains from all other known *Oligokyphus* populations is undertaken. Previously described *Oligokyphus* material from Windsor Hill, England is found to consist of one species, morphologically identical to that of Pant 4. Both populations are referred to *Oligokyphus major* Kühne, 1956. *O. minor* Kühne, 1956, is a junior synonym of *O. major*.

Morphological and morphometric comparisons between British, German, North American and Chinese species confirm each to be unique. Based on cheek tooth and incisor counts, *Oligokyphus* from the U.S.A and China may be closer to each other than the German or British *Oligokyphus*, and may represent the primitive condition for the genera. Dating of the different species is difficult for all but *O. major*, and these findings renew speculation

about the age of the Kayenta (U.S.A) and Lower Lufeng (China) formations, as *Oligokyphus* has been used there as a biostratigraphic indicator.

A NEW SKELETON OF THE LATE CRETACEOUS LAMNIFORM SHARK, *CRETOXYRHINA MANTELLI*, FROM WESTERN KANSAS

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Cretoxyrhina mantelli (Agassiz) is a Late Cretaceous lamniform shark, which is common in middle Cenomanian–early Campanian marine deposits worldwide. Most remains of *C. mantelli* occur as isolated teeth, but a few reasonably complete skeletons are known from the Smoky Hill Chalk Member of the Niobrara Chalk in western Kansas. Those skeletal remains suggest that the body form of *C. mantelli* was possibly similar to the modern great white shark, *Carcharodon carcharias* (Linnaeus), and that the largest individuals may have attained 6 m in total length (TL). In April of 2002, a new skeleton of *Cretoxyrhina mantelli* was recovered from the Upper Coniacian portion of the Smoky Hill Chalk in southeastern Gove County, Kansas. The skeletal elements are mostly articulated and extended over a 5 m by 2 m area. Although the posterior portion of the vertebral column is missing due to weathering, the specimen, still largely unprepared, preserves much of the skeleton. It is catalogued as VP-14010 in the Sternberg Museum of Natural History, Fort Hays State University (FHSM), Hays, Kansas. The anterior portion of the skeleton is heavily weathered but does include parts of the skull and jaws. Much of the lower dentition is covered by cartilaginous elements, whereas the anterior half of the upper dentition is well exposed. The upper dentition exhibits a typical lamnoid tooth pattern with at least one row of symphysial teeth, two rows of anterior teeth, and several rows of post-anterior teeth including intermediate teeth. The crown height (= maximum vertical enameloid height) of the tallest tooth (one of the anterior teeth) is 43.5 mm, and the diameter of the largest vertebrae measures 95 mm. Calculations suggest that these dental and vertebral measurements are approximately 9% larger than those in the most complete *C. mantelli* skeleton known (FHSM VP-2187, which measures 5 m TL), indicating that FHSM VP-14010 probably had a TL of at least 5.4-5.5 m.

FOSSIL TURTLES OF NEBRASKA'S WHITE RIVER GROUP: A BIAS TOWARD THE CARAPACE-UP POSITION

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A database of fossil turtles and associated stratigraphic, sedimentologic and taphonomic data is being built by systematic sampling of the White River Group (Chadronian through Arikareean) in the Toadstool Park region of Nebraska. We have located 240 turtles ranging from the Peanut Peak Member of the Chadron Formation through the "Brown Siltstone" member of the Brule. Stratigraphic sorting of the turtles into 10-meter intervals reveals a number of interesting situations. First, turtle size decreases significantly above the Orella, reaching a nadir in the middle Whitney, after which size begins to increase. This trend is roughly in agreement with size trends reported by Hutchison (1996). Second, there is a strong bias, for both large and small turtles, toward the carapace-up position for all intervals containing statistically significant numbers. This indicates that these turtles in general died and were preserved in low-energy environments. Third, in all intervals with statistically significant numbers of turtles there is a strong bias toward retention of non-shell elements. This observation, combined with the fact that most turtles remain upright regardless of size, suggests that in general, these turtles were not scavenged by medium- to large-sized animals. Fourth, our data allow us to make a rough evaluation of turtle densities in the Chadron through the Orella. A preliminary census of mammals associated with the turtles reveals apparent greater fluctuation in preserved numbers of turtles than that for mammals.

EFFECTS OF GRAIN SIZE, MORPHOLOGY, AND PRESERVATION ON TRANSPORT-INDUCED ABRASION OF FOSSIL TEETH

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The preservation state of fossilized remains is often used to discern the amount of preburial transport the element underwent. The dense enamel coating of teeth has led most workers to think that teeth are relatively unaffected by abrasive damage incurred during transport, making recognition of allochthonous teeth especially difficult. Previous studies employing Late Cretaceous reptilian teeth demonstrated that enamel surfaces incur almost no abrasive damage when transported in a sand-dominated fluvial system, even over extreme (>350 km) transport distances. However, other variables, including tooth morphology, completeness of enamel preservation, and sedimentary grain size may influence the susceptibility of fossil teeth to abrasion. To test the effects of these variables, fossil mammalian and reptilian teeth were subjected to simulated fluvial transport with bedloads comprised of various grain sizes. The analyzed teeth represent an array of morphologies and preservation states, ranging from pristine to heavily worn. Results to date indicate that smaller teeth do not incur more damage than larger specimens when other variables are held constant. Also, gravel bedloads can induce significant abrasion, especially for teeth lacking pristine enamel preservation. These results indicate that a combination of enamel preservation and grain size determine the potential for tooth abrasion. Thus, teeth transported in high-energy environments may accrue damage sufficient to be recognized as allochthonous elements, particularly if the teeth experienced prolonged weathering prior to transport and burial.

LATE PLEISTOCENE MYLODONTIDAE (XENARTHRA) FROM THE VALLEY OF MÉXICO

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During the construction of a gas station in Tlalnepantla, in Estado de México, vertebrate fossils appeared. The outcrop is 362 m^2 of area. The fossiliferous layer is .70 m thick and consists of a consolidated tuff, with lenses of sandstones and pebbles. Previous geological reports suggest that this kind of deposit is common in the central part of the Valle de México, as a consequence of the volcanic activity of the Chichinautzin and Popocatépetl during the Late Pleistocene.

The recovered vertebrate fossil taxa includes: *Equus conversidens*, *Mammuthus*, *Camelops*, *Arctodus*, *Canis*, *Paramylodon harlani* and also microfossils were collected. The association is assigned to Rancholabrean age.

The fossil remains are quite well preserved; some skeletal elements were found articulated. The xenarthran material is the most abundant and includes skulls, lower jaws, isolated teeth, vertebrae and postcranial elements. At least 9 individuals were present in the sample. Marked size and morphological variation had been noticed among the elements indicating the presence of juvenile and old individuals. This study provides information to assess the variation within a mylodontid population, an issue that is not well understood. This is the first assemblage of mylodontids found in México. Its comparison with the large sample from Rancho La Brea shows some differences in the range in size.

In México, the mylodont record ranges from the Blancan until the Rancholabrean. Mylodonts are only known by one record in the Irvingtonian, but fairly widely distributed in Mexico during the Rancholabrean. Most of the records are from the Mexican Plateau and Central part of the country. In the Valley of Mexico this species had been already reported, but unfortunately the fossil material is lost.

DIVERSIFICATION OF MESOTHERIIDS (MAMMALIA: NOTOUNGULATA: TYPOTHERIA) IN THE MIDDLE LATITUDES OF SOUTH AMERICA

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Much of the early and middle Cenozoic terrestrial mammal record of South America derives from the higher latitudes, especially Patagonian Argentina. Over the past 20 years, fieldwork in other parts of the continent has resulted in new insights into the evolution and distribution of many mammal clades, including the endemic South American Mesotheriidae (Notoungulata: Typotheria).

Mesotheriids are unknown in pre-late Eocene (Mustersan and earlier) faunas and are poorly known prior to the late Oligocene Deseadan South American Land Mammal "Age" (a single specimen has been reported from the earliest Oligocene Rocas Bayas locality and two specimens are known from the ?late Eocene/Oligocene Divisadero Largo Fauna). In Argentina, mesotheriids occur in most Deseadan faunas (though in low abundance), but are not recorded between the Deseadan and Mayoan SALMAs (early and middle Miocene). They are familiar components of late Miocene through early Pleistocene Argentine faunas.

In contrast, mesotheriids are common and diverse in most middle Cenozoic faunas of northern Chile and Bolivia, and hence there is no hiatus in their stratigraphic occurrence at intermediate latitudes. The Chucal Fauna of northern Chile, likely of Santacrucian (late early Miocene) age, includes abundant and well-preserved remains of three new mesotheriid species. These species are closely related to the basal mesotheriine *Microtypotherium*, otherwise known only from Bolivia, and help clarify the early evolution of the Mesotheriinae. *Plesiotypotherium*, common in Bolivian faunas of Friasian (s.l.) age (middle Miocene), is unrepresented at Chucal. The late Miocene Caragua locality (~40 km west of Chucal) has yielded only three fossil specimens, all appearing to pertain to a previously unrecognized species of mesotheriine, closely related to *Plesiotypotherium* and later-occurring Argentine taxa.

These distributional patterns suggest that the intermediate latitudes, possibly more montane areas, may have been biogeographically distinct from both equatorial and Patagonian regions, and possibly served as a center of diversification for mesotheriids and other groups of indigenous South American mammals.

NEW SPECIMENS OF *ARAPAHOVIUS GAZINI* (MAMMALIA, PRIMATES), WITH COMMENTS ON THE EARLY EOCENE (LYSITEAN, BIOCHRON WA6) PRIMATE COMMUNITY OF THE WASHAKIE BASIN, WYOMING

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The early Eocene omomyid primate *Arapahovius gazini* is known from a limited spatiotemporal range (a 15 meter stratigraphic interval of the Washakie Basin of southern Wyoming), and is easily distinguished from sympatric primates based on its size and strongly crenulated enamel. *A. gazini* is known from a rather larger sample (n > 100), and field work during 2001 and 2002 has produced a number of new specimens, representing all tooth positions of the lower dental arcade, thereby greatly increasing the hypodigm of this species. Because of its limited distribution and distinct dental anatomy, *A. gazini* provides an excellent taxon with which to investigate dental variability in extinct primates. Here we present data on the patterns of dental variation in *A. gazini*, and discuss these patterns within the context of the early Eocene (Lysitean, Biochron Wa6) primate community of the Washakie Basin. This primate community was comparable in its diversity to many extant prosimian primate communities, with at least four primate genera (e.g., *Arapahovius, Anemorhysis, Cantius,*

Copelemur) and the plesiadapiform ("archaic primate") *Microsyops* present. Despite a sample that spans several distinct strata within the overall stratigraphic interval, the degree of metric variation in *A. gazini* is quite limited, with lower molar length CVs of 3.49 for m1 (mean = 2.29 mm, n= 25), 3.57 for m2 (mean = 2.24 mm, n = 34), and 4.44 for m3 (mean = 2.93 mm, n = 25). This pattern of limited variability in *A. gazini*, seen across its entire stratigraphic distribution, may be due in part to habitus features, as the adaptations of *A. gazini* (e.g., crenulated enamel) are quite distinct from those of sympatric primates (e.g., *Anemorhysis savagei* and *Copelemur australotutus*).

MORPHOLOGICAL ANOMALIES IN A MOSASAUR, *PLATECARPUS*, FROM MANITOBA

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During the Late Cretaceous a shallow marine seaway occupied central North America from the Arctic Ocean to the Gulf of Mexico. Mosasauridae (Order Squamata) were highly successful marine reptiles that displayed a remarkable evolution in their geologically brief existence in this inland waterway. Mosasaur genera native to southwestern Manitoba include *Clidastes*, *Hainosaurus*, *Tylosaurus* and *Platecarpus*. Of these genera, *Platecarpus* was selected for intensive study because (1) *Platecarpus* fossil material in Manitoba is abundant (2) preliminary analysis suggests considerable morphological variation, and (3) several characteristics exhibit a graded progression of development.

Analysis of *Platecarpus* specimens from Morden, Manitoba, reveals variation in several skeletal characters. Variation of the position of the frontoparietal suture results in inclusion of the frontal at the anterior margin of the parietal foramen in some specimens. Relative size of the parietal foramen is extremely variable. The presence of some extremely large skulls suggests the possibility of progressive increase in body size. Considerable morphological variation is also observed in the form and overall robustness of the humerus. An infrastapedial process of the quadrate, inconspicuous in typical *Platecarpus*, is moderately developed in some individuals.

In some specimens, these skeletal features diverge greatly from previously described *Platecarpus*, and approach those of the closely related *Plioplatecarpus*. However, *Plioplatecarpus* is not known from southwestern Manitoba. What taxon is represented by these fossil specimens? Are the ancestral genera more variable than previously known, or is this possibly a new taxon, intermediate between these 2 known genera, adapted to the local habitat? Currently, ongoing morphological analysis hopes to resolve the taxonomic placement of this unique mosasaur fauna.

A GLYPTODONT (MAMMALIA: XENARTHRA) FROM NORTHERN OKLAHOMA

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A portion of the carapace of the glyptodont *Glyptotherium arizonae* occurred at a locality in northern Oklahoma about 260 km north of the only previous state record. It is the northernmost record of a glyptodont in North America. The occurrence probably reflects a late Pliocene-early Pleistocene (late Blancan-early Irvingtonian land mammal age) distal expansion onto the southern Great Plains of habitat characteristic of the lowland tropical-subtropical Gulf of Mexico Coastal Plain that was inhabited by glyptodonts and many other mammal taxa of South American origin that were a part of the Great American Biotic Interchange.

A STUDY OF SMALL DINOSAUR FOOTPRINTS (*ANOMOEPUS*) FROM THE EARLY JURASSIC GARY GAULIN TRACKSITE, HOLYOKE, MA

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On March 25,1996, while digging for a fish pond on his property, Holyoke resident Gary Gaulin discovered an outcrop of mudstone possibly belonging to the East Berlin formation containing dinosaur footprints. When completely excavated the outcrop consisted of multiple layers bearing footprints primarily referable to the ichnogenus *Anchisauripus*. Recently a single trackway referable to the ichnogenus *Eubrontes* has been discovered. Additionally, multiple trackways identified as *Anomoepus* represent very small dinosaurs, and were discovered in finely laminated mudstone layers. Much of the rock bearing these small fossils was excavated before the discovery of the footprints, and as a consequence most of the footprints occure on 16 disarticulated slabs. However the longest trackway remains *in situ*. These small footprints are the subject of the present study.

We documented the footprints using a variety of techniques including photography, mylar tracing, rubber moulding, and mapping. Measurements recorded from the fossils include length and width of the manus and pes, pace, stride, and straddle. We were able to calculate a gleno-acetabular distance of 12.5 cm for one of the trackmakers from a trackway containing both manus and pes impressions. These ichnites are significant because they provide evidence for multiple, possibly juvenile, animals inhabiting the same locality. Additionally some of the trackways indicate that some of the animals moved in a plantigrade quadrupedal manner, a mode of locomotion unusual for this ichnogenus from the Connecticut Valley.

ADHESIVES AS LIQUIDS

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Adhesives work because they can flow as liquids that then solidify in extremely close contact with the surface to which they are applied. Adhesion of the two solids is due to secondary attractive forces and mechanical interlocking. In their liquid phase and in their setting mechanisms, adhesives vary widely but all must be able to flow. Factors that affect flow such as viscosity, wetting, and interaction of liquid adhesives with surface contaminants and entrapped air will be discussed, along with techniques to manipulate adhesive flow for the preparation of fossil vertebrates.

SYSTEMATICS AND RELATIONSHIPS OF "PEDIOMYID" MARSUPIALS (LATE CRETACEOUS, NORTH AMERICA)

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Pediomyidae are moderately diverse, biotically significant marsupials known only from the Late Cretaceous (Campanian-Maastrichtian) of North America, though they have been implicated in the ancestry of part or all of the later marsupial radiation in South America. Known principally by dental remains, "pediomyids" have a generally opossum-like dentition; presumed apomorphies include reduction of the anterior stylar shelf and reduction to loss of the stylocone on upper molars, and attachment of the cristid obliqua labial to the protocristid notch on lower molars.

Due to their distinctive molar specializations (among Late Cretaceous North American marsupials), Pediomyidae have long been recognized as a monophyletic group (initially regarded as a subfamily of Didelphidae). However, an hypothesis proposed by Fox suggests that the family is instead an artificial assemblage, comprised of at least two lineages that independently acquired "pediomyid"-like molar characteristics. Central to this hypothesis is the early Campanian genus *Iqualadelphis*, which retains several plesiomorphies and has been postulated by Fox to be related to a specific clade of later "pediomyids". To test these contrasting hypotheses, I constructed a data matrix comprised of 60 qualitative and quantitative upper and lower molar characters and 25 taxa, including basal marsupials (e.g. *Kokopellia*) and representatives of all other major marsupial taxa from the Late Cretaceous of North America. Preliminary results of algorithm-based (PAUP) analyses provide tentative support for a monophyletic Pediomyidae, including *Aquiladelphis* and some species of "*Pediomys*." Tree topology places *Iqualadelphis* well outside the family. However, tree geometry within the family suggests that at least two clades may be recognized (along similar lines as proposed by Fox- "*P.*" *prokrejcii-krejcii* and "*P.*" *clemensi-cooki*), and that the genus "*Pediomys*" itself is potentially not monophyletic. These results underscore the need for systematic revision of this important group of Late Cretaceous mammals.

PHYLOGENETIC ANALYSIS OF CLIMATE TOLERANCES INDICATES CLIMATE-DRIVEN SPECIATION WITHIN *MARMOTA* (RODENTIA: SCIURIDAE)

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Several recent debates have centered upon whether mammalian species originate in response to changing climate. I address this question by examining patterns of climatic tolerances of extant species in the rodent genus *Marmota*. Specimens assigned to this genus are common in the fossil record. If new species originate through allopatric invasion of new climate regimes, their climatic tolerances should show a poor fit to their evolutionary history. Alternatively, if new species originate within the same climatic regime as their parent species, their climatic tolerances should fit well with their evolutionary history.

To test these hypotheses, the relationship between geographic distribution, climatic tolerance, and phylogeny was examined for extant species of the rodent genus *Marmota*. ArcInfo was used to transfer range maps of the 14 species to a GIS containing 2.5° latitude/ longitude data of monthly temperature and precipitation averages. Average temperature and precipitation values for the species were then compared to the published molecular phylogeny. Comparisons were made using UPGMA and Neighbor Joining methods to construct dendrograms that represent climate affinity between the species.

Neither climate dendrogram showed a topology similar to the phylogeny. Three pairs of species appear in both dendrograms. The evolutionary tree shows *M. caudata* and *M. menzbieri* to be sister species, *M. olympus* and *M. vancouverensis* to be a paraphyletic group, and *M. broweri* and *M. camtschatica* to be from two different subclades on two different continents. A regression of climate distance against published distances from the maximum likelihood phylogeny indicates a significant positive correlation ($p = 0.043$); however the R^2 value (0.045) is very low, reflecting the poor nature of the fit. These results support the hypothesis that species of *Marmota* were originating through allopatric invasion of new climate regimes; also, they imply that climate influences mammal species formation, and that the geographic distribution of fossil species may hold a climatic signal. Additional work in other groups is necessary to determine whether this pattern persists.

PHYLOGENETIC AND GEOGRAPHIC AFFINITIES OF THE EARLY MIOCENE VERTEBRATE FAUNA OF DEVON ISLAND, NUNAVUT, CANADA

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Freshwater and terrestrial vertebrate fossils and fossil plants are preserved within Haughton Crater, a meteorite impact structure located in north central Devon Island, at 75° north latitude. The fossils occur in sediments of the Haughton Formation, which were deposited in the crater lake that formed soon after the impact at approximately 23 MA, very early in the Miocene. Paleobotanical and palynological studies have provided evidence of cool temperate, probably maritime, climatic conditions at the time of deposition of the formation.

Fishes, a bird, and four to six kinds of mammals are the currently known vertebrates. A heterosoricine shrew, rhinocerotid, and leporid are relatively primitive for the early Miocene, whereas the tragulid artiodactyl is highly derived. Establishing the phylogenetic affinities of these diverse and surely highly endemic vertebrates suggests that Eurasian and/or North American derivation is possible for the insectivore, lagomorph and perissodactyl, whereas the tragulid must be of Eurasian origin. The Miocene geography of high northern latitudes is examined in relation to these paleobiogeographic indicators in an attempt to determine time(s) and place(s) of dispersal of the varied elements of the Haughton vertebrate fauna.

BERNISSART'S *IGUANODON*: THE CASE FOR "FRESH" VERSUS "OLD" DINOSAUR BONE

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In order to better localize the limits of the geological local accident (or "cran") which caused the Lower Cretaceous (Wealden) clays containing numerous *Iguanodon* skeletons (Dinosauria, Ornithischia, Ornithopoda) to collapse into the underlaying coal measures (Carboniferous) strata, where they were discovered and excavated in the 1876-78, a party of the Faculté Polytechnique of Mons, Belgium, organized a drilling campaign in early 2003. Wealden clays were indeed recovered from the drilling cores and peculiar structures were noticed in the clay at depth of -296.5 m and -309 m from drilling pit number 3. Histological examination of the structures demonstated that the drilling had crossed through *Iguanodon* skeletons still *in situ*. Identification is based on statistical probabilities and more specifically on the structure of bone and teeth materials. The *Iguanodon* skeletons recovered in the 1870s were highly pyritized and this has caused lasting curation problems ever since. The new drilling discoveries offer the opportunity to compare "fresh" specimens hardly ever submitted to atmospheric oxygen to "old" specimens kept in standard Museum conditions for more than a century. The various physico-chemical and structural comparisons in progress will help to decipher how the pyrite oxydation causes fossil bone degradation at the micro- and macroscopical levels and hopefully devise efficient preservation strategies. Histological preservation of the "fresh" bone and dental material is very good. The" old " material allowed to oxydize for 120 years or more in contact to the air at room temperature does not show any significant histological degradation but rather generalized macroscopic breakage.

A PALEONTOLOGICAL INVENTORY OF ZION NATIONAL PARK, UTAH, AND THE USE OF GIS TECHNOLOGY TO CREATE PALEONTOLOGICAL SENSITIVITY MAPS FOR USE IN RESOURCE MANAGEMENT

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The spectacular rocks exposed in Zion National Park, Utah, include many fossiliferous units ranging in age from Permian through Holocene. Important vertebrate fossil-bearing formations include the Triassic Chinle Formation, and the Jurassic Moenave and Kayenta Formations, among others. In cooperation with the Utah Geological Survey (UGS), several National Park Service interns have been conducting a comprehensive inventory of paleontological resources located within the park. The goal of this work is to identify new fossil localities and to assess the distribution of fossils within formations to establish baseline paleontological resource data to support the management and protection of non-renewable fossils.

We have identified over 100 new sites as a result of this project. Terrestrial vertebrate body fossils have been found in the Shinarump and Petrified Forest Members of the Chinle Formation, including the remains of phytosaurs, aetosaurs, metoposaurs, and a possible ornithischian dinosaur. Dozens of new dinosaur tracksites have been discovered in the Whitmore Point Member of the Moenave Formation and the Kayenta Formation. These include numerous *Eubrontes* and *Grallator* trackways as well as probable swim tracks.

To put our results in an easily usable format, we are using Geographic Information System (GIS) programs to not only record site localities, but also to create paleontological sensitivity maps from recently completed UGS 7.5-minute geologic quadrangle maps of the park. We have developed this type of map for other public lands in Utah in which we assign sensitivity levels to the geologic units based on the type and distribution of fossils. These maps are intended to aid land managers in making decisions regarding the protection of fossil resources. We intend these maps to serve as models for paleontological resource management on public lands in other states. The identification of scientifically important new localities illustrates the value of cooperative projects in the National Parks.

PRODUCERS AND CONSUMERS: HOW DID WESTERN INTERIOR PLANTS SUPPORT THE MEGAHERBIVORE FAUNA?

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Large herbivorous dinosaurs were abundant during the Cretaceous and are postulated to have had elevated metabolisms and accelerated growth rates. In the Western Interior of North America, they were dependent on the flora present between the Western Interior Seaway and the ancestral Rocky Mountains. Given the limited land area available for plant growth, it is uncertain how the dense megaherbivore populations there were sustained.

In order to assess photosynthetic and primary productivity rates, Cretaceous-like atmospheric conditions were created in a hyperbaric chamber at the Duke University Medical Center (Durham, NC). *Ginkgo biloba* seedlings were systematically exposed to elevated carbon dioxide concentrations up to 2000 ppm (5.5 times modern concentration) and elevated oxygen concentrations to 30% (50% increase above modern levels). Instantaneous photosynthetic rate measurements show an increase of 200-300% under Cretaceous conditions due to the atmospheric enrichment. These results suggest that higher photosynthetic rates from gaseous enrichment could have counterbalanced the restricted terrestrial habitat in the Western Interior. Hence, the presence of megaherbivore fauna may be explained by higher primary productivity.

A NEW SPECIES OF BALEEN WHALE (CETACEA: MYSTICETI) FROM THE PLIOCENE OF CALIFORNIA AND ITS IMPLICATIONS FOR HIGHER MYSTICETE PHYLOGENETIC RELATIONSHIPS

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Partial and articulated skeletons of a new species of mysticete cetacean have been recovered from nearshore marine sandstones of the Pliocene age San Diego Formation, eastern North Pacific. The available fossil material includes skulls of immature and adult individuals as indicated by size and degree of cranial suture closure. Condylobasal lengths range from 146 cm to 235 cm (N = 5), with the larger skulls indicating a total body length of 11 meters. This falls within the lower end of the adult size range of the living gray whale, *Eschrichtius robustus*.

The skull and mandible of the new species preserve a mosaic of apomorphic character states that are more traditionally seen exclusively in either gray whales (Eschrichtiidae) or rorquals (Balaenopteridae). Eschrichtiid features include a narrow and slightly arched rostrum, robust and dorsally oriented premaxillae, delicate and laterally oriented ascending maxillary processes, large and dorsally elevated nasals, narrow supraorbital processes of the frontals, elevated parietal/frontal suture, small and triangular anterior process of petrosal, conjoined fenestra rotundum and perilymphatic foramen, dorsally elevated and posterodorsally oriented mandibular condyle, and bulbous mandibular symphysis. Balaenopterid features include bluntly trapezoidal occipital shield, overhanging lambdoidal crests, parietal/maxillary overlap, and maxillary/frontal 'pocket.'

Morphologic and molecular phylogenies of mysticetes recognize Eschrichtiidae and Balaenopteridae as monophyletic sister taxa in a mysticete crown clade. Inclusion of the new fossil species in a phylogenetic analysis of fossil and extant mysticetes lends support to this Eschrichtiidae + Balaenopteridae clade and offers the potential to resolve some current controversy concerning the possible paraphyly of Balaenopteridae.

COMPARISON OF HADROSAUR SKIN PRESERVATION IN THE LANCE AND JUDITH RIVER FORMATIONS (UPPER CRETACEOUS; WESTERN NORTH AMERICA)

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The Lance Formation (Upper Cretaceous, Maastrichtian) of Wyoming is well known for its dinosaur skeletons with associated skin impressions. Most are the hadrosaur *Edmontosaurus*. Nine specimens are presently recorded. Another twelve *Edmontosaurus* with skin come from the laterally equivalent Hell Creek Formation of Montana and the Dakotas. More recently, three excellent hadrosaurs (all *Brachylophosaurus*) have turned up in one small collecting area within the slightly older, lower Judith River Formation (Upper Cretaceous, Campanian) of Montana. Comparison of these Lance/Hell Creek and Judith River specimens shows a modest range of diagenetic histories, as well as pronounced variation in the amount, quality, and preparability of skin. However, these same fossils reveal a single set of biostratinomic conditions.

In both formations, skin is generally associated with articulated, well-preserved skeletons. With a few spectacular exceptions, each fossil has only a few flattened patches of skin. One Hell Creek skeleton lay within a crevasse splay, but most occur within point bar sands. The Judith River specimens lay within sandstones that are relatively clean and well sorted. Skin preservation varies considerably within individual specimens. Preparation is generally difficult.

The Lance/Hell Creek and Judith River skin-bearing hadrosaurs present a biostratinomic paradox—both sets of carcasses shows signs of desiccation but all were buried by fast-moving water in a humid setting. One hypothesis to explain this paradox is strong seasonality—a carcass is fortuitously mummified in open air during the dry season, then the toughened carcass gets transported and quickly buried during the early days of the rainy season. Supporting this hypothesis is a Lance specimen that was buried in stages. The skeleton on later-buried portions is partly disarticulated, the bones are abraided, and the skin is poorly preserved or missing.

MULTIVARIATE ANALYSIS OF MAMMALIAN COMMUNITIES: MEMBERSHIP AND SPECIES LINEAGE RANGES IN THE TERTIARY OF NORTH AMERICA

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Reconstruction of the paleoecology of an individual fossil community is informed by functional characterization of its members in their ecological context, with an understanding of the abiotic factors that shape the community. In order to understand the ecological pattern of evolutionary changes over time, it is necessary to use statistical tools that can parse out differences among numerous fossil localities simultaneously. Previous research on fossil mammals has focused on species turnover and potential coevolutionary scenarios among predators and prey, but this work focuses on communities.

For this study, occurrence data for mammalian species were summarized from the literature and subjected to multivariate analyses. This database incorporated some 680 fossil mammal species from more than 200 localities from the western interior of North America. These localities span a 30 million year time period, from the early Wasatchian to the latest Arikareean. In an effort to minimize the effects of differential preservation, terrestrial carnivores, ungulates, and archaic groups over 1 kg were the main focus of these analyses. Examination of this time range allowed interpretations of several important shifts in mammalian evolution. Among these are the possible effects of the Eocene-Oligocene climatic transition on mammalian community membership. It is difficult to assess direct effects of climate or competition on species extinctions, but it is possible that the immigration of modern groups

had a major effect on community changes and on the extinction of archaic lineages such as creodonts and "condylarths." A goal of this study was also to determine which superposed fossil localities were the best-preserved and correlated, making them good candidates for more in-depth paleoecological characterization. Not unexpectedly, the long range of localities in Wyoming and Nebraska were found to be prime candidates.

MAGNETIC STRATIGRAPHY OF THE LOWER-MIDDLE MIOCENE PAWNEE CREEK AND MARTIN CANYON FORMATIONS, NORTHEASTERN COLORADO

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The Pawnee Creek Formation consists of about 50 m of volcaniclastic siltstones and sandstones incised into White River Group deposits in northeastern Colorado. Since Matthew's classic 1901 study, it has produced an important assemblage of early and late Barstovian (middle Miocene) mammals, including large collections in the Frick Horse & Mastodon Quarry. Paleomagnetic samples were taken spanning the entire formation at Davis Ranch, and at the type section near Eubanks. The samples showed a single component of remanence, with little overprinting, and most of the remanence is held in magnetite. The normal and reversed mean directions passed a reversal test, showing that the direction is primary and overprints have been successfully removed. Most of the section is reversed in polarity, except for a short normal magnetozone in the top of the lower Pawnee Creek Formation. Based on Ar/Ar dates of 14.5 +/- 0.09 Ma and 14.3 +/- 0.02 Ma on the middle part of the section, we correlate the Pawnee Creek Formation with Chrons C5ACr to C5ADr (14.0-14.9 Ma). This places the Proboscidean Datum (long used to mark the beginning of the late Barstovian) at 14.5 Ma.

Unconformably beneath the Pawnee Creek Formation lies the Martin Canyon Formation, which yields an important early Hemingfordian (early Miocene) fauna. A section was taken through the Frick Clay Quarry to the top of the formation. Samples also had a remanence held in magnetite that passed a reversal test, showing that the remanence is primary. The base of the formation (including Clay Quarry) was reversed in polarity, but the remaining 30 m of section to the top were normal. Based on the early Hemingfordian fauna, we correlate the Martin Canyon Formation with Chron C5Er-C5En (19.0-18.3 Ma).

VARIATION IN HISTOLOGICAL MICROSTRUCTURES AMONG THE SKELETAL ELEMENTS OF *BOTHRIOLEPIS CANADENSIS* (PLACODERMI)

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Placoderm histology has received only scattered attention since the middle twentieth century. This is despite the fact that a detailed, anatomically complete study of placoderm tissue microstructures has the potential to clarify both the developmental relationships among vertebrate skeletal systems (dermal skeleton, splanchnocranium, axial and appendicular endoskeleton) and the phylogenetic relationships among the major clades of gnathostomes. Recent advances in the techniques of preparing and imaging fossil microstructure have made such an analysis possible, revealing new sources of information even within previously studied fossil tissues. For this study, I conducted the first survey of histological variation within a placoderm individual using two imaging methods: thin-section microscopy using Nomarski interference optics, and SEM imaging of specimens etched with chromium (III) sulfate. This survey included two nearly complete, three-dimensionally preserved specimens of *Bothriolepis canadensis* recovered from calcium carbonate nodules of the Escuminac Formation (Late Devonian, Frasnian Stage) near Miguasha, Quebec. Acetate-buffered acetic acid preparation enabled the careful isolation of each element for individual observation. This process removed any question that may otherwise arise regarding the identity and topographic position of each element studied. I report on the variation in histological microstructures within an individual of *B. canadensis* and use this new information to address the developmental relationships among the various placoderm skeletal systems.

MAGNETIC STRATIGRAPHY OF EOCENE-OLIGOCENE MARINE -MAMMAL-BEARING FORMATIONS IN NORTHWEST WASHINGTON AND SOUTHERN BRITISH COLUMBIA

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The Oligocene Sooke Formation near Victoria, British Columbia, and the Eocene-Oligocene Makah Formation on the northwestern tip of the Olympic Peninsula, Washington, have long been important localities for marine mammals. The Sooke Formation produces the type material of the desmostylian *Cornwallius sookensis*, plus an undescribed jaw fragment of a primitive new species of the "beach bear" *Kolponomos*. The Makah Formation yields numerous specimens of some of the most primitive known baleen whales, most still bearing teeth. Paleomagnetic samples were collected from both formations, and demagnetized using both alternating fields and thermal demagnetization. In most cases, the samples showed a single component of remanence held in magnetite with minor overprinting due to goethite. This component passed a reversal test, and in most cases showed counterclockwise tectonic rotations.

Comparisons to previously published Eocene-Oligocene magnetic sections in the Lincoln Creek Formation at Canyon River, Washington, and the Alsea-Yaquina-Nye formations at Yaquina Bay, Oregon, allowed us to correlate both our sections. The Sooke Formation is entirely reversed in polarity, but the presence of late Oligocene *Liracassis apta* Zone mollusks, plus the presence of *Cornwallius sookensis* in the upper Nye Mudstone, suggests a correlation with Chron C6Cr (24-25 Ma). The whale-bearing portion of the upper Makah Formation was entirely reversed in polarity. It yields early Oligocene mollusks and benthic foraminifera, so we correlate it with Chron C12r (31-33 Ma), making the primitive toothed baleen whales earliest Oligocene in age. Thus, these whales are among the oldest mysticetes known, comparable in age to the oldest specimens found elsewhere in the world.

A PRELIMINARY REPORT ON A DIVERSE ASSEMBLAGE OF EARLY CRETACEOUS PLESIOSAURS AND ICHTHYOSAURS FROM THE CLEARWATER FORMATION, NORTHERN ALBERTA, CANADA

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Open-pit mining in the Athabasca Oil Sands deposit by Syncrude Canada, Ltd., has serendipitously resulted in the discovery of nine specimens of large marine vertebrates—seven plesiosaurs and two ichthyosaurs, recovered from the Wabiskaw Member of the Clearwater Formation, a fine- to medium-grained, glauconitic sandstone of Lower Albian age (108-112 Ma). These successions were deposited during the first major marine transgression of the Boreal Sea southward into the Western Interior Basin of North America.

Three of the seven plesiosaur specimens are plesiosauromorph (long-necked) taxa, two are pliosauromorph (short-necked) forms, and two are fragmentary and taxonomically indeterminate. One of the pliosauromorphs, tentatively referred to the cosmopolitan genus *Leptocleidus*, is remarkably complete and constitutes one of the best-preserved plesiosaur specimens from North America. Both ichthyosaurs are referred to *Platypterygius*, including one nearly complete skeleton.

The Syncrude specimens are an important addition to the dearth of Early Cretaceous plesiosaur and ichthyosaur material, and are significant in several regards. A preliminary analysis suggests that several of the plesiosaur specimens represent new taxa, helping to bridge a 40 million year gap between the much greater diversity of plesiosaurs known from the Late Jurassic of Eurasia and the Late Cretaceous of North America. Collectively the specimens represent the oldest Cretaceous plesiosaur and ichthyosaur remains known from the Western Interior Basin, prior to the establishment of the Western Interior Seaway. New morphological data on *Leptocleidus* and other plesiosaur specimens will assist in clarifying aspects of plesiosaur systematics, which is currently in a state of flux. Finally, new phylogenetic data on *Leptocleidus* will allow the testing of biogeographic hypotheses with respect to sister taxa of similar age known from South Africa, Australia, and England.

NEW MATERIAL FROM AN OLD SPECIMEN: A CRANIAL DESCRIPTION OF *OPETIOSAURUS BUCCICHI* FROM THE LOST COUNTERPART

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For over a century aigialosaurs have been considered as a sister group to the Cretaceous marine mosasauroids. Their importance in this regard has been reinforced by the recent re-emergence of the snake origins debate. *Opetiosaurus buccichi*, a Cenomanian aigialosaur sometimes synonymized with *Aigialosaurus dalmaticus*, is known from a single specimen housed in the Museum of Natural History in Vienna, Austria. The holotype is composed of a part (the Museum specimen) and counterpart (the Geological Survey in Vienna) of a partially disarticulated skeleton. Fragments of the counterpart were recently located, after having been missing for the better part of the last century, including several portions of the vertebral column and the posterior two-thirds of the skull. The discovery of the skull material allows for a first glimpse at the ventral aspect of the skull morphology in addition to verification of previous descriptions and examination of the taxonomic debate.

The posterior skull region of *Opetiosaurus* is well preserved in the counterpart, allowing for a detailed description of the jaw joint and posterior cranial elements that was not previously possible. The dorsal cranial elements are also well preserved, showing large prefrontals, medially fused frontals and a transverse articulation between the frontals and parietals. The right jugal is long and slender, joining posteriorly with the large transverse process of the postorbitofrontal. The foramen magnum remains largely intact along with a well preserved exoccipital-paroccipital complex. The quadrate has a large suprastapedial process that lends it a circular shape commonly seen in mosasaurs; however, there is no evidence of an ossified tympanum within the alar cavity. As the aigialosaurs are known from few relatively complete specimens, the new information acquired from *Opetiosaurus buccichi* represents a significant increase in knowledge of the group.

FOSSILS AND THE EVOLUTIONARY RELATIONSHIPS OF CHARADRIIFORMES: A TREE AND A TIMESCALE FOR SHOREBIRDS

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We present a comprehensive cladistic analysis of shorebird genera (Aves, Charadriiformes) based on osteological characters. Trees resulting from our analyses include more than 50 living genera of these cosmopolitan birds and a number of fossil taxa that range in age from Paleocene through Oligocene. In line with recent hypotheses founded on molecular data, as well as some older morphological studies, parsimony analyses of this new data set indicate the presence of two large and well-supported clades within Charadriiformes: (1) gulls, auks, terns, skimmers, skuas and relatives; (2) plovers, lapwings, snipe, curlew and related birds.

Drawing on molecular sequences and fossil information we present a well-corroborated time scale based on internal calibration points for major divergences within shorebirds. Divergence-time estimates founded on fossil anchorpoint taxa suggest that the basal radiations of Charadriiformes took place in the Cretaceous even though all verifiable fossil records for these birds are from the Tertiary and younger. This study represents the first combinatorial approach to reconstructing the evolutionary history of this diverse clade of modern birds.

TOWARDS A REFINED VERTEBRATE BIOSTRATIGRAPHY FOR EOCENE STRATA OF THE EUREKA SOUND GROUP, CANADIAN HIGH ARCTIC

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Recent fieldwork in lower-middle Eocene terrestrial vertebrate-bearing strata of the Margaret Formation, Eureka Sound Group near Bay Fiord, central Ellesmere Island, Nunavut boosts the known diversity of the Eureka Sound vertebrate fauna and provides detailed stratigraphic relationships amongst fossil localities. Some 50 fossil vertebrate localities have now been tied into stratigraphic sections. Stratigraphic correlation of beds identifies three fossil vertebrate-bearing horizons near Bay Fiord. The fauna from the two stratigraphically lower horizons (containing over 20 mammalian genera) appears to correlate to late Wasatchian (i.e., Lostcabinian) faunas from mid-latitudes. Although the known sample from the third and stratigraphically highest fossil vertebrate-bearing horizon is of relatively low diversity, the fauna appears most similar to Bridgerian (i.e., early middle Eocene) faunas from mid latitudes. Bridgerian localities appear to be a few hundred meters stratigraphically above the highest Wasatchian localities.

Sample collection and stratigraphic analysis of fossil vertebrate-bearing strata of the Margaret Formation near Stenkul Fiord, southern Ellesmere Island, was carried out in 2002. Fossil localities were tied into the well documented coal stratigraphy in that area. Previous palynological studies of others suggested that the Eureka Sound Group strata at Stenkul Fiord range from Late Paleocene to Early Eocene in age. However, the vertebrate faunal assemblage in this area appears most similar to the Early Eocene (i.e., Wasatchian) fauna at Bay Fiord. Investigation of the mammalian taxa and palynology samples collected in 2002 should help resolve the apparent mismatch of the age of this section.

LAS AGUILAS: AN UNUSUALLY RICH CAMPANIAN-AGE VERTEBRATE LOCALE IN SOUTHERN COAHUILA, MEXICO

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Las Aguilas (LA) is a rich vertebrate fossil locale in Coahuila, Mexico, that yields new faunal and paleoecological data about N. America's southernmost Campanian-age dinosaur community. Flat-lying strata of the Cerro del Pueblo Fm. (CdP) at LA contrast with dipping strata elsewhere in the region and suggest that fossil richness may reflect local structure. A composite 800m thick section places LA strata in the middle of the CdP. Facies analysis confirms a year-round warm/wet climate and indicates the locale was part of a vast, low-gradient embayment that experienced storm activity and cyclical changes in relative sea level.

Three stratigraphically discrete trackway sites at LA represent the most extensive dinosaur ichno-localities in Mexico. At least nine partially articulated hadrosaur skeletons occur through a 35 m stratigraphic interval. Each is encased in calcareous mudrock and some lie immediately above storm-generated shell coquinas. Mollusk assemblages suggest a brackish-water setting during burial. Concretionary development around bones indicates early diagenetic cementation of adjacent muds, probably driven by bacterial decomposition of soft tissue. The presence of skin impressions and unmodified bone surfaces, and the absence of evidence of scavenging, preclude an interpretation of lengthy subaerial exposure. Bloat and float, and/or possibly trampling in shallow water are suggested by a preservational mode of partial-to-complete skeletons consisting of partially disarticulated to associated remains that are largely unbroken. At one spectacular site an associated lambeosaurine partial skull and postcranium rest on a bed of wave-rippled sandstone that hosts dinosaur tracks and trackways.

A diverse non-dinosaurian vertebrate fauna of 13 taxa yields notable specimens of *Melvius* (two braincases and associated vertebrae of large size), a teleost (partial skull), the mosasaur *Clidastes*, a longirostrine crocodile, the turtle *Adocus*, and an unidentified turtle with large peripherals similar to those of *Neurankylus*. A varanid lizard and a pterosaur of small size are each represented by one element.

3-D ANALYSIS AND RETRODEFORMATION OF DEFORMED FOSSILS

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The morphology of fossils is important as fundamental data in paleontology. However, some fossils are so severely deformed by compaction and/or tectonic strain that reliable information is hardly obtainable. Precise analysis and retrodeformation of deformed fossils needs to utilize the 3-D strain ellipsoid concept. For calculation and rendering of 3-D computer graphics, morphological data of fossils is restricted to 3-D grid data, while conventional 2-dimensional analysis is possibly made by 2-D ellipse and 2-D (plane) digital images. In order to obtain such 3-D grid data, surfaces of fossils are converted to numerical grid data with (x, y, z) format of 0.1 mm interval by a simple laser measurement system newly developed. Visualization on a computer display was made by commercial 3-DCGs software with own programming.

The ratio and orientation of the principal strains can be calculated by measuring the distortion between such original perpendicular elements (OPEs) as the median and transverse line or plane in bones, shells and carapaces. In order to represent an OPE as a formula for line or plane, it can be given principal component analysis of a set of grid data that corresponds to an OPE. An equation of 3-D strain ellipsoid that represents deformation in shape contains 5 unknown quantities, that is, 2 principal plane strain ratios that consist of 3 principal longitudinal strains, and 3 rotations in 3 dimensions. The simultaneous equations of strain ellipsoids and statistical comparison of them give the value of those 5 unknown quantities.

We developed a statistical method and calculating programs to find these unknown quantities. Shape of strain ellipsoid from several OPEs is obtained. We applied this method and calculations to several skeletal elements of the *Utatsusaurus hataii* (Reptilia, Ichthyosauria) specimen excavated from the Lower Triassic of Japan.

ANTEATER, SLOTH, AND ARMADILLO BIOMECHANICS THEN AND NOW: ADAPTATIONS OF MODALITY IN THE ORDER XENARTHRA THROUGH TIME

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Xenarthra (anteaters, sloths, and armadillos) constitute a bizarre and fascinating group of mammals with a singular evolutionary history. The evolutionary hypothesis that Xenarthra represent a group derived from a single ancestor is undisputed due to an abundance of exclusive derived characters when compared to other mammals. Today, the four extant families are remarkably diverse: anteaters and armadillos are adapted to digging while the two extant families of sloths are adapted to an arboreal life of hanging by all four appendages. How are they different than their predecessors?

The biomechanics of this group remain unstudied. Examination of this aspect of xenarthran biology undoubtedly will lead to some interesting conclusions. This is the only taxon of mammals that possess a unique structure on their vertebrae (called a xenarthrous articulation—doubly articulated vertebrae, vs. remaining mammals' single articulation). All members, except glyptodonts, have xenarthrous articulations, and no other mammal group has them. They have a solid pelvis, with the transverse process of the caudal vertebrae fused with the ischium. How did the adaptations to such different modalities evolve? Are there intermediate forms? By examining extant and fossil xenarthrans, the answer to these questions will be elucidated.

Thirty-six measurements were taken from 14 individual sloth, armadillo, and anteater specimens housed in museum collections. These measurements were then analyzed by a variety of indices to examine the differences of modality among families and within genera. These will be compared to xenarthran fossil biomechanical measurements. The results will allow a biomechanical evaluation among the extant and extinct families within the order. These biomechanical data also could lead to novel hypotheses about evolutionary relationships as well as certainly novel ecomorphological inferences.

DISCOVERY OF *"PTERODON" DAHKOENSIS* (CREODONTA) FROM THE EOCENE PONDAUNG FORMATION, MYANMAR

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The Pterodontinae is a group of hyaenodontid creodonts, and the majority of members existed in the late Eocene to middle Miocene of southern Europe, Africa, and south Asia. As exceptions, one species of pterodontine,*"Pterodon" dahkoensis*, is known from east Asia. This species was previously represented by a mandible with P_2-M_3 from the Upper Lumeiyi Formation (middle Eocene, southern China) and an isolated M_3 from the Rencun Member of the Heti Formation (middle Eocene, central China). New materials of this species have been collected from the upper middle Eocene Pondaung Formation in Myanmar. This discovery fills the gap in the pterodontine distribution that existed between China and western half of Afroeurasia.

The materials from Myanmar consist of a mandible with P_2-M_2 and two maxillary fragments. Both of the maxillary materials are poorly preserved but provide information on upper tooth morphology of the species for the first time. We found several differences in dental morphology of *"P." dahkoensis* from those of African and European *Pterodon* species. *"P." dahkoensis* is more primitive in having a vestigial metaconid on M_3, a well basined talonid with three distinct cuspids on P_4-M_3, more diagonally oriented and shorter carnasial blades on upper and lower molars, and less anteroposteriorly enlarged amphicone on M^1. On the other hand, it is unique in lacking P_1, in having a bulbous main cusp with distinct anterior and posterior ridges on lower premolars, in having a pronounced protocone on P^4, and in indicating more complete fusion of paracone and metacone on M^1. Because of the above-mentioned features, we agree with the exclusion of *"P." dahkoensis* from the genus *Pterodon* and consider it a primitive pterodontine which should be assigned to a new genus.

PSAMMOSTEIDS (AGNATHA, HETEROSTRACI) FROM THE LATE DEVONIAN OF ARCTIC CANADA

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Psammosteids are extinct armored agnathans with paired posterolaterally placed common branchial openings. They occur from the Early (Pragian) to Late (Frasnian) Devonian of Germany, Poland, the Baltic States, and Russia and extend also into Scotland, Spitsbergen, Greenland, and arctic Canada before becoming extinct (in the ?Famennian). Although well known from the Baltic States where they have been used to develop a biostratigraphic scheme they are poorly known from arctic Canada.

A few fragments collected in Southern Ellesmere Island by the Norwegian Fram expedition (1900-1902) provided the basis for the description of three new psammosteid taxa. No further material was discovered until 100 years later when the Nunavut Paleontological Expeditions (1999-2002) collected specimens from the Devonian clastic wedge that extends

from Melville across Bathurst, Devon, and Ellesmere islands. Preliminary study of these specimens shows that the succession of psammosteid genera is similar to that in the Frasnian of the Baltic. Among the common genera are *Psammolepis*, *Psammosteus*, and *Ganosteus*, the latter characterizing the lowest part of the succession. The upper part of the sections contains a relative of the aberrant psammosteid *Obruchevia*, otherwise known only from Russia.

It is already clear from correlations developed within the Arctic that the Parry Islands Group on Ile Vanier (Bathurst Islands) has been placed too high in the Devonian. It is expected that further refinement of the arctic Late Devonian will be possible once study of this material is complete, and that the biostratigraphic scheme developed for the Late Devonian of Arctic Canada will then be used to correlate with the NW of the East European Platform succession.

STRUCTURE OF BIOLOGICAL APATITES

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The mineral in bones and teeth is a poorly crystallized impure hydroxyapatite (OHAp), $Ca_{10}(PO_4)_6(OH)_2$, that contains a few percent carbonate, has a variable Ca/P mole ratio and a variable amount of acid phosphate. Fossil bones and teeth may also contain substantial amounts of F^- ions. Structural differences from OHAp are difficult to investigate because of the submicron dimensions of the crystals. Nevertheless, infrared spectroscopy (IR) and Rietveld X-ray and neutron powder diffraction studies have proved very informative. X-ray diffraction, together with other techniques, also provides information about crystal dimensions.

As regards the CO_3^{2-} ion, studies on mineral and synthetic apatites have established that CO_3^{2-} ions may replace either OH^- (A-type) or PO_4^{3-} (B-type) ions in the unit cell. These substitutions are most readily identified with IR. Although it is thought that most of the CO_3^{2-} ions replace PO_4^{3-} ions in biological apatites, a small amount probably replaces the OH^- ions. We have recently studied a precipitated B-type CO_3Ap (CO_3 content 12.5 wt%) through Rietveld analysis of neutron powder diffraction data. Soft constraints were applied to the atoms of the CO_3^{2-} ion so its bond distances and angles were close to those in calcite. Refinements were possible with the CO_3^{2-} ion allowed to move freely. In the refined structure, the CO_3^{2-} ion occupied, randomly, the upper and lower faces of the tetrahedron normally occupied by the PO_4^{3-} ion, with its plane making an angle of approximately 30° to the mirror plane. This angle is consistent with previous polarized IR measurements on single crystals of francolite (a fluorcarbonate apatite) and human dental enamel.

LOCOMOTOR MODULES, LINKAGE AND MORPHOLOGICAL DISPARITY IN PTEROSAURS AND OTHER FLYING VERTEBRATES

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Ternary plots were used to investigate morphometric disparity of the lengths of principal hind limb elements (femur, tibia, metatarsal III) of pterosaurs. The results were also compared with similar analyses of data for bats and birds. Approximately half the known species (37) and genera (25) presently considered valid and almost all the principal clades currently recognised were represented in the pterosaur data set. This yielded a relatively tight, compact cloud of points, similar in volume to the cluster for bats, but less than half that for birds. The continuity of the pterosaur cluster at the finest level of resolution (5 per cent triangles), absence of outliers and a bootstrap test suggest that, at higher taxonomic levels, the data set accurately reflects known pterosaur diversity and may encompass much of their original true diversity. Pterosaurs are generally distinguished from birds by the relatively short metatarsus and in this respect are more similar to bats. Derived 'rhamphorhynchoids' such as *Rhamphorhynchus* have a relatively long metatarsus compared to the most basal known forms, whereas pterodactyloids show the opposite trend with a relatively short metatarsus in derived taxa such as *Pteranodon*. The relatively restricted range of morphometric disparity exhibited by pterosaur hind limbs is concordant with their remarkably conservative morphology which, apart from the fifth toe and length of the fibula, shows little variation across the entire clade. We argue that this conservatism is directly related to the structural and functional linkage, by the wing membranes, of the fore and hind limbs in the flight apparatus. Thus pterosaurs had a single locomotor module that served for both aerial and terrestrial locomotion and this exerted a strong constraint on morphological diversity, especially of the hind limbs. The same applies to bats, but not birds. Birds have three locomotor modules and the hind limbs, which are independent of the wings and tail, exhibit a far greater degree of morphometric and morphological diversity.

NEW CERATOMORPHS (MAMMALIA, PERISSODACTYLA) FROM THE EOCENE OF THE ILY BASIN, KAZAKSTAN

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The brontothere bonebed at Kyzyl Murun near Aktau Mountain in the Ily basin of eastern Kazakstan has yielded numerous skeletons of the middle Eocene (Irdinmanhan) brontothere *Protitan* and a skull, jaw and some postcrania of the amynodontid rhinoceros *Sharamynodon mongoliensis*. Additional preparation has revealed two new ceratomorph taxa represented by cranial, dental and postcranial material. Ily specimens of *Rhodopagus* are a skull, parts of three lower jaws and distal limb bones. These specimens are larger (M1-3 length ~ 30 mm) than previously described species of the genus and in the size range of *Yimengia laiwuensis*. However, the Ily specimens display morphological features that distinguish *Rhodopagus* from *Yimengia* (more prominent upper molar parastyles, more molariform upper and lower premolars, including p3-4 entoconids, and lower molar metalophids that are low and separated from the protolophids by a notch), so we judge the Ily material to represent a new, large species of *Rhodopagus*.

The second new ceratomorph from the Ily basin is represented by a complete skull and lower jaws with complete dentition and a partial postcranium, all from a single individual. This specimen belongs to a new genus related to but more primitive than *Teleolophus*. Thus, like *Teleolophus* it has high-crowned teeth and submolariform premolars, but the characteristic lophoid loop on the upper molars formed by labial joining of the protoloph and metaloph is less pronounced, and a distinct metacone is present. The relatively dolicochephalic skull of the Ily specimen has procumbent, chisel shaped and cuspate incisors, curved, saber-like canines, long diastemata, a shallow nasal incision (back to over the posterior end of the diastemata) and a weakly developed facial fossa. The new Ily taxa thus add to the extensive evolutionary diversification of ceratomorphs that took place (began) in Asia during the Irdinmanhan.

LATE CRETACEOUS MARINE VERTEBRATES FROM THE PEE DEE RIVER VALLEY, FLORENCE COUNTY, SOUTH CAROLINA

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Despite the first report of Cretaceous vertebrate remains from South Carolina nearly 150 years ago, the marine vertebrate faunas of most of South Carolina's Cretaceous units have never been described. Marine vertebrate faunas ranging in age from Middle Campanian to Late Maastrichtian recovered during a period of unusually low rainfall from localities in the Pee Dee River Valley of South Carolina are reported herein. The faunas contain abundant selachians, bony fishes, and reptiles. The chondrichthyian fauna includes *Hybodus, Lissodus, Squatina, Ginglymostoma, Plicatoscyllium, Carcharias, Scapanorhynchus, Archaeolamna, Cretolamna, Serratolamna, Squalicorax, Raja, Ischyrhiza, Ptychotrygon, Brachyrhizodus, Rhombodus,* and *Ischyodus*. Osteichthyians include pycnodonts, albulids, and the large predators *Enchodus, Lepisosteus,* and *Xiphactinus*. The marine reptile fauna is usually represented by isolated elements, but remains of chelonians, plesiosaurians, mosasaurs and crocodylians have been recognized.

The occurrence of temporally limited suites of species, particularly selachians, within the faunas allows for the correlation of their containing units with others in the region. The potential utility of vertebrates as biostratigraphic markers for the field recognition of Cretaceous units that are defined allostratigraphically and have no lithologic definition is suggested.

TUMORS, TEARS, FUSION, DECALCIFICATION, FRACTURES AND INFECTION—TOUGH TIMES FOR A TYRANNOSAUR

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Preparation of a recently discovered skeleton of *Gorgosaurus* sp. (Theropoda: Tyrannosauridae) from the Two Medicine Formation of Montana (Campanian) has revealed a multitude of pathologic findings and yields insight into behavior, sexual dimorphism, and disease. These findings include: calloused gastralia (fracture and calcified hematoma); bifurcated pes ungual I (split claw sheath); remodelled scapula-coracoid (consistent with a proliferative process and fracture); calloused and deformed right fibula (fracture and tendon retraction); detached greater trochanter of the left femur, with bone remodeling and fistulous tracts (trauma, reattachment and osteomyelitis); and calloused, right and left dentaries with fistulous tracts and subsequent loss of tooth positions (trauma and tooth root abscess with osteomyelitis).

Two pathologic findings appear to relate to sexual dimorphism in this robust (female) morphotype. The first is fusion of the 4th and 5th caudal centra (and their shared chevron), presumably in response to stress caused by the "overload" of a mounting male, as seen elsewhere in robust morphotype tyrannosaurids. The second is the collapse of the articular surfaces of at least eleven caudal centra, possibly the result of decalcification due to skeletal stripping of calcium for egg production. A heterogenous, spherical mass, occupying the caudal aspect of the braincase, is consistent with the presence of a large tumor which could have caused the incapacitation and death of this individual.

CRANIAL OSTEOLOGY AND ONTOGENY OF *CORYTHOSAURUS* (ORNITHISCHIA: HADROSAURIDAE)

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The lambeosaurine *Corythosaurus* from the Dinosaur Park Formation, southern Alberta, is known from over 20 articulated skulls. Skulls represent a nearly complete postnatal growth series ranging in size from small juveniles to large adults, but juvenile material is comparatively rare. Several recently collected juvenile skulls allow for an in-depth assessment of cranial growth and variation in *Corythosaurus*.

The precise taxonomic identification of juvenile lambeosaurines is complicated by the fact that the taxonomically important elements forming the cranial crest pass through morphologically similar ontogenetic stages. To confirm taxonomic homogeneity of the putative *Corythosaurus* ontogenetic series, I examined material from each of the four lambeosaurines known from the Dinosaur Park Formation to establish discrete, ontogeny-independent cranial characters that distinguish genera. Of these, the nature of the articulation between component crest bones is the most diagnostic character of lambeosaurines. *Corythosaurus* can be distinguished at all ontogenetic stages from other genera by a distinctly bifurcated anterior projec-

tion of the nasal that overlaps the dorsal premaxillary process in the anterior region of the crest.

Cranial growth is investigated using both quantitative and qualitative approaches. Most facial bones do not change shape significantly with growth, however the crest is a late-maturing feature that changes drastically through ontogeny. Net posterodorsal expansion of the nasal dominants crest growth. There is considerable intrageneric variation in crest shape, however two relatively distinct adult morphotypes can be recognized, suggestive of sexual morphs. One morph (putative females) exhibits differential dorsal and posteroventral growth of the nasal leading to a characteristic indentation along the posterior crest margin. Conversely, peripheral nasal growth is more uniform in the alternate morph, resulting in a relatively smooth outward curvature of the crest margin. The premaxilla-nasal fontanelle is prominent late into ontogeny, and subsequently closes in morph-related patterns.

A MIDDLE TURONIAN MARINE FISH FAUNA FROM THE UPPER BLUE HILL SHALE MEMBER, CARLILE SHALE, OF NORTH CENTRAL KANSAS

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A diverse piscine fauna is reported for the first time from the Late Cretaceous Carlile Shale of Kansas. The relatively shallow (<100 m) marine assemblage derives from a thin (1-3 cm) fish-tooth conglomerate which lies 3-4 m below the top of the formation near Lovewell Reservoir in Jewell County, and which accumulated during the late middle Turonian regressive deposition in the Greenhorn Sequence. In contrast to larger material from transgressive lag faunas at the bases of sequences, the Lovewell fauna consists mostly of very small material (teeth, dermal denticles, vertebrae, and scales), suggesting winnowing by weak, intermittent currents. Due to size sorting for smaller particles, and the presence of a nearby nursery ground, teeth of juvenile individuals are unusually well represented. The fauna consists of 17 taxa (first records for Kansas are marked with an asterisk): 7 sharks (*Ptychodus whipplei*, **Chiloscyllium greeni*, **Cantioscyllium d. decipiens*, *Otodus appendiculatus*, *Scapanorhynchus r. raphiodon*, *Squalicorax falcatus*, and **Scyliorhinus* sp.); 4 rays (**Rhinobatos incertus*, **Ptychotrygon triangularis*, **Ischyrhiza mira schneideri*, and **Brachyrhizodus mcnultyi*); and 6 bony fish (*Hadrodus priscus*, *Pachyrhizodus minimus*?, *Xiphactinus a. audax*, *a small unidentified albulid, *Enchodus gladiolus* and *E. petrosus*). As is found in many Late Cretaceous assemblages of marine shallow-water fishes, *Scapanorhynchus* is the most abundant shark and *Enchodus petrosus* is the most abundant of the bony fish. Both occur in far greater numbers than recorded in the younger, deeper water fauna of the Niobrara Chalk. Several elements of the fauna, however, do indicate a nearby deep-marine habitat (*Ptychodus*, *Chiloscyllium*, *Otodus* and *Scyliorhinus*). The rare albulid teeth may evince a small estuarine component, but neither freshwater nor terrestrial vertebrate remains are represented. This Kansas fish fauna closely resembles that from the Carlile of SW South Dakota, but less closely resembles that from the Carlile of NE South Dakota The Lovewell fauna suggests a relatively shallow marine environment located far from the eastern shore of the Western Interior Sea.

CERATOPSID DINOSAUR CRANIAL MORPHOLOGY AND BEHAVIOR REINTERPRETED: EVALUATING THE BOVID PARADIGM

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Since their discovery over 100 years ago, ceratopsid dinosaurs have been compared to bovid mammals, primarily due to the common presence of horns in both groups. This "bovid paradigm" has colored interpretations of ceratopsid behavior, sexual dimorphism, systematics, functional morphology, and pathology. However, a critical comparison of horn morphology in bovid mammals and ceratopsid dinosaurs has not been undertaken. Ceratopsid postorbital horns typically point rostrally and dorsally, whereas bovid horns point caudally or laterally. Additionally, the cornual sinus within the postorbital horns of ceratopsids is a simple tube extending for no more than one-third of the horn's length. This contrasts with the internally strutted, frequently extensive cornual sinuses seen in bovid horns. These differences have important implications for ceratopsid behavior, particularly if it is assumed that at least some ceratopsids engaged in intraspecific combat. Work with scale models of ceratopsid skulls allows exploration of possible fighting modes. In addition to horn locking, skull roof contact is an important part of combat in many bovids. Such skull roof contact was impossible in some chasmosaurine taxa, such as *Triceratops*, due to near-vertical postorbital horn orientation, the presence of a nasal horn or boss, and limitations in skull mobility. Also, this horn orientation would have made frontal charges and head butting (as in *Bison* or *Capra*) nearly impossible to execute without great risk of injury. The presence of a nasal horn in many ceratopsids also complicates the bovid analogy. Ultimately, the wide range of ceratopsid horn morphologies illustrates the difficulties of inferring dinosaur behavior and evolution from modern analogues. For instance, some centrosaurine ceratopsids, such as *Pachyrhinosaurus*, may have evolved flank butting from a "jousting" fighting style. This possibly counters previously proposed, bovid-based models of ceratopsid horn evolution, in which flank butting behavior is hypothesized to evolve inevitably into jousting and horn locking. Many aspects of ceratopsid horn use will likely remain unknowable.

FEMORAL DIMENSIONS AND BODY SIZE OF *ALLIGATOR MISSISSIPPIENSIS*: ESTIMATING THE SIZE OF FOSSIL CROCODYLIANS AND THEIR KIN

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Body size (total length or body mass) is tightly correlated with femur length and other femoral dimensions in *Alligator mississippiensis*. Regression equations of body size against femoral dimensions for alligators satisfactorily predict the body sizes of other species of extant crocodylians, suggesting that alligator-based equations may be appropriate for extinct species of crocodylians and their close relatives. Predicted total lengths and body masses of some extinct forms are close to estimates made from other skeletal parameters. However, femur-based size estimates of a presumed large individual of *Deinosuchus* are considerably less than previously published estimates based on other bones of other big individuals. If our individual attained such sizes, *Deinosuchus* must have reduced femur size relative to overall body size.

A NEW INTERPRETATION AND DESCRIPTION OF THE *ANCHISAURUS POLYZELUS* (SAURISCHIA: SAUROPODOMORPHA) BRAINCASE AND ITS IMPLICATIONS FOR PROSAUROPOD SYSTEMATICS

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A new description and reconstruction of the braincase of *Anchisaurus polyzelus* (YPM 1883) are produced based on comparisons with *Thecodontosaurus* (YPM 2192), *Sellosaurus* (SMNS 12667) and *Plateosaurus* (AMNH 6810).

The skull of *Anchisaurus polyzelus* was apparently separated into several pieces shortly after collection in 1883, with a transverse fracture separating the posterior quarter from the remainder of the skull. The skull was repaired sometime afterwards, with the two major pieces attached cleanly along the dorsal elements of the skull. However, a ventral wedge of bone rostral to the transverse break was not reattached and its current whereabouts are unknown. The missing wedge of bone affects the majority of the basisphenoid and the posterior area of the left mandibular ramus. Contrary to previous accounts, the basipterygoid processes are not preserved in the skull of YPM 1883, therefore the often-cited apomorphy "small basipterygoid processes" cannot be reliably demonstrated.

Based on this new information, the preserved braincase elements appear similar to those in other well-known prosauropods. Many of the braincase sutures are still visible suggesting the specimen is a juvenile, however histological analysis of the specimen is required for a definitive ontogenetic age assessment.

These observations have significant implications for assessing phylogenetic hypotheses proposed for the Sauropodomorpha. A major apomorphy for the genus *Anchisaurus* is shown to be absent, suggesting the validity of the genus requires clarification in future work. The condition of the *Anchisaurus* braincase provides important comparative material for the upcoming description of new prosauropod material from Nova Scotia and future studies of *Ammosaurus* or *Massospondylus*, the other prosauropod genera previously reported from North American deposits.

DETERMINATION OF RESOURCE PARTITIONING IN A PREDOMINANTLY C3 ENVIRONMENT BY THE ANALYSIS OF STABLE ISOTOPE VALUES FROM HERBIVORES IN YELLOWSTONE NATIONAL PARK

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Stable isotope values have been used to examine resource partitioning among ancient taxa in paleoenvironments where both C3 and C4 flora were present, but partitioning has rarely been shown by this method in strict C3 environments. Before 7 million years ago in North America, and above 45º N latitude even today, only C3 flora occurs. To provide a modern analog useful in interpreting fossil data, this study examined resource partitioning of large herbivores living in the C3 environment of present-day Yellowstone National Park, an ideal site for this study because it has the largest diversity of ungulates of any single ecosystem in North America. Stable carbon, nitrogen, and oxygen isotope values were determined in both tooth enamel and scat. The following questions were addressed: (1) how is niche partitioning among large herbivores accomplished in a strict C3 environment; (2) How well are the partitioning patterns reflected in the isotope data of both scat and tooth enamel samples?

The herbivores included in this study were *Antilocapra*, *Bison*, *Cervus*, *Odocoileus*, and *Ovis*. These genera inhabit different parts of the park and feed on different resources during the summer. Both inter-generic and intra-generic comparisons were made using the fecal and tooth enamel isotope values. The carbon isotope values suggest that the tooth enamel and scat samples faithfully record predominantly C3 forage for the five ungulate genera. Genera that live in a more closed habitat, such as *Cervus* and *Odocoileus*, appear to have more negative carbon isotope values than do open habitat animals such as *Bison*, signifying that resource partitioning in either forage or habitat is possible to ascertain. Results suggest that (1) resource partitioning among ungulate genera is possible to distinguish by the analysis of stable isotope values in predominantly C3 environments; and (2) the existing Yellowstone ecosystem provides a model for understanding resource use and partitioning among fossil taxa in the predominantly C3 environments that dominated prior to the worldwide C4 global carbon shift 7 million years ago.

THE FIRST PALEOGENE MAMMAL RECORD OF MIDDLE AMERICA: HELOHYIDAE NEW GEN. AND SP.

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The new taxon is based on a small mandible fragment with bunodont M_{1-3} (total antero-posterior length, 28.5 mm), collected from the amberiferous strata of Simojovel, in north-central Chiapas. These rocks are part of an unnamed formation, and consist of dark gray to black, organic matter-rich, fine-grained, very fossiliferous, shaly phyllarenitic sandstone to mudstone, laid down in an estuarine to swampy lagoonal environment. These strata belong to the upper part of the *Globigerina opima opima* Range Zone and the lower part of the *G. ciper-*

oensis ciperoensis Interval Zone. They were later calibrated and found to fall within Chrons C10-C9, which are placed between 29.4-29.0 Ma, *i.e.,* in the early late Oligocene.

The Simojovel specimen's lower molars are low crowned, typically bunodont, increase in size from M_1 to M_3, and the M_3 hypoconulid is large. These features sharply set it apart from the tayassuids and leptochoerids, *i.e.,* the known late Oligocene North American bunodont artiodactyls, and bring it within the Helohyidae. It differs from the genera already included in the family Helohyidae (*Helohyus*—includes *Lophiohyus-Discritochoerus, Parahyus* and *Achaenodon* in North America; and *Gobiohyus* in Asia) in having cristids on the anterior slope of the trigonid cuspids, short cristid obliqua, a tiny paraconid, and small mesoconid and hypoconulid, except in M_3, where it is very large and blunt.

This record extends the geochronologic range and geographic distribution of the Helohyidae from the late Eocene of North America and Asia, to the early late Oligocene (early Arikareean) of southernmost North America, *i.e.* Chiapas, which is regarded as part of Middle America. The new helohyid is also the southernmost record of Paleogene mammals, not only from Mexico, but from all North America. The new helohyid significantly adds to the meager, but exceedingly important, database of Paleogene vertebrates in the tropics.

PRELIMINARY NOTES ON THE TAPHONOMIC AND PALEOECOLOGIC SETTING OF A *PACHYRHINOSAURUS* BONEBED IN NORTHERN ALASKA

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The northern part of Alaska contains a number of Cretaceous dinosaur localities, the most famous of which is the Liscomb bonebed. Virtually all localities are along the Colville River. These localities are most prevalent in the Prince Creek Formation (Campanian-Maastrichtian), a rock unit comprised largely of fluviatile sediments shed off the rising Brooks Range during the Late Cretaceous.

Extensive excavation of the Kikak-Tegoseak Quarry in 2002 has shown this site to contain a preponderance of remains of *Pachyrhinosaurus* (Dinosauria: Ceratopsidae). Excavation of a 4 m by 4 m pit within the bonebed yielded the skeletal remains of at least eight individuals of *Pachyrhinosaurus*, as determined from the number of recovered occipital condyles. Based on the nearly adult size, and incomplete fusion of cranial elements, these individuals appear to all be sub-adults. The condyles ranged in diameter from five to eight centimeters. Other taxa from this quarry are osteichthyan fishes, dromaeosaurs, tyrannosaurids, ornithomimids, and hadrosaurs.

Pollen from this site includes the insect-pollinated taxa, *Aquiliapollenites* and *Fibulapollis scabratus*. Small pieces of amber were also recovered. The vegetation of northern Alaska during this time was largely a confier forest on the coastal plains, with a riparian broad-leafed deciduous forest. The understory of the conifer forest was likely comprised of ferns and angiosperms.

Both the Liscomb and Kikak-Tegoseak bonebeds were formed predominantly by catastrophic capture of *Edmontosaurus* in the former, and *Pachyrhinosaurus* in the latter, suggesting that seasonal runnoff from the rising Brooks Range may have been a substantial hazard to gregarious dinosaurs on the ancestral North Slope.

COMBAT-INDUCED INJURIES IN ADULT MALE *MAMMUT AMERICANUM*

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Several well preserved specimens of adult male American mastodons (*Mammut americanum*) from late Pleistocene deposits in the Great Lakes region, USA, show evidence of perimortem injuries that were probably sustained during combat with another adult male mastodon. The most consistently repeated type of damage observed on these specimens is a circular to irregular, unilateral puncture through the lateral skull wall defining the medial surface of the temporal fossa, anterior and medial to the mandibular articulation. Although such an injury was probably not immediately fatal, it implies damage to the masticatory musculature that would have precluded normal feeding. Season of death of these individuals, determined from tusk growth increments and seasonal variation in oxygen isotope composition of tusk dentin, is generally middle to late summer. Tusk increments near the end of life show reduced rates of dentin apposition that may indicate onset of musth, the male reproductive period during which (in extant elephants) the likelihood of aggressive encounters between males is greatly increased. Other patterns of bone breakage on these animals include rib fractures, fractures of caudal vertebrae near the base of the tail, and impact damage to bones, including instances of vertebral damage that imply trauma to the spinal cord. Much of the bone damage on these specimens is explicable as a consequence of impact of a tusk tip of another male mastodon. Given the upwardly (and slightly inwardly) directed tusk tips of adult mastodon males, these injuries imply a style of combat in which the head is deeply depressed and then forcefully elevated. Thickening of the premaxilla along the dorsolateral margin of the tusk alveolus is associated with a distinctive, high-relief region on the alveolar surface suggestive of greatly thickened and lengthened fibers of the periodontal ligament. Such a configuration could have accommodated high dynamic loads associated with accelerating the massive tusks upwards and impact with an opponent. Some combat victims were scavenged and butchered by humans, but others show no evidence of human association.

THE ABANICO FORMATION OF THE CHILEAN ANDES: AN EXCEPTIONAL EOCENE-MIOCENE RECORD OF SOUTH AMERICAN MAMMAL EVOLUTION

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Since our initial discovery of fossil mammals in volcaniclastic sediments of east central Chile, we have recovered more than 1,000 specimens from at least 12 new assemblages, spanning the Eocene to mid-Miocene and ~ 4º of latitude, in the Andean Main Range. Fossils are so ubiquitous in this unit (the Abanico Fm.) that it now represents a premiere archive of mammal evolution in South America. The unusual depositional setting of these faunas accounts for their remarkably high proportion of well-preserved specimens, and permits the first precise radioisotopic dates for many Land Mammal "Ages."

The earliest Oligocene (to late Eocene?) Tinguiririca and ?middle Eocene Tapado faunas along the upper Río Tinguiririca were our first two finds in the region. At least three late Oligocene (to early Miocene) assemblages (Boca Toma, Los Sapos, Estero San Francisco) in the upper Río Maipo drainage ~100 km N of Tinguiririca represent our northernmost localities within the formation. Slightly further south (~60 km N of Tinguiririca) at least three new earliest Oligocene to earliest Miocene faunal assemblages were discovered along the upper Cachapoal and Las Leñas rivers. The latter is noteworthy for producing the earliest well-preserved New World anthropoid primate skull. Sparse Eocene? fossils have been recovered along the Río Azufre, just N of the Tinguiririca valley. To the south, important assemblages have been discovered at Laguna de Teno, Río Vergara, and Río Upeo (all ~15-25 km S of Tinguiririca; late Oligocene to early Miocene) and, in strata correlative to the Abanico Formation, new fossiliferous mid-late Miocene sites at Laguna del Laja (~300 km S of Tinguiririca).

The ~ 31.5 Ma Tinguiririca Fauna is remarkable for: a) the completeness of its >400 specimens; b) its diversity (>25 taxa, most new); c) representing a new South American Land Mammal "Age"; d) containing the oldest known caviomorph rodents; e) providing evidence (hypsodonty, cenogram, macroniche) of the earliest open grassland habitats known globally; and f) clarifying events near the Eocene/Oligocene boundary and its associated climatic, paleoenvironmental and biotic changes.

FOSSILS TEST HOW THE MOLECULAR CLOCK TICKS

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Much as molecular data test taxon relationships, fossil data test dates for phylogenetic splits hypothesized by extrapolated molecular clocks. When the fossil record is "good," it stands as a strong data source that constrains time of origin of groups, that time otherwise estimated by assuming a constant rate of molecular change. It remains to specify and define what is "good."

Some molecular data have supported a *Homo-Pan* split in excess of 7 Ma. This seemed extreme, but did not violate the fossil record. The discovery of *Sahelanthropus* at 6-7 Ma came as a surprise for paleontology and filled the fossil record as predicted by molecular data.

In contrast, molecular split estimates for Glires are consistently extremely old, such that they do indeed violate the fossil record. Early murine rodents have an excellent fossil record in the Indian subcontinent and point clearly to a late Miocene split for *Mus-Rattus*. Dates of 40 and 20 Ma are excessively old. A revised molecular approach placing the split near 16 Ma is still simply too old. Fossil murines provide an example to illustrate conditions in the fossil record that require recalibration of the molecular clock: densely sampled fossil sequence with data preceding and succeeding the split; sister taxa occurring in the fossil record preceding the split; fossil data from adjacent biogeographic provinces preceding the split and including outgroups but no ingroups. In this case, murine diversification began no earlier than 12-13 Ma, based on a combined absence of ingroups and presence of outgroups in older rocks sampling the same habitat.

Given conditions such as these, fossil evidence provides additional tie points for the molecular clock and refines the time-keeping ability of the clock. Fossil data have the potential to expose phenomena that cause the clock to tick at varied rates. Such complementary data have to be considered together in analyzing evolutionary patterns.

EARLY CROWN-GROUP CETACEA IN THE SOUTHERN OCEAN: THE TOOTHED ARCHAIC MYSTICETE *LLANOCETUS*

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From northern Tethyan origins, cetaceans expanded into the proto-Southern Ocean in the later Eocene, reaching 45°S by >37 Ma (New Zealand) and >60°S by >34 Ma (Seymour Island, Antarctica). Seymour Island Cetacea from the Eocene shallow marine La Meseta Formation include fragmentary presumed basilosaurid archaeocetes. More notable is the toothed stem mysticete, *Llanocetus denticrenatus*, from the uppermost La Meseta Formation (nearby Sr date: ~34.2 Ma). The species has a *Basilosaurus*-like cranium but a broad-based, dorsoventrally thin rostrum which appears to have been attenuated apically (the tip is lost). Teeth are heterodont but not obviously polydont; the cheek-teeth are small with strongly palmate denticles. Wide diastemata probably allowed some teeth to alternate, forming a food-sieving mechanism. Some teeth occluded, however, as indicated by crown wear. Abundant fine grooves around the alveoli suggest an enhanced palatal blood supply. The mandible is oval in section, with a strong coronoid process and large mandibular foramen. Associated elements include a cervical vertebra, the manubrium, many ribs, a putative femur and a possible part of the pelvis. Isolated large pachyostotic vertebrae and ribs from other localities in the La Meseta Formation probably also represent *L. denticrenatus*. With cbl estimated at >1800 mm, *L. denticrenatus* was perhaps >9 m long, markedly larger than other named stem-mysticetes. The species is interpreted as a filter feeder that is structurally intermediate between basilosaurid archaeocetes and more-crownward mysticetes. Because *L. denticrenatus* is the most basal named mysticete, it provides a minimum age of origin for the mysticete sister-group Odontoceti.

A smaller putative species of *Llanocetus*, known from a part skull and teeth, is from the basal Oligocene Ototara Limestone of New Zealand. Species of *Llanocetus* lived in the Southern Ocean at a time of significantly fluctuating productivity associated with the opening

of ocean gateways and the Oi-1 ice advance. Such oceanic change probably played a major role in mysticete evolution.

NEW MORPHOLOGICAL SUPPORT FOR THE PHYLOGENETIC AFFINITY OF ARTIODACTYLA AND CETACEA

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Results from both morphological and molecular phylogenetic reconstruction independently support a close relationship between Cetacea and Artiodactyla (Cetartiodactyla). Evidence from the paraxonic foot, astragalar and calcaneal anatomy indicate a sister-taxon relationship between artiodactyls and whales. Extensive molecular data support a whale-hippo relationship; however, there is a lack of morphological data to support this hypothesis. The fact remains that molecular studies cannot elucidate the morphological character transitions that must have taken place in the evolution of whales and artiodactyls, nor can they help in understanding the phylogeny of the numerous extinct members of both groups.

Morphological analysis of specimens of early artiodactyls from the Bartonian (MP 19, late Eocene) deposits of France reveals that they share features of the deciduous dentition with those of some derived archaeocete whales. These characters provide the first morphological evidence supporting the inclusion of whales within Artiodactyla, and may improve the resolution of basal nodes in the topology. That these characters are not seen in the earliest members of Cetacea and Artiodactyla has broad implications for the distribution of dental characters in key artiodactyl and cetacean clades and may suggest that considerable homoplasy has occurred. These data are crucial to our understanding of the artiodactyl-whale relationship, and suggest a potential mechanism that would account for previously unexplained morphological transitions in whale and artiodactyl evolution.

***ALLOSAURUS* AS A GENERALIZED PREDATOR IN THE MORRISON FORMATION PALEOECOSYSTEM (LATE JURASSIC; NORTH AMERICA)**

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In simplified models of ecosystems with a fixed number of herbivorous species and a fixed amount of biomass transfer from prey to predator species, several end-member patterns are possible. The main variables are predator diversity, abundance, and specialization. The possible patterns these variables can take include low predator diversity with equal abundance and low specialization, high diversity with equal abundance and high specialization, low diversity with equal abundance and moderate specialization, and high diversity with unequal abundance and mixed specialization. A more complex model incorporating approximate Morrison Formation predator-prey diversity ratios and within-group abundance proportions for both predators and prey suggests that the last of the above simplified models most closely matches the situation in the Late Jurassic of North America. Theropods are relatively diverse in the Morrison Formation; the fauna includes ten theropod dinosaur genera compared to 12 herbivorous dinosaur genera. The abundances of the theropod genera are uneven, with *Allosaurus* accounting for nearly 75% of the specimens. In both the simplified and more complex models, the most common theropod (*Allosaurus*) must feed on more types of prey species than other theropod taxa in order for the modeled abundances to match those observed in the Morrison Formation. These models suggest that *Allosaurus* was a generalist predator and that other theropod taxa were more specialized. Other large theropods such as *Torvosaurus* and *Ceratosaurus* may have overlapped to some degree with *Allosaurus* in prey species targeted, but small theropods such as *Coelurus* and *Ornitholestes* probably fed largely on small, perhaps non-dinosaurian prey.

THE TAPHONOMIC SETTING OF TWO MIRED SAUROPODS (WESSEX FM, ISLE OF WIGHT, UK), PALAEOECOLOGICAL IMPLICATIONS AND TAXON PRESERVATION BIAS IN A LOWER CRETACEOUS WETLAND

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The Wessex Fm. (Barremian, Lower Cretaceous) of the Isle of Wight, UK, has historically yielded many tantalising fragments of sauropod dinosaurs. Here we describe the taphonomic setting of a new site preserving two small conspecific individuals, possibly diplodocid, and discuss the palaeoecological implications.

Three small forelimbs (1.2 m in length) are preserved articulated in life position with both individuals facing south, 4 m apart, in the same horizon. The vertical attitude of the bones, a lack of elements other than the limbs, and their preservation in smectite rich palaeovertisols (mottled/red marls) strongly suggests a miring event. A shed theropod tooth found with the bones supports the likely hypothesis that the mired carcasses were subsequently scavenged, leaving only the embedded limbs to be preserved. The coincidental miring of two possibly juvenile conspecific sauropod dinosaurs raises many intriguing palaeoecological questions. Other unpublished sauropod sites within the Wessex formation similarly demonstrate taphonomic conditions suggestive of miring events.

Tentative evidence supports the hypothesis of taxon preservation bias between different facies. Sauropod remains, many recognisably *in situ*, constitute a higher percentage of the megafauna within red and purple marls (medium to well drained oxidised sediment) than other facies. The most productive facies, plant debris beds (waterlogged reduced sediment, formed by fire-flood associations), yield an allocthonous megafauna dominated by the large ornithopod dinosaur *Iguanodon*. The *Hypsilophodon* bed (mottled sand/mud facies, mudflows) yields a megafauna almost exclusively composed of small subadult/juvenile *Hypsilophodon* very commonly preserved articulated in 3 dimensions. These morphologically dissimilar taxa were likely susceptible to different preservation biases, manifested in the fossil record by their preferential preservation in different facies.

COMPARISON OF ELEMENTAL AND OXYGEN ISOTOPE VARIATION PROFILES IN PROBOSCIDEAN TUSK DENTIN

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Reconstructions of the paleobiology of extinct vertebrates based on the stable isotopic composition of bioapatites rely on preservation of original compositions by fossils, but recognition of alteration has proved difficult. Variation in elemental composition of fossil relative to modern bioapatite is a potential indicator of mineralogical, hence isotopic, alteration. We have measured isotopic and elemental profiles in tusk dentin from four fossil proboscideans. Tusks are ideal for this study because dentin is argued by some to be easily altered and the size and simple accretionary geometry of tusk growth allow high-resolution serial sampling. Despite differences in preservation that range from pristine to altered, these tusks each have variable $\delta^{18}O$ values. Two mammoth tusks from Siberia and Wrangel Island look like modern ivory and have $\delta^{18}O$ values that vary by 4.7 and 3.8 permil without regular seasonal patterns. A mammoth tusk from South Dakota is chalky and friable, but exhibits clear seasonal variations in $\delta^{18}O$ of ca. 4 permil. A mastodon tusk from New York that is well-preserved but stained reddish-brown has $\delta^{18}O$ values that vary by 3 permil without a seasonal pattern. Elemental profiles measured parallel to the isotope profiles by laser ablation inductively-coupled mass spectrometry show little correlation with the isotope profiles. Ca and P concentrations vary, but neither exhibits seasonality and the Ca/P ratios are more or less constant. All tusks have measurable amounts of B, Na, Mg, K, Ti, Sr, Ba, and Zn; 12 other elements are present in some but not all tusks. In each tusk, different combinations of elements are variable, but none vary seasonally. Some elemental variations may be primary and reflect a dietary or migratory signal, but elements that only vary near the pulp cavity or cracks in the dentin suggest some localized post-mortem alteration. While each element must be considered individually, overall our results imply that elemental variations are not necessarily direct indicators of isotopic alteration.

BASICS OF MOLDMAKING—FILLING AND MOLD DESIGN CONSIDERATIONS

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Moldmaking is an integral part of the preparation of fossil vertebrates. It is often the best way to share the information within the specimen across time and space. Sometimes, a cast is the only way for a researcher to see a particular specimen. Unfortunately, molding can also cause great stress or even severe breakage to the specimen. It is therefore vital that if a specimen is put through the stress of molding that the resulting mold and cast be of the highest quality possible and that the process itself be done in ways that afford the specimen the most protection.

The beginning steps in the creation of any mold can be the most important in helping to avoid damage. Preparation of the specimen before beginning the mold, filling voids, and mold design are the basics that can either cause or prevent damage. Because no two specimens are alike, each specimen will present different challenges. Therefore, it is difficult to present one method for all cases. Rather than a listing of the steps involved in making a mold, this paper will instead entail some ideas on the thought processes that should accompany any attempt to replicate a fragile specimen, so that methods can be adapted for each individual case.

LUNCHTIME AT LA BREA: ISOTOPIC RECONSTRUCTION OF *SMILODON FATALIS* AND *CANIS DIRUS* DIETARY PATTERNS THROUGH TIME

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The La Brea tarpits preserve the remnants of a late Pleistocene ecosystem that hosted a set of mammalian carnivores whose diversity is unparalleled today. Extensive morphometric and faunal analyses of the carnivore assemblage at La Brea suggest a shift in their feeding habits near the end of the Pleistocene, potentially in response to dietary stress caused by changes in productivity or competition. Stable isotope data from bones and teeth can complement these previous studies by characterizing the dietary interactions of the La Brea carnivore guild.

In this study, we used the $\delta^{13}C$ and $\delta^{15}N$ values of bone collagen to investigate the diets of two extinct carnivore species (*Smilodon fatalis* and *Canis dirus*). We tracked these factors through the LGM and into the current interglacial by analyzing specimens from 30, 15 and 11 ka. The $\delta^{13}C$ value of bone collagen primarily reflects the $\delta^{13}C$ value of the primary production of an ecosystem. Mammal $\delta^{15}N$ values are most strongly affected by trophic level, but also reflect physiological factors and the $\delta^{15}N$ values of primary production.

Isotopic results demonstrate that although both carnivore species were feeding within a C_3 plant ecosystem throughout the LGM, their dietary ecologies differed. *S. fatalis* had a constant average $\delta^{13}C$ value through time (-19.6 per mil), but there was a significant decrease in the values of *C. dirus* after the LGM (from -18.3 to -19.9 per mil). The higher $\delta^{13}C$ values of *C. dirus* at 30 and 15 ka cannot yet be explained by known prey species. *S. fatalis* had an average $\delta^{15}N$ value of 11.7 per mil with low variability, indicating a limited prey base. There was a significant increase in *S. fatalis* $\delta^{15}N$ variability through time possibly reflecting a more diverse prey base at 11 ka. *C. dirus* had a similar average $\delta^{15}N$ value of 11.1 per mil,

but with higher variability than that of *S. fatalis*. This suggests that *C. dirus* was a generalist and scavenger with a wide prey base.

OBSERVATIONS ON THE MIOCENE TERRESTRIAL AND MARINE LOCALITIES OF THE IPOLYTARNOC REGION, NORTHERN HUNGARY

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The Ipolytarnoc sites in northern Hungary have been known for over one hundred and fifty years, initially as a result of the discovery of a huge petrified tree. This 90-meter specimen of *Pinus tarnocziensis* was partially housed in what is probably the oldest cultural artifice specifically built to preserve a fossil in situ. Later in the 19th century, the discovery of numerous well-preserved footprints, fossil leaves, many more tree remains, and interbedded marine sandstones with abundant shark teeth, marine mammals, and other materials have surpassed the importance of the original tree discovery and added markedly to the significance of the site. The first discoveries were made in 1836 and continue to the present day, providing a rich and detailed history of investigations by local geologists as well as several new papers in preparation. What is in doubt is why this series of localities, with such a demonstrably superb record of Miocene biotas and behaviors, has been largely overlooked by international paleontologists and biostratigraphers. Each of these different kinds of fossil resources is important in and of themselves, but the presence of all of these interbedded marine and terrestrial elements in one small geographic area contributes to the overall international significance of the area. The fossiliferous localities are concentrated in an area that covers an extended period of geological time, in that sequences correlative with the entire Miocene paleogeography of the Carpathian Basin are represented. The assemblages preserved in the various strata are very speciose, including diverse ichnofossils such as long and complex trackways, assigned to varied mammalian orders including several types of carnivores, artiodactyls, perissodactyls, birds, and other taxa. A variety of tree species are also preserved as leaves and intact trunks, some of spectacular dimensions; all bracketed by dateable tuffs (analysis of samples with abundant sanidines, plagioclase, and biotite in prep).

ELUCIDATING THE NATURE OF DINOSAUR ECOLOGY AND BEHAVIOR USING CARBON ISOTOPE RATIOS OF TOOTH ENAMEL AND ASSOCIATED SEDIMENTARY ORGANIC MATTER

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Carbon isotope studies of dinosaur tooth enamel paired with the analysis of associated organic matter can increase dramatically our knowledge of dinosaur ecology and behavior. In particular, this approach can be used to investigate (1) dinosaur diet, (2) environmental differences between regions, (3) photosynthetic pathways of ingested plants, and (4) ecological niche partitioning among herbivorous dinosaurs.

Carbon isotope ($\delta^{13}C$) data from North American samples of the Late Cretaceous and data from the literature illustrate this potential. A global-scale comparison of $\delta^{13}C$ from dinosaur eggshell carbonate with $\delta^{13}C$ of tooth enamel carbonate from herbivorous dinosaurs reveals a variation from -14 to +8‰ with a bimodal distribution similar to that observed for modern plants. On the basis of paired $\delta^{13}C$ values of tooth enamel and associated organic matter from the Judith River Formation of Montana, enamel carbonate of herbivores is ~20‰ higher than ingested plant material. Thus it can be inferred that Cretaceous dinosaurs relied on plant resources with a range in $\delta^{13}C$ similar to that of the present (~-35 to -12‰).

$\delta^{13}C$ of C3 plants varies between ~-35 and -21 ‰ in response to environmental conditions such as salt stress, aridity, and temperature, thus variation in $\delta^{13}C$ of enamel/eggshell carbonate between -15 and -1‰ likely reflects regional differences in these conditions. However, higher $\delta^{13}C$ ratios of enamel carbonate (primarily from North America) indicate that the four different herbivorous dinosaurs studied were eating aquatic C3 plants, or a mixture of C3 and C4 plants, almost exclusively. These results provide the first evidence that plants utilizing C4 photosynthetic pathways may have been an important part of some terrestrial ecosystems.

Lastly, a comparison of $\delta^{13}C$ values between different herbivorous dinosaurs living in the same are can reveal niche partitioning between taxa. In the Judith River Formation, average $\delta^{13}C$ for hadrosaurs tooth enamel is 0.5‰ and average $\delta^{13}C$ for ankylosaurs is 3.3‰. These results indicate that hadrosaur diet consisted of salt-stressed C3 plants, while ankylosaurs were eating a mixture of aquatic C3 plants and C4 plants.

NEW MATERIAL OF THE LATE DEVONIAN LUNGFISH *SOEDERBERGHIA GROENLANDICA* (SARCOPTERYGII: DIPNOI) FROM EAST GREENLAND WITH COMMENTS ON THE STATUS OF THE RHYNCHODIPTERIDAE

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The lungfish *Soederberghia groenlandica* co-occurs abundantly with *Ichthyostega* and *Acanthostega* in the Late Devonian (Famennian) *Remigolepis* series of East Greenland, but it has not enjoyed the same degree of examination as its tetrapod contemporaries. Most of the morphological information available for this species is contained in the original descriptions, which focused primarily on dermal skull roofs. Additional material assignable to *Soederberghia* has since been recovered in Pennsylvania and two Australian localities, and has clear distributional implications. However, with the exception of a poorly-preserved postcranium associated with one Australian specimen, these finds have added little to our understanding of the anatomy of this lungfish. Preparation of new material coupled with a re-examination of original specimens has revealed considerable information about the morphology of *Soederberghia*. Study of novel material has yielded previously unknown details of the neurocranium, palate, lower jaw, pectoral girdle and median fins, and has also potentially clarified some contentious details of the dermal cheek.

Soederberghia is traditionally placed in the family Rhynchodipteridae along with *Griphognathus* and *Rhynchodipterus*. Characters including dentition, lower jaw morphology, and snout elongation have been used to define this group, although some of these features are unknown in *Rhynchodipterus*. Recently, it has been suggested that a suite of apparent dissimilarities between the early Frasnian *G. whitei* and *Soederberghia* indicate that the two genera are phylogenetically distant, and that *Griphognathus* should be removed from the Rhynchodipteridae. The new material of *Soederberghia*, coupled with a consideration of the two other nominal species of *Griphognathus*, allows for a more robust examination of this claim. Several derived characters shared by these lungfishes would seem to indicate that this recent proposal regarding the membership of the Rhynchodipteridae may be premature.

CONSTRUCTIONAL MORPHOLOGY OF THE PELVIC GIRDLE AND HIND LIMB OF *TETRAGONIAS NJALILUS* (SYNAPSIDA, ANOMODONTIA) FROM THE MIDDLE TRIASSIC OF EAST AFRICA AND THE PROBLEM OF APPLYING REPTILIAN MYOLOGICAL NOMENCLATURE IN NON-MAMMALIAN THERAPSIDS

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Tetragonias njalilus is a medium-sized dicynodont known from the Middle Triassic (Anisian) Manda Formation of the Ruhuhu Valley, Tanzania. It belongs to the Shansiodontidae, which represents a basal taxon within the Kannemeyeriiformes. This major group of Triassic dicynodonts had a radiation after the end of the Permian. Rich and well preserved material, especially of the postcranial skeleton of *Tetragonias*, representing different ontogenetic stages, was collected during several long-term excavations by British and German expedition teams in the twentieth century.

Functional analyses of the postcranium in dicynodont anomodonts so far included Permian taxa as well as Triassic forms, but the main focus of these studies was on the proximal hind limb elements and on unusual genera, differing from the typical locomotor type in being very primitive or advanced, or in having invaded peculiar locomotor habits, e.g. a fossorial locomotion mode. Kannemeyeriiformes in general are advanced in showing an adducted hind limb position. The study of *Tetragonias* provides an insight into the locomotory abilities of a basal form of this group. The investigation focuses on the first description of the step cycle of the entire hind limb including the girdle.

In addition, special reference is given to the pelvic and hind limb myology. The muscle organization of the appendicular skeleton in synapsids and particularly in advanced non-mammalian therapsids has been extensively discussed in the past. The opinion of workers varied concerning the nomenclature and the type of muscle set to reconstruct the muscular configuration. Since the establishment of the extant phylogenetic bracket approach, it appears reasonable to question the previous practice of applying a reptilian myology to the locomotor apparatus of advanced non-mammalian therapsids. Therefore, the reptilian hind limb muscle set is compared with the mammalian muscle set concerning the reconstruction of the hind limb myology of *Tetragonias*. The efficiency of both is tested with biomechanical methods and a mechnanically optimal musculature is reconstructed from both sets.

FIRST ANKYLOSAUR FOOTPRINTS IN JAPAN AND THEIR SIGNIFICANCE

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Over 300 footprints of sauropods, large and small non-avian theropods, ornithopods, and birds, as well as a few theropod teeth, have been recovered from the exposure, which is now called "Dinosaur footprint site of Ohyama Town", in Ohyama Town, central Japan since 1995. The fossil bearing beds are the Atotsugawa Formation of Akaiwa Subgroup, which is the upper most of three subgroups of the Tetori Group that ranges from the Middle Jurassic to Lower Cretaceous. The Atotsugawa Formation is currently correlated to the Aptian age based on the fission track age of 113 ± 6 Ma. Twelve manus and fifteen pes ankylosaur footprints were recovered from the same site by the Toyama Dinosaur Research Group during the field seasons of 2000 to 2002.

The footprints were made by a quadrupedal animal with pentadactyl manus and tetradactyl pes. The manus prints are wider than long, showing short, blunt and widely divergent digits. The outer digits (I and V) of manus project rather backward. Average of the length and width of manus are 16 cm and 24 cm, respectively. One distinct digital pad is present on each end of all digits on well preserved specimens. The pes prints are longer than wide with blunt digits that are slightly longer than those of manus. The size of pes is 24 cm long and 22 cm wide in average. The morphology of the footprints closely resembles that of *Tetrapodosaurus borealis* from North America, which is attributed to ankylosaur. Ceratopsians also have pentadactyl manus and tetradactyl pes, but it is unlikely that the footprints were made by ceratopsian, because the morphology of the footprints are different in ceratopsians and also Early Cretaceous ceratopsians were too small to make them. Thus, we believe the trackmaker of the footprints to be an ankylosaur.

The Early Cretaceous ankylosaur footprints so far known are from North America, Europe, and Central Asia. The two other records known from Mongolia are Late Cretaceous. Thus, the new material from Japan is the oldest record of ankylosaur footprints in eastern Asia and provide new data on migration and paleobiogeography of ankylosaurs.

PALEOCLIMATE OF ZHOUKOUDIAN: A GLIMPSE INTO THE ENVIRONMENT OF PEKING MAN

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Stable isotopes provide a useful tool for examining paleoenvironments occupied by *Homo erectus*. In addition to contributing valuable information about hominid migrations and behavior, the new data can further continental paleoclimate research. Located 50 km to the southwest of Beijing, the area of Zhoukoudian was occupied by *Homo erectus pekinensis* from about 570 ka to 230 ka. Previous paleoenvironmental studies indicate a relatively stable climate during this time, which spans three mild glacial and interglacial periods. Carbon and oxygen isotopes from the enamel of fossil herbivore teeth provide an independent means for reconstructing past environments. Carbon isotopes are used to examine the relative abundance of C3 and C4 plants in the diet of each herbivore. Oxygen isotopes can indicate a change in the temperature and/or precipitation at the site. Carbon and oxygen isotopes from the abundant vertebrate fossils from the upper 13 layers of Locality 1 at Zhoukoudian provide a glimpse into the environment of Peking Man. Six species have been analyzed from Locality 1 and include *Equus sanmeniensis*, *Dicerorhinus choukoutienensis*, *Megaloceros pachyosteus*, *Sus lydekkeri*, and *Pseudaxis grayi*. *Equus* values show a mixed C3/C4 diet, indicating the presence of both plant types in the area throughout the entire interval. However, two deer sampled show decreasing $\delta^{13}C$ values over time, suggesting a possible decrease in the relative amount of C4 plants in the area. Accompanying the decrease in warm season grasses is a decrease in $\delta^{18}O$ values. Further microsampling should indicate whether this decrease is due to overall colder temperatures at the site or, more likely, an increase in the influence of the winter monsoons in northern China. Colder winters with a shorter growing period could have caused the area to become less suitable for *Homo erectus pekinensis*, possibly resulting in site abandonment.

COMPARATIVE TAPHONOMY OF VERTEBRATE FOSSIL CONCENTRATIONS IN THE LATE CRETACEOUS-EARLY TERTIARY SEQUENCE OF NEW JERSEY

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Gridded excavations at several sites containing abundant vertebrate remains in New Jersey's Atlantic coastal plain reveal differences in depositional environment, taphonomic mode, and faunal composition for these fossil concentrations. Data are presented for three sites: Ellisdale (medial Campanian), Big Brook (late Campanian), and Inversand (Maastrichtian/Danian). Orientations and dips on vertebrate and invertebrate bioclasts were mapped and plotted on rose diagrams, and faunal abundances and taxon percentages measured for 1 m^2 grids. At Ellisdale and Big Brook, the vertebrate fossil assemblages are associated with (usually just below) sequence boundaries. The Ellisdale site is the most terrestrial of the three horizons and may represent a storm deposit in an estuarine setting. Big Brook is intermediate in its mixing of marine and terrestrial faunas, and is a near-shore shallow marine environment.

Inversand is at the base of a deeper water glauconitic unit and is the most marine in faunal content; it also contains the most complete vertebrate remains. The basal Hornerstown level at Inversand yields the last fossils of Late Cretaceous age, as well as species of crocodilians and turtles that continue upward into the Paleocene section. The microstratigraphy of this horizon displays a graded distribution of bioclasts, with abundant oyster shells at base, overlain by vertebrate and invertebrate remains, grading upward into pockets of numerous small chondrichthyan teeth. A possible explanation for this bed is that it represents the aftereffects of the passage of a K/T boundary tsunami wave; such a wave could have created a lag deposit of Cretaceous fossils with protracted Paleocene mortality in its wake. As a result of the extinction of the large apical predators of the Late Cretaceous oceans, the mosasaurs, crocodiles underwent a radiation into marine environments and became the dominant predators in the Paleocene ocean in this area.

***ENALIORNIS* SEELEY, 1876, THE EARLIEST FOOT-PROPELLED DIVING BIRD (AVES, ORNITHURAE, HESPERORNITHIFORMES, ENALIORNITHIDAE), AND OTHER BIRD BONES FROM THE CAMBRIDGE GREENSAND (EARLY CRETACEOUS, ALBIAN, ~100 MA) NEAR CAMBRIDGE, SOUTHERN ENGLAND**

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Most isolated bird bones from the "coprolite" diggings of the mid-1800's in the Cambridge Greensand represent *Enaliornis,* the earliest foot-propelled diving bird. The specific density was increased by reducing the dorsal tympanic recess of the braincase and by the extreme thickening of the walls of the apneumatic long bones. Flightlessness is indicated by the simple form of the proximal end of the humerus. Eight postcranial synapomorphies place *Enaliornis* as an early Ornithurae and others, e.g. tibiotarsus with large cnemial crest shaped like an isosceles triangle in anterior view, tarsometatarsus transversely compressed with distinct anterolateral edge leading to lateral trochlea (IV) that is at least as large and distally extending as middle trochlea (III), show that it is a basal hesperornithiform, not a primitive loon. The slender femur was laterally directed, with the proximal articular surface fitting against the antitrochanter that, because of its small lateral extent, permitted a waddling gait. The proximal fibulae/ulnae are adult proximal tarsometatarsi and the form of the distal trochlea indicates that the feet were lobbed, as in all hesperornithiformes and grebes, not webbed as in loons. Three species are recognized based on size (large *E. barretti*, medium *E. seeleyi*, small *E. sedgwicki*), differences in the distal end of the tibiotarsi, etc. Adult distal femora of each species show a probable sexual dimorphism in the patellar groove, which is either shallow or deep. The articular surfaces of bones of juveniles are poorly developed so the nesting sites were probably quite close; two bones show numerous gnaw marks from the incisors of a small, presumably terrestrial mammal. The last cervical and the last thoracic vertebrae are both heterocoelous, as in other hesperornithiforms, so the small amphicoelous thoracic vertebrae with a large neural canal represent a non-hesperornithiform bird, Aves incertae sedis, as do two vertebrae, a cervical and an anterior synsacral, plus one end each of a coracoid, a humerus and a femur. Non-avian bones originally referred to *Enaliornis* represent a theropod dinosaur (partial sacrum) and a turtle (caudal vertebrae).

THE RECORD OF ARCTIC DINOSAURS FROM NORTHERN ALASKA, PALEOGEOGRAPHIC AND PALEOECOLOGIC IMPLICATIONS

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The record of dinosaurs from the Arctic outside of Alaska is widespread, highly fragmentary and heavily dominated by trace fossils and skeletal remains of Cretaceous ornithischians. The record on Alaska's North Slope is unique for it far exceeds that found at polar latitudes in either hemisphere is respect to variety and numbers of fossils.

The Arctic dinosaur record begins in the Early Cretaceous (Albian), but the record is dominated by remains from the Late Cretaceous(Campanian to Maastrichtian). The Early Cretaceous is characterized by a great abundance of tracks and trackways representing ornithopods, theropods, and thyreophorans. The Late Cretaceous is dominated by hadrosaurs and theropods. Six theropod taxa are known, *Troodon* being the most common. Remains of *Pachyrhinosaurus* are abundant and a pachycephalosaur is present. Most are found in bonebeds associated with organic-rich crevasse-splay and overbank deposits while others are found with microscopic mammal remains in distributary channel-lags. The Cretaceous of the North Slope is represented by over 10 km of marine and non-marine coal-bearing sediments that were part of highly active prograding deltas fed by the ancestral Brooks Range. Dinosaurs were associated with a mixed-coniferous forest with a low diversity angiosperm understory and ground cover. The understory and ground cover also included ferns, cycadophytes, horsetails, and some aquatic plants. Conifers are often represented by trees up to 40 cm in diameter. The Arctic of Alaska, for most of the Cretaceous, was much like the present-day coast of Oregon and Washington and likely supported resident populations of some ornithopods and theropods.

Alaska holds the key to the distribution and movements of important Cretaceous clades such as the troodontids, tyrannosaurids, marginocephalians, thyreophorans, and hadrosaurines. Several lines of evidence support the presence of an Asian-Alaskan land bridge from late Aptian to earliest Turonian time and the movements of representatives of the aforementioned clades from northeastern Eurasia to North America.

A NEW COLOSTEID WITH UNUSUAL DERMAL SQUAMATION FROM HANCOCK COUNTY, KENTUCKY

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The Hancock County site has yielded fossilized remains of a diverse assemblage of Mississippian fish and tetrapods. Three distinct facies have yielded vertebrate remains, with a dark gray shale of the Buffalo Wallow Formation (Chesterian) producing the most diverse fauna, including dipnoans, palaeoniscoids, rhizodonts, xenacanths, and a colosteid amphibian. The colosteid specimen represents a previously undescribed taxon. The specimen is a nearly complete individual, preserving the anterior two-thirds of the skull and the entire post-crania, excluding the distal half of the caudal series. It is identified as a colosteid by the following characters: dentary teeth larger than maxillary teeth, triradiate parasphenoid, rhachitomous vertebrae, uniradiate ilium, and deeply pitted ornamentation on the skull.

The Hancock specimen can be distinguished from other colosteids by its possession of thick osteodermal squamation that covers the dorsal surface of the specimen. The squamation begins slightly anterior to the pectoral girdle and continues posteriorly to the pelvic girdle. The rectangular osteoderms are arranged in rows of 5-7 individual elements, angling posterolaterally at about 55º to the axis of the vertebral column. Dorsal squamation is seen among some advanced temnospondyls and Permian chroniosuchids. Among these more advanced and terrestrial tetrapods, the osteoderms likely served to strengthen the vertebral column. The osteoderms are closely aligned with, or articulate to, the neural spines. The relatively small size and mail-like arrangement of the squamation in the Hancock colosteid and the lack of articulation to the vertebral column, along with its likely aquatic habits, argue against such a function for this squamation. The presence of numerous large (5+ meter) rhizodonts within the ox-bow deposit suggests that this squamation may have been a defensive adaptation. Mississippian colosteids without thick squamation are not found associated with predators larger than themselves and were likely apex predators in their respective ecosystems.

DROUGHT IN THE VERTEBRATE FOSSIL RECORD: A REVIEW OF FOSSIL AND MODERN DROUGHT-RELATED ASSEMBLAGES

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Drought has been recognized as one of the major instigators for bonebed accumulations in the fossil record. We reviewed a suite of modern and fossil vertebrate assemblages attributed to drought in search of spatial and/or temporal trends, and to identify potentially diagnostic sedimentologic and taphonomic indicators. The long-term objective is to develop a set of diagnostic criteria for recognizing drought-related mortality in the fossil record.

Bonebeds ranging in age from Devonian to Pleistocene have been attributed to drought conditions. The literature of the Triassic-Cretaceous of western North America records a disproportionate number of such accumulations. Common taphonomic characteristics of purported drought assemblages include: moderate time averaging, mild to extensive bone modification (e.g. physical weathering, trample traces, tooth traces), copious juvenile remains, and low taxonomic diversity. However, diverse multi-taxon bonebeds have also been attributed to drought, suggesting there are various pathways to the drought assemblage. Age-structure and perhaps taxonomic diversity appear to be the strongest taphonomic drought indicators.

A summary of sedimentologic data from these studies presents a more variable set of criteria for recognizing drought assemblages. Commonly reported sedimentary characteristics of drought assemblages include pedogenic carbonate, evaporites, clay minerals such as sepiolite and palygorskite, slickensides, and deep rhizoturbation. The most commonly cited depositional environments are ephemeral streams, ponds/watering holes, and well developed paleosols.

The reports we reviewed focus on drought assemblages in semi-arid environments. Further work is needed in temperate and tropical settings. In addition, care must be taken not to over-interpret the presence of drought assemblages in arid and semi-arid paleoenvironments. Mock aridity also needs to be explored before accurate reconstructions can be made. Finally, numerous new tools exist (e.g., isotopic analysis, rare earth element analysis), that may aid researchers in recognizing drought-related mortality in the fossil record.

SKIN IMPRESSION MICROTOPOGRAPHY IN TRIASSIC THEROPOD TRACKS

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In 2001, theropod trackways preserving skin impressions were collected from the Fleming Fjord Formation (Norian-Rhaetic) of Jameson Land, East Greenland. We studied track microtopography using silicone putty casts, which were viewed by light and scanning electron microscopy. Multiple SEM images were combined to produce montages and stereopairs.

Skin impressions, like an entire track, are not perfect molds of pedal anatomy, but a record of integument interacting with a malleable substrate. Given that all impressions have been affected by motion and preservation, we focused on the most detailed, highly patterned areas in search of the least distorted records of skin morphology. The clearest skin impressions are characterized by roughly circular dimples averaging 0.6 mm in diameter and loosely packed into irregular hexagonal arrays. Such dimples were likely formed by reticulate scales, as found on the digital pads of extant birds. Variation in dimple size, shape, depth, and interconnectedness is present in even the best preserved areas. Analysis of impressions made by the same patch of skin within a trackway will help resolve which of these features are anatomical and which are artifactual. Better knowledge of integumentary morphology will help explain the topography of more distorted impressions present in most tracks.

PHYLOGENY OF SLOTHS (MAMMALIA, XENARTHRA, TARDIGRADA) – A CRANIO-DENTAL ANALYSIS REVISITED

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Recent revisions to a study presented in 1994 provide an opportunity to assess the current state of understanding concerning the phylogenetic relationships among extant and extinct sloth taxa. A computer-based cladistic investigation of the phylogenetic relationships among 34 sloth genera is performed based upon 286 craniodental characters. Characters are polarized via comparisons to the following successive edentate outgroups: Vermilingua, Cingulata, Palaeanodonta; and Pholidota. Two most parsimonious trees resulted (TL=1941 steps; CI=0.365; RI=0.649). These trees corroborate the diphyly of living tree sloths, a finding consistent with those of most recent analyses of sloth phylogeny. The three-toed sloth *Bradypus* is positioned as the sister-taxon to all other sloths, and the two-toed sloth *Choloepus* is allied with extinct members of the family Megalonychidae. However, Templeton tests suggest that alternative placements for these extant taxa cannot be ruled out, and no consensus exists as to their precise relationship to other sloths. The monophyly of the three traditional ground sloth families Megatheriidae, Megalonychidae, and Mylodontidae is confirmed, as is the monophyly of a fourth family recognized in several recent studies, the Nothrotheriidae. The results also support the monophyly of Megatherioidea, a clade including megatheriids, megalonychids, nothrotheriids to the exclusion of mylodontids. Relationships among Nothrotheriidae, Megatheriidae, and Megalonychidae have historically been controversial. The present study clearly supports those who previously allied nothrotheriids with megatheriids. The two families are placed in a monophyletic group termed the Megatheria. The relationships within the families Megatheriidae and Mylodontidae are fully and consistently resolved, although the hypothesized scheme of relationships among late Miocene–Pleistocene members of the subfamily Mylodontinae differs strongly from any proposed by previous authors. Relationships within the families Megalonychidae and Nothrotheriidae are not fully or consistently resolved, and merit additional study.

COMBINING MORPHOLOGICAL AND MOLECULAR DATA TO ADDRESS THE PHYLOGENY OF THE CETACEAN CROWN GROUP

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The phylogeny of Cetacea was revisited using a dataset that combines 304 morphological characters, 8077 aligned base pairs from mitochondrial (12s, 16s, cytochrome b) and nuclear (IRPB, vWF, transferrin, lactalbumin, casein) genes, 43 molecular insertion/deletion characters, and 12 retroposon characters. The matrix has 1300 informative characters (296 morphological, 1004 molecular) that are coded for 37 extinct and 20 extant taxa. Whereas the morphological partition supports paraphyly of Delphinoidea and monophyly of four groups: Odontoceti, Physeteroidea (Ziphiidae + Physeteridae), Delphinidae + Phocoenidae, and river dolphins; the molecular partition supports paraphyly of Odontoceti, paraphyly of river dolphins, monophyly of Delphinoidea, and Phocoenidae + Monodontidae. Despite these differences, both partitions support Mysticeti, Balaenoidea, *Inia* + *Pontoporia*, Ziphiidae, and Physeteridae. The most parsimonious trees for the combined matrix include all five of those clades and in other respects are intermediate in topology between the trees supported by the partitioned analyses. Like molecular data, the combined analysis supports Delphinoidea, paraphyly of river dolphins, and paraphyly of Physeteroidea. In contrast, it is similar to morphology in supporting odontocete monophyly and Delphinidae + Phocoenidae. The phylogenetic positions of several fossil taxa, as supported by the combined matrix, are surprising. The supposed pontoporiid *Brachydelphis* is the sister group to an *Inia* + *Pontoporia* clade, *Lipotes* and *Parapontoporia* are sister-groups, the platanistid *Zarhachis* is the sister-group to *Eurhinodelphis*, and the latter two taxa join *Notocetus* to form a clade inside Delphinida. *Platanista* does not appear to be closely related to any extinct taxon, specifically *Squalodon*, *Prosqualodon*, and *Waipatia* are excluded from the odontocete crown group. Bremer support values for many clades are low, and additional analyses are needed to assess the affects of alternative molecular alignments and recently described fossil cetaceans.

PRELIMINARY REPORT OF A NEARLY COMPLETE SKELETON OF *CLEMMYS OWYHEENSIS* (REPTILIA: EMYDIDAE) FROM THE UPPER BLANCAN (PLIOCENE) GLENNS FERRY FORMATION, HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO.

GENSLER, Philip A., Hagerman Fossil Beds National Monument, Hagerman, ID; KELLY, Amy, Northern Arizona Univ., Flagstaff, AZ

The testudinine fauna from the Glenns Ferry Formation of Idaho and eastern Oregon is limited to two species, *Trachemys idahoensis* and *Clemmys owyheensis*. Recent field efforts at Hagerman Fossil Beds National Monument, Idaho have yielded a nearly complete turtle shell (carapace and plastron) and the majority of its associated skeletal elements. This specimen was recovered, in situ, from a silty-clay unit immediately above the Peters Gulch Ash (3.79 Ma) in the Glenns Ferry Formation. Based on nuchal and entoplastron morphologies, the preliminary identification of this specimen is *C. owyheensis*.

C. owyheensis is separated from most other *Clemmys* spp. by having a gular-humeral sulci of 33° or less from the mid-line of the entoplastron, a prominent anterior knob on the entoplastron, and a bifurcate pygal. These traits, however, have also been found to occur in some *C. marmorata* to which *C. owyheensis* is believed to be ancestral. This specimen represents the first evidence of *C. owyheensis* skeletal elements being associated with a carapace and plastron. The previous lack of skeletal element description of *C. owyheensis* precluded any comparison with *C. marmorata*. Further research on the skeletal elements of this specimen is pending. Hagerman Fossil Beds, considered to represent a delta system, is located on the western margin of what was Lake Idaho. *Clemmys owyheensis* appears to be restricted to the ancient Lake Idaho drainage system and spans the Hemphillian and Blancan NALMAs.

THE ANALYSIS OF WEAR IN HORSE TEETH USING GIS

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Quantification in taphonomy is usually limited to large collections of bones, and is not applied to single specimens. My study utilizes a geographic information systems (GIS) approach to analyze taphonomic aspects of dental wear on single specimens. My sample consists of 52 isolated lower second premolars of *Equus sp.* from Leisey Shell Pit, an early Pleistocene coastal deposit in Florida. Only adult teeth, based on crown height and wear stage, were sampled. I applied GIS to the study of the occlusal surface morphology of the teeth to test for statistically significant differences in the distribution of ontogenetic (within adults) and taphonomic wear. Using a standard optical flatbed scanner, a digital image was imported into GIS software (ArcView 3.0). The occlusal surface was treated as a 2-dimensional plane to simplify the analysis. Areas of ontogenetic and taphonomic wear were digitized separately in ArcView as polygons. In general, each tooth showed multiple areas of both ontogenetic and taphonomic wear. The x and y coordinates of the vertices of the polygons were then exported from ArcView to Excel. From these coordinates, I calculated the mean center of wear of each individual polygon and the mean center of all of the polygons. The average distance of each polygon from the mean center was calculated. A t-test showed a statistically significant difference between the average distances of ontogenetic and taphonomic wear from the mean center of wear. This study shows one potential application of GIS to small-scale taphonomic problems. GIS can be used on any problem that involves the analysis of spatial relationships; therefore, these techniques could be adapted to any taphonomic, morphometric or allometric problem.

TAPHONOMY OF A CHASMOSAURINE CERATOPSIAN SKELETON FROM THE CAMPANIAN KAIPAROWITS FORMATION, GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, UTAH

GETTY, Mike, ROBERTS, Eric, LOEWEN, Mark, Utah Museum of Natural History, Salt Lake City, UT.

Recent field research in the Kaiparowits Formation within the Grand Staircase-Escalante National Monument in southern Utah has produced a number of new vertebrate localities, including the first associated ceratopsian skeleton from the Campanian of Utah. Excavation of this specimen, conducted by the UMNH from 2000 to 2002, has resulted in collection of more than 300 individual elements and fragments representing >50% of the entire skeleton. The disarticulated skull is approximately 80% complete, with most elements repre-

sented. Morphologic characters of the skull provide conclusive evidence that this specimen is a chasmosaurine ceratopsian, which is now under systematic study.

Detailed taphonomic analysis of the ceratopsian quarry suggests a complex biostratinomic history. The quarry is characterized by a three meter thick fining-upwards sequence of muddy, fine-grained sandstone grading into a mollusk rich silty mudstone, with bones concentrated in the lower 0.8 meters. Taphonomic analysis reveals that the carcass was subject to surface weathering, insect modification, scavenging and trampling prior to burial. In addition, small skeletal elements appear to be poorly represented. Based on both the sedimentology and taphonomy, the carcass appears to have been sub-aerially exposed on a dry floodplain, where it was subjected to disarticulation, as well as physical and biological weathering, prior to burial. A relatively low-energy overbank flooding event resulted in the development of an ephemeral floodplain pond, which subsequently led to the burial and preservation of the carcass. This flooding event may have caused minor winnowing of distal limb elements. The unusual preservation of this disarticulated fragmented skeleton was the result of a complex, multi-event taphonomic history.

IN SITU DINOSAUR FOOTPRINTS AT THE MURRAY QUARRY (LOWER JURASSIC ?EAST BERLIN FORMATION), HOLYOKE, MA

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Slabs containing dinosaur footprints from the William Murray quarry were excavated and sold to institutions and private collectors during the 1920s and 1930s. Currently slabs are on display at Forest Park in Springfield, the Wisteriahurst Museum in Holyoke, and Mount Holyoke College in South Hadley, MA. I began researching the Murray quarry footprints in the fall of 2001 by examining these slabs. All of the footprints examined are attributable to the ichnogenera *Eubrontes* and *Anchisauripus*. One trackway showed evidence for trotting behavior and another showed evidence for acceleration.

When Murray ceased quarrying a portion of the track surface remained exposed and was subsequently reburied to protect it from vandals. To continue my research I began to reexcavate the quarry in November 2002. I exposed the track surface and identified numerous footprints of bipedal dinosaurs, most of which are associated with trackway sequences. Footprint preservation is variable, with most of the footprints showing little more than a tridactyl pes but others with pad and claw impressions. Sedimentary structures associated with the footprints include ripple marks and mud cracks. In addition to the vertebrate ichnites, numerous invertebrate *Skolithos* burrows are present on the main track surface as well as on bedding planes above and below it.

Data recorded for each footprint include length, width, and total angle of devarication; which were used for ichnogeneric identification purposes. Measurements for trackways include stride, pace, pace angle, and orientation. The results of this research are presented here and include a map of the track surface showing the relationship of the trackways to each other.

PHYLOGENETIC RELATIONSHIPS OF THE PLIOCENE KILLIFISH *FUNDULUS DETILLAE* (TELEOSTEI: CYPRINODONTIFORMES)

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The Family Fundulidae includes the North American killifishes with thirty-six extant species in North America, Bermuda, and the Yucatan Peninsula. The fossil record of fundulid fishes includes North American fossils of Miocene to Pleistocene age. The species *Fundulus detillae* from the Pliocene of western Kansas has figured prominently in previous hypotheses of evolution in this family. A phylogenetic analysis of representative extant taxa in the family and *Fundulus detillae* do not place this species in one of the traditionally recognized subgenera of *Fundulus*. However, the plesiomorphic presence of a lower arm of the post temporal is present only in *Fundulus detillae* and the extant Plains killifish, *Fundulus zebrinus*.

FURTHER DISCOVERIES OF CENOMANIAN-TURONIAN (EARLY LATE CRETACEOUS) PLESIOSAURS FROM THE TROPIC SHALE, SOUTHERN UTAH

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In 2001 we reported the recovery of several articulated remains of plesiosaurs from the Late Cretaceous, Turonian aged deposits of the Tropic Shale in southernmost Utah. Taxonomic identification was indeterminate at that time because only minimal preparation had occurred. Since that time additional specimens have been discovered, all specimens have been prepared, and a taxonomic assessment has been conducted. The numerous collected specimens appear to represent juvenile and adult individuals of at least two different species of the polycotylid *Trinacromerum*, and juvenile and adult remains of *Brachauchenius* sp. cf. *B. lucasi*. The adult *Trinacromerum* individual is represented by the distal portions of the premaxillae and mandible, a complete pectoral and pelvic girdle, both hind limbs, a forelimb, and several vertebrae. The juvenile is also represented by the distal portions of the premaxillae and mandible, a complete pelvic girdle, partial pectoral girdle, a complete front and hind paddle, and several vertebrae. The adult specimen of *Brachauchenius* sp. cf. *B. lucasi* is represented by most of the cranium and complete mandible, several components of the axial skeleton, and parts of the pectoral and pelvic girdle. The juvenile individual of this taxon is represented by a nearly complete mandible and partial cranium. Although all specimens noted above were recovered from slightly-to-several-meters above the Cenomanian-Turonian boundary (but below the *Mammites nodosoides* North American Ammonite Zone), another exceptionally large individual was recovered from a late Cenomanian stratigraphic interval. The latter specimen consists only of several vertebrae, but they are significantly larger, and of different morphology, than either the large, adult polycotylid or the adult *Brachauchenius* sp. cf. *B. lucasi*, likely indicating another taxon. Our ongoing work in the Tropic Shale of southern Utah is providing a significantly different view of the vertebrate diversity of the southwestern region of the Late Creatceous Interior Seaway than previously realized.

EVOLUTION OF EOCENE ARCHAEOCETI (CETACEA) IN RELATION TO SKELETAL PROPORTIONS AND LOCOMOTION OF LIVING SEMIAQUATIC MAMMALS

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Aquatic adaptations can be identified in the body proportions of living semiaquatic mammals. Here principal components analysis is used to compare 14 trunk and limb lengths in 50 semiaquatic species representing all nine orders and 17 families of semiaquatic mammals. PC-I represents overall size (water mice and shrews to hippos); PC-II represents a spectrum of aquatic adaptation (seals to tapirs); and PC-III represents a spectrum ranging from hindlimb- to forelimb-dominated locomotion (sea otters to platypus).

Archaeocete skeletons complete enough to be informative about early whale locomotion include the protocetid *Rodhocetus* and the basilosaurid *Dorudon*. The latter fits poorly into a morphospace defined solely by living semiaquatic mammals; thus a second 53-species set of semiaquatic species was analyzed, adding *Elomeryx* to represent an artiodactyl ancestral morphology, and *Rodhocetus* and *Dorudon* to represent successive stages of whale evolution. These additions had little effect on the first two principal axes but changed the third. PC-III now represents a contrast of lumbus (and presumably tail) versus hindlimb-dominated locomotion (*Dorudon* to *Rodhocetus* and otter shrew to desman). Mammals that are more aquatic have a shorter ilium and femur and longer manual and pedal phalanges, while the reverse is true for terrestrial taxa. Lumbus and tail dominated swimmers have a longer lumbus and shorter pedal elements, while the reverse is true for hindlimb-dominated swimmers.

Trunk and limb proportions of early middle Eocene *Rodhocetus* are most similar to those of living desmans. Trunk and limb proportions of late middle Eocene *Dorudon* are most similar to modern whales. Thus the land-to-sea transition in whale evolution involved two distinct phases of locomotor specialization: (1) hindlimb domination for drag-based pelvic paddling in protocetids, with tail elongation for stability; followed by (2) lumbus domination for lift-based caudal undulation and oscillation in basilosaurids. Known archaeocetes were not proportioned like otters and did not swim like otters.

MICROEVOLUTIONARY TRENDS IN TOOTH MORPHOLOGY OF FAMENNIAN SHARKS

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Recently found rich assemblages of Famennian chondrichthyan microfossils from North Gondwana, makes it possible to reveal small-scale steps in the evolution of tooth morphology among the Phoebodontiformes, a group of sharks possibly closely related to Late Paleozoic xenacanthiforms. Of particular interest are forms partly filling morphological gaps between the dentitions of the genera *Phoebodus* and *Thrinacodus*, such as *Ph. gothicus transitans*, and those intermediate between the phoebodont species.

Computer-generated reconstructions of anterior parts of phoebodont and thrinacodont jaw apparatuses, show that several different tooth morphotypes might have functioned simultaneously in a single dentition. A proposition on how to distinguish mesial from distal sides of asymmetrical elements is forwarded.

USING DIGITAL SCANNING AND MODELING TO RECONSTRUCT AND TEST THE FORELIMB FUNCTION OF *DEINONYCHUS ANTIRRHOPUS*

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Understanding the function of the forelimbs of maniraptors is important for understanding the origin of avian flight. Three-dimensional digital scanning and modeling allows for the reconstruction of both bones and muscles of extinct organisms without the limitations of traditional methods of actualistic modeling using original material or casts. Due to its relative completeness, high quality of preservation, and phylogenetic closeness to the avian stem, *Deinonychus* offers a unique opportunity to test the flight stroke capabilities of non-avian maniraptors through the digital reconstruction of its limb function.

In order to digitally reconstruct the function of the forelimbs in *Deinonychus*, high-quality molds and casts were made from specimens of *Deinonychus* (type specimen left manual elements YPM 5208, YPM 5206, left radius, left ulna, right ulna YPM 5220, right metacarpal II YPM 5270, proximal end left ulna and left humerus of the Harvard specimen MCZ 4371 and coracoid YPM 5236). Surface scans were taken of the casts and the three-dimensional data were imported into Alias|Wavefront's scientific and entertainment industry standard animation software, Maya 4.0. A composite virtual forelimb was articulated and the range of motion about each joint was reconstructed using motion-limiting parameters. Muscle scars and phylogenetic bracketing were used to determine the positions of dynamic musculature, and inverse kinematic constraints were then applied to analyze the elevation, depression, protraction, and retraction of the complete arm.

The results of this modeling clearly show that *Deinonychus* was capable of a coordinated, automatic extension and flexion of the arms in a rudimentary form of an avian flight stroke. This gives the best support yet for the hypothesis that non-avialan maniraptors possessed flight stroke capabilities and that they could have made use of their forelimbs in preflight adaptive behaviors such as wing-assisted inclined running.

REVISION OF THE PHASIANIDS (AVES, GALLIFORMES) FROM THE LOWER MIOCENE OF ST.-GÉRAND-LE-PUY (FRANCE)

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The galliforms from St.-Gérand-le-Puy (Allier, France) were first studied by Milne-Edwards (1867-71) in his monographic work on the fossil birds from France. Therein he

described three new species of phasianids, which were distinguishable by their size: *Palaeortyx brevipes* Milne-Edwards, 1869, *Palaeortyx gallica* Milne-Edwards, 1869, *Palaeortyx phasianoides* Milne-Edwards, 1869. St.-Gérand-le-Puy is the type locality of these three species. Later, *Palaeortyx intermedia* Ballmann 1969, a taxon originally described from the early Miocene of Wintershof-West (Southern Germany), was additionally mentioned from St.-Gérand-le-Puy.

Recently, *Palaeortyx brevipes* has been synonymized with *Palaeortyx gallica*, and *Palaeortyx intermedia* has been synonymized with *Palaeortyx longipes* Milne-Edwards, 1869. The latter was described from the middle Miocene of Sansan (France) and formerly was a junior synonym of *Palaeortyx phasianoides*.

In the present study, a revision of the phasianids from St.-Gérand-le-Puy, based on nearly all available skeletal remains, is made. The morphological and mensural studies on these fossil phasianids and investigations on metric variability statistics of the recent quails and partridges, *Coturnix coturnix*, *Perdix perdix*, *Alectoris graeca* and *A. rufa*, lead to differing results: *Palaeortyx brevipes*, *Palaeortyx gallica*, and *Palaeortyx phasianoides* are recognized to be separate and valid taxa. *Palaeortyx intermedia* is synonymized with *Palaeortyx prisca*, which was described from the middle Miocene of Sansan (France).

Additionally, it was recently proposed to refer the species *Palaeortyx gallica* to the recent genus *Coturnix* and *Palaeortyx prisca* to the extant *Alectoris*. However, the present comparisons with some recent quails and partridges of the genera *Coturnix*, *Perdix*, and *Alectoris* show osteological differences between these Recent and Miocene taxa and confirm the distinction of the Tertiary genus *Palaeortyx*.

HIBERNATION IS RECORDED IN PRAIRIE DOG INCISORS

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A hibernation mark (HM) has previously been identified on the external surface of incisors of *Spermophilus* (ground squirrels) and *Marmota* (marmots). We investigated whether hibernation is similarly recorded on the incisor surface of *Cynomys* (prairie dogs). A putative HM was observed in some specimens of *C. gunnisoni* and *C. leucurus*, both white-tailed prairie dogs that are obligate hibernators, correlating with timing of hibernation in these species. In contrast, *C. ludovicianus* (a black-tailed prairie dog and facultative hibernator) seldom exhibited a putative HM (one clear case). The HM was typically characterized by a zone of indistinct or finely incremented dentin, irregularities at the enamel-dentin junction, and abnormalities in the surface structure of enamel.

We also explored temporal variation in dental growth rates. While there was significant variation over much of the active season, hibernators typically showed progressively decreased growth rates for several weeks going into hibernation, and a rapid increase in growth rates after emergence from hibernation.

Examination of a collection of Pleistocene *C. niobrarius churcherii* from Alberta, Canada, indicated that none of these incisors (n=11) represented animals that died within about two months of emerging from hibernation. At least some of these specimens show decreased growth rates basally and may have been approaching hibernation at time of death.

CARBON ISOTOPE ANALYSIS AND MINERALIZATION IN FOSSIL AND MODERN MYSTICETE WHALE BALEEN PLATES

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The baleen plates of living mysticete whales are composed principally of amorphous alpha and beta keratin, a fibrous protein that is also a major component in the horny epidermal tissues of mammalian horns, hooves, claws, and nails. Baleen is the most highly calcified of keratin materials, and grows continuously as parallel, transversely aligned, triangular plates from the palates of mysticetes. Each baleen plate is composed of a central section of tubules, within a cementing keratin matrix, bounded by a horny covering. These "hair-like" tubules, when exposed on the frayed medial margins of the baleen plates, act as a sieve for capturing prey. The tubules are highly calcified, contain crystals of hydroxyapatite, and have an inner hollow core. We know these features in modern baleen, but very little is known about fossil baleen because it is very rare in the fossil record.

A well preserved example of fossil baleen (UCMP 86438) from the latest Miocene or earliest Pliocene part of the Purisima Fm. in northern California consists of 16 sequential plates, averaging 180 mm in length. The baleen is from a relatively small, flat-headed mysticete, most likely from a balaenopterid, or possibly a late-occurring cetotheriid. The individual plates are neither thick as in gray whales (Eschrichtiidae), nor long as in right whales (Balaenidae). This fossil allows us to: compare its microstructure and stable carbon isotope geochemistry with modern baleen; compare the mineralized state of modern baleen with fossil baleen; and evaluate diagenesis in the fossil relative to modern keratin. If closely comparable to modern baleen, we can then attempt to evaluate the life history of this fossil whale using stable carbon isotope analysis.

Stable-isotope studies of modern baleen have revealed patterns of seasonal migration, feeding, and growth. Similarly, if an original biogeochemical signal is preserved in the fossil, we will attempt to reconstruct annual growth rates from a periodic $\delta^{13}C$ signal. If this fossil whale migrated annually through isotopically different foodwebs, $\delta^{13}C$ values in the baleen may provide a seasonal record of its migratory history and paleobiology.

PRELIMINARY ANALYSES OF THE INFLUENCES OF ONTOGENY, PHYLOGENY, AND FUNCTION ON MORPHOLOGICAL INTEGRATION IN THE CARNIVORAN SKULL

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Recent genetic and developmental studies have produced compelling hypotheses of the importance of trait correlations to morphological evolution. However, these hypotheses have never been tested with a broad, comparative data set or with fossil material. This study uses the analysis of morphological integration to examine discrete sets of highly correlated cranial traits and their relationship to factors influencing mammalian skull evolution. Here, I present detailed analyses of patterns of cranial trait correlations across a broad range of taxa within the terrestrial Carnivora and address the relationship of these patterns to phylogeny, ontogeny, and function.

A 3D digitizer was used to record homologous skull and jaw landmarks from 20 specimens of >30 extant species, representing all 8 terrestrial families. While previous studies generally exclude fossil taxa due to small sample sizes, some extinct carnivoran taxa (e.g., *Hesperocyon, Dinictis, and Hoplophoneus*) have sufficient numbers of intact specimens for inclusion in this study. The inclusion of fossil taxa expands phylogenetic breadth and permits testing of temporal trends in skull modularity and the influence of increased brain size within lineages.

Matrix correlation analysis supports a loose relationship between phylogeny and patterns of trait correlation within Carnivora. Comparisons of carnivorans, primates, and marsupials show that patterns of morphological integration are not conserved across these mammalian orders. Brain size and convergence of diet are explored as alternative or additional influences on cranial integration. I also present a new method for comparing independent data sets and summarizing patterns of trait correlations derived from principal components analysis. Rather than pooling data and generating a single principal component structure, our method compares the ordering of eigenvectors and the angle between matched eigenvectors among multiple covariance matrices, generating a measure of similarity. This method is more appropriate for comparative studies of trait correlations than are traditional principal components analyses.

A GONDWANATHERIAN? MAMMAL FROM THE CRETACEOUS OF TANZANIA

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We report here the discovery of a Cretaceous mammal jaw from the 'Red Sandstone Group' of southwestern Tanzania. This specimen represents one of only a very few records of Cretaceous mammals from Gondwana in general and Africa in particular, and, if from the Late Cretaceous, the only known Late Cretaceous mammal from mainland Africa. The specimen consists of a short, deep left dentary with a large, procumbent, laterally compressed central incisor, and five, single-rooted, hypsodont cheek-teeth, separated from the incisor by a short diastema. The cheek-teeth are represented only by their dentine stumps, but are sufficiently well-preserved to show that they are hypsodont. In some respects, the Tanzanian specimen resembles the dentary of the sudamericid gondwanatherian *Sudamerica ameghinoi* from the Paleocene of Argentina, and the Tanzanian jaw is tentatively identified here as a (probable sudamericid) gondwanatherian, a clade otherwise known from the Late Cretaceous and Paleogene of several non-African Gondwanan landmasses.

Unfortunately, the age of the Red Sandstone Group sediments that produced this and other vertebrate specimens is not yet tightly constrained. A Cretaceous age is indicated by the overall vertebrate fauna, but no definitive statements can as yet be made regarding which stage in the Cretaceous is represented. If the lower jaw is a pre-Campanian gondwanatherian, it would be the oldest known record for the group; if Campanian or Maastrichtian, it would refute a recently formulated biogeographic hypothesis predicting the absence of gondwanatherians from Africa during this interval.

AN ALLOMETRIC STUDY COMPARING METATARSAL II'S IN *EDMONTOSAURUS* FROM A LOW-DIVERSITY HADROSAUR BONE BED IN CORSON CO., S.D.

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The sample studies were taken from a population of *Edmontosaurus*, varying in size and age, from an ongoing dig from 1998 until present. The purpose was to determine if sexual dimorphism occurred within the sampled population. In the collection there were the presence of two apparent subgroups of bones, a robust and gracile form. The purpose was to determine if the groups were actually distinct, if there was a significant difference, and if the two groups indicate sexual dimorphism within the species.

A total sample size of 40 metatarsal II's, both left and right, were used. Four were in poor repair, with little valuable information, and twenty of the bones had at least one measurement that could not be used. The length, distal width, proximal length and width, and least circumference were taken. Multiple statistical analyses were then run to determine if the measurements taken indicated sexual dimorphism. Methods used were a two-tailed t-test, and a residual test.

As the total length of the bone increased, there was a significant variance between the least circumference taken, exhibiting a robust and gracile form. There was also a significant variance when greatest length was compared with the length on the proximal end. However, there were no significant findings of this occurring in the length and width of the proximal end, nor in comparing the greatest length to the width of the distal end.

The elements examined in the collection of *Edmontosaurus* bones consists of juvenile, sub-adult, and adult individuals, as well as super-adult; no infant or hatchling.

THE PALEONTOLOGY OF DINOSAURS MOVEABLE MUSEUM: EXTENDING MUSEUM EDUCATIONAL RESOURCES

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The American Museum of Natural History's Moveable Museum Program originated in 1993 with the mission of providing interactive inquiry-based educational experiences to the neighboring communities. Today the Moveable Museum Program consists of six full-time educators and three converted Winnebago recreational vehicles containing hands-on exhibit space. The Paleontology of Dinosaurs Moveable Museum allows students to become junior paleontologists and engage in scientific discoveries in a vertebrate paleontologist's lab and while traveling through the Gobi Desert. Through the combination of in-class education, Moveable Museum exploration, and a brief on-site wrap-up, scientific literacy is developed in accordance with national science standards. The following questions are explored utilizing multiple medias and interactive displays: What is a fossil? Where do we find fossils? What can we learn from bone fossils? What can we learn from trace fossils? What do we know about dinosaur extinction?

The Paleontology of Dinosaurs Moveable Museum is a free educational outreach program that primarily serves K-8 private and public school children within the five boroughs of New York City. Transporting exhibits to schools allows children the opportunity to increase their exposure to the American Museum of Natural History's paleontological and educational resources. Museum opportunities may otherwise be unfeasible due to financial and/or political reasons including moratoriums on inter-borough field trips. The Paleontology of Dinosaurs Moveable Museum is a valuable educational commodity due to its potential to increase cognitive gains of students as a product of the convenience of immediate exhibit visits after in-class instruction and the lack of lengthy or exhaustive field trip commutes. Improving a child's scientific literacy through the combined use of curriculum material, experienced educators, and traveling exhibits can improve a museum's educational and community outreach potential.

TWO ANATOMICAL FEATURES CHARACTERIZE MOST MAMMALIAN JAWS

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The great diversity of mammalian teeth, jaw muscles, and jaw shapes tends to mask two important similarities. First, there is virtually always a space between the joint and the back of the tooth row; teeth might otherwise be expected in this region of high bite force. Second, the muscles that close the jaw tend to be located closer to the rear of the jaw; more anterior muscles with better leverage might be expected. An explanation for these apparently less than optimal features follows from an elementary analysis of the potential magnitudes and directions of bite and joint forces along the entire length of the jaw.

Both the potential bite and joint forces are low to moderate in front of a resultant vector of muscle force and are quite high behind the vector. When biting in front of a vector the joint surfaces are pushed together. However, when biting behind a vector these surfaces are pulled apart by very high forces and the joint capsule and its ligaments may well be damaged. Potential disruption of the joint ligaments is prevented when all the teeth are located in front of the vector.

Furthermore, when all the teeth are in front of a vector and if the vector is very far forward, the bite forces might be high enough, but the tooth row may well be too short to contain the required number of teeth. Vectors that are far to the rear allow tooth rows that are long enough, but their poor leverage produces bite forces that are very low. When the muscle vector is located at the anterior end of the posterior third of the jaw, both the leverage and the length of the tooth row, taken together, are optimal.

Thus, a muscle vector that is located closer to the rear of the jaw insures that the tooth row is long enough and at the same time produces bite forces that are not too low. The space between the joint and the last tooth is present because the teeth are located in front of a vector that is, itself, some distance in front of the joint.

RECONSTRUCTING THE DIETARY HABITS OF FLORIDA MASTODONS VIA LOW-MAGNIFICATION STEREOMICROSCOPY

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A large sample (N= 76) of Pleistocene American mastodon (*Mammut americanum*) teeth from a variety of localities in Florida were analyzed for enamel use-wear features via low-magnification stereomicroscopy. Deciduous premolars and permanent molars were tested for consistency of enamel scar patterns. We used Analysis of Variance with Tukey's post-hoc test of Honestly Significant Differences (HSD) to test for differences across the tooth row in: (1) average pit frequency, (2) average scratch frequency, (3) gouges, (4) scratch texture, (5) presence or absence of large pits, and (6) presence or absence of cross scratches. Only the gouges showed significant between-tooth differences at $p < .05$, and even at this level of analysis the differences were trivial. Tukey's post-hoc tests of significance reveal that the anterior-most premolar (dP2) has significantly fewer gouges than do other cheek teeth (especially molars), but that there are no significant differences in gouging between any other pair of teeth.

Results are compared to an extant herbivore use-wear trophic triangle representing average scratch and pit morphospaces. Enamel scar patterns for *M. americanum* for six use-wear variables are consistent with a browsing diet unlike that of typical extant browsers, with extensive bark and some fruit consumption. Our results are also consistent with a predominantly C3 diet for Florida *M. americanum* suggested by stable isotope analysis. Cluster analysis reveals a clear segregation of *M. americanum* from typical extant leaf-dominated or fruit-dominated browsers, from grazing or mixed-feeding taxa, and from extant African and Indian elephants. Euclidean distance comparisons reveal a dietary profile most similar to that of the extant *Diceros bicornis* (black rhino), a well-known browser with a prehensile lip used for gathering twigs into its mouth. Our results are consistent with reports of bald cypress (*Taxodium* sp.) twigs in preserved mastodon digesta from Florida.

GROWTH AND DERMAL BONE DEVELOPMENT IN *LEPIDASPIS SERRATA*

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Exceptionally preserved specimens from the Mackenzie Mountains, NWT, Canada, have allowed for the description and analysis of bone growth of *Lepidaspis serrata*. This species belongs to an informal group of early vertebrates known as 'tessellate heterostracans' which have dermal armour composed of interlocking tesserae.

In *Lepidaspis serrata* the tesserae have a single tubercle projecting from the center of the basal plate. The basal plates themselves show varying degrees of fusion to each other. In some specimens the plates are completely fused and the distinction between individual plates is lost. However, in other specimens, there are distinctly visible spaces between the basal plates; fusion and contact are entirely absent.

Where on the body the tesserae are located may determine the extent to which they fuse. The lateral and anterior margins of the cephalothorax tend to be more robustly fused than the medial regions of the shield. However, in cases of near complete fusion, fusion around the midline is more robust than between this region and the fused lateral margins.

The morphology of the tubercles also varies between specimens. Tubercles tend to be elongate with lateral barbs projecting in an anterior direction. There is usually a slight crest along the midlines of the tubercles and of the barbs. The height of the tubercle above the basal plates varies from being extremely tall in some specimens to being relatively short in others. There is also evidence for the formation of secondary tubercles. These are larger, more robust, and have a smooth top, lacking the medial crest present on primary tubercles. This occurs on areas of the shield that would likely have been susceptible to some abrasion during life.

Growth of the basal plates could have allowed the armour to fuse eventually, though fusion is not always associated with a larger size. The lack of significant size differences of the basal plates suggests that tesserae were first laid down synchronomorially near their final size. Later, limited cyclomorial growth occurred around the basal plates allowing contact and fusion with each other.

TITANOSAURID EGGS FROM AUCA MAHUEVO (ARGENTINA)

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We provide a detailed description of the titanosaurid sauropod eggs from the Late Cretaceous Auca Mahuevo site (Neuquén Province, Argentina), the only sauropod eggs that allow a positive association between a dinosaur taxon and the Megaloolithidae family of the traditional egg parataxonomy. The eggs are sub-spherical with greater diameters ranging between 12.5 and 14 cm and a smaller diameter that is 10 to 20% smaller according to the specimen. The eggshells display a pronounced nodular ornamentation in well-preserved specimens. This ornamentation mostly consists of nodes that average 0.58 mm in diameter and 0.28 mm in height (base to apex); their internodular values vary from 0.52 to 0.87 mm. Although rare, some nodes coalesce and are readily visible under microscope. Pore canal network consists of vertical and horizontal canals intersecting on a one-to-one basis between the base of each eggshell unit. Vertical canals may fork defining a 'Y' pattern and their diameters vary between 0.08 and 0.2 mm. The pore apertures vary from 0.15 to 0.29 mm and are funnel-shaped, creating round depressions between nodes. In pristine specimens, the eggshell thickness equals 1.31 mm and its radial section exhibits a single structural horizontal layer composed of juxtaposed vertical units. Each unit consists of acicular calcite crystals radiating from an organic core, with a crystallography that resembles layer 1 (innermost layer) of dromaeosaurid and oviraptorid theropods. We regard this condition as primitive for saurischians, a condition that is observed in the eggshell of early ontogenetic stages of extant birds. Examination of the South American megaloolithid eggshells reveals that the titanosaurid eggs from Auca Mahuevo are mostly similar to those described as *Megaloolithus patagonicus* (Neuquén, Argentina) and *Megaloolithus pseudomamillare* (Laguna Umayo, Perú). *In situ* preservation of the membrana testacea coupled with the surficial ornamentation, and the geometry and distribution of pores suggests that these eggs were incubated in moist nesting environments, thus supporting the notion that adult titanosaurid covered their nests with vegetal matter.

REPRODUCTION OF FOSSILS: FROM MOTHER MOLDS TO FULL-GROWN MOUNTED SKELETONS (AN OVERVIEW AND SUGGESTIONS)

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Researchers, curators, and exhibit personnel make wide use of molding and casting for comparative study, preservation, and public educational display of fossil specimens. Reproduction of fossils makes possible their wider dissemination, helps avoid overhandling of fragile material, and allows for dramatic presentation of mounted skeletons that might not be readily possible with original specimens. As such, molding and casting are vital parts of our discipline, and yet present us with an often bewildering array of methods and media from which to choose. We present a short overview of some of the most common of these, and make suggestions about their appropriateness for particular types of projects, based on our experi-

ences with materials and techniques as they were applied to vertebrate taxa from the Eocene of Pakistan and Egypt, and the late Cretaceous of Madagascar.

This survey covers comparison and application of silicone, latex, and polyurethane rubbers, with assessment of factors such as cost, durability, ease of use, separators, ability to manage heat generated by curing resins, and risk of use with different types of fossils. In addition, we examine a range of casting materials and methods, from small strip casts suitable for scanning electron microscopy to large, durable hollow casts for heroic museum mounts. Among the methods discussed are recommendations for improving the seating and closure of molds within fiberglass-and-polyester mothermolds; use of thixatropic additives to tin-based silicones to capture details on deep, delicate recesses often otherwise blocked off during the molding process; use of mixed-media molds (silicone and polyurethane) to allow safe demolding of complex surfaces on large bones; silicone paint-and-pour techniques to avoid problems of flow into fine cracks and foramina; and adding steps in polyester hollow-casting to hide flash lines and make a stronger seal between cast parts. Finally, we present a rationale for creating a register of molding and casting methods, comments, and experiences on the SVP webpage, as an open resource for all.

DESCRIPTION OF LITTLE TWO SPINE, A NEW EUCHONDROCEPHALAN CHONDRICHTHYAN FROM THE BEAR GULCH LIMSTONE (SERPUKOVIAN, NAMURIAN E2B) OF MONTANA

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The small euchondrocephalan, previously referred to by the code-name Little-two-spine (L2SP), is now described. This operculate, autodiastylic chondrichthyan is closest in cranial, suspensorial, and pectoral anatomy to the Debeeriids, *Debeerius ellefseni* and *Heteropetalus elegantulus*. Details of the cranium include a precerebral fontanel, elongate hypophyseal opening, paired preorbital canals, and a highly robust foramen magnum. The dentition is supported not only by upper and lower jaw cartilages but also by paired lower parasymphysials and an upper symphysial. Each of the latter support a whorl of in-line cusps and are found anterior to the upper and lower jaws. Teeth of the upper and lower jaw are notable in their staggered alignment, each trenchant tricuspid tooth displaying a short base and a crown that represents the major portion of the tooth height. Only distally does the crown form a central cusp, flanked on either side by a slightly smaller cusp. Two simple, unornamented and non-serrated dorsal fin spines are found; the first is supported by a basal cartilage but is not associated with a fin. The second precedes a fin of long, low design supported by nonbranching radials and shows no evidence of support by a basal cartilage. The caudal fin is heterocercal, the epichordal lobe significantly larger and longer than the hypochordal lobe. Squamation is restricted to patches of scales that are sexually dimorphic. The lateral line of the body is supported by ring-scales. The male pelvic clasper shows evidence of significant mobility in the supporting, jointed elements. Both male and female forms show a well-circumscribed, heavily pigmented, ventral abdominal structure but only the male shows extensive ornamentation of the region with specialized scales. Previous and current cladistic analyses identify L2SP as a basal euchondrocephalan. A more detailed evaluation of this paradigm can now be presented, as the other basal euchondrocephalans previously identified as Sup1-Sup 5 have now been described.

SEXUAL DIMORPHISM IN THE PELVIS OF SHASTA GROUND SLOTHS (*NOTHROTHERIOPS SHASTENSIS*)

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Only two articulated Shasta ground sloth skeletons are known. One is the Aden Crater sloth at the Yale Peabody Museum, and the other is the Devil Peak sloth at the Nevada State Museum in Las Vegas. The Aden Crater sloth has been known since 1930, but the absence of other articulated Shasta ground sloth skeletons has precluded comparative morphometric studies of this species. The discovery in 1990 of a nearly complete Shasta ground sloth skeleton near Devil Peak, about 100 km south of Las Vegas, Nevada, has provided an opportunity for comparative studies. Here we report one aspect of our morphometric analysis of the Devil Peak sloth and a comparison with the Aden Crater sloth. Both of these sloths are late Rancholabrean in age; the Aden Crater sloth is latest Wisconsin, while the Devil Peak sloth is mid-Wisconsin in age.

In nearly all anatomical dimensions, the Devil Peak sloth and the Aden Crater sloth are nearly identical. The conspicuous exception is in the pelvis. The Devil Peak sloth's pelvis is consistently larger than the Aden Crater pelvis. Differences range from 7% larger for the greatest length of the pelvis, to 79% larger for the smallest breadth between the tubera coxarum. A regression analysis of all comparative measurements between the Devil Peak sloth and the Aden Crater sloth reinforces the conclusion that the Devil Peak pelvis is unusually large compared with the rest of the skeletal dimensions. We conclude that measurable sexual dimorphism is present within Shasta ground sloth pelves; the Aden Crater sloth was probably a male, and the Devil Peak sloth was probably a female. This conclusion has implications for the size of the fetus at birth and the gestion interval.

***LIMNOFREGATA*—NOT A FRIGATEBIRD ANY MORE**

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Limnofregata azygosternon, a fossil pelecaniform (Aves: Pelecaniformes) from the Green River Formation of Wyoming, has traditionally been cited as the oldest occurrence of the family Fregatidae, which includes the extant genus *Fregata* (frigatebirds). However, a cladistic analysis employing 153 morphological characters across eleven taxa (nine extant members of Pelecaniformes, two outgroup representatives, and the holotype of *Limnofregata*) places *L. azygosternon* as the sister-taxon to a clade containing the extant *Sula* (boobies) and *Morus* (gannets). This position is supported by the following synapomorphies: 1. extensive papillae remigalis caudalis of the ulna absent or greatly reduced, 2. edge of the bicipital surface of the humerus does not reach over the sulcus ligamenti transverses, 3. crista cnemialis lateralis of the tibiotarsus slightly hooked. The relocation of this fossil genus to the Sulidae, a more derived clade within Pelecaniformes than Fregatidae, affects previous "molecular clock" hypotheses of early neornithine radiation that used *Limnofregata* as a calibration point. Furthermore, the oldest occurrence of a fossil sulid is shifted back to the early Eocene (53.5-48.5 Ma), providing insight into the early diversification of one of the basal orders within Neornithes.

NEW PRIMITIVE MICROBAT (CHIROPTERA) FROM THE GREEN RIVER FORMATION (UPPER LOWER EOCENE), FOSSIL BASIN, SOUTHWESTERN WYOMING

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Fossil mammals from the Green River Formation are relatively rare. However, complete skeletons of the microbat *Icaronycteris index* have been found in Green River lake sediments. *Icaronycteris*, along with *Archaeonycteris* from the early middle Eocene of Germany, are among the most primitive known microbats. Each retained three upper and lower premolars, had a relatively high humero-radial index (radius only moderately elongated), lacked a calcar, retained claws on wing digit II and apparently had a poorly developed uropatagium. Together these two taxa constitute the archaic microbat family Archaeonycteridídae.

Recently, a new microbat from the Green River Formation (FOBU 9840) has been discovered. The original specimen is in private hands, however, a high quality cast and photographs of the original are available. This specimen was collected from the middle unit of the Fossil Butte Member of the Green River Formation (upper lower Eocene) in Fossil Basin, Wyoming. It consists of a complete skeleton of a relatively large microbat with an estimated body weight of 32 grams.

The new microbat differs from *Icaronycteris* and *Archaeonycteris* in being larger with a comparatively longer tail, in retaining claws on all wing digits, in having a relatively shorter radius compared to humerus, and in retaining a moderately well developed ulna that extends distally past mid-shaft before becoming fused to the radius. FOBU 9840 has a relatively low aspect ratio (5.51) and a high wing loading index (19.9), indicating that its flight pattern was one of relatively high speed but low maneuverability. Like archaeonycteridids, the new bat retained three upper and lower premolars, lacked a calcar, and had a long, free tail (apparently lacking a uropatagium). FOBU 9840 differs from contemporaneous *Honrovits* in being larger, in lacking substantial premolar reduction, and in having upper molars with a more buccally extended centrocrista, weaker pre- and postprotocristae, and lacking a hypocone shelf. FOBU 9840 represents the most primitive definite microbat yet known.

A NEARLY COMPLETE SKELETON OF *PACHYRHIZODUS CANINUS*

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The Cretaceous teleost species *Pachyrhizodus caninus* was described in 1872 on the basis of jaws. In the subsequent 130 years, the only published information on the species was based on heads and caudal skeletons. PF 3326 in the Field Museum of Natural History was probably the most complete specimen known, although it lacks the caudal skeleton. In July of 2002, the authors recovered a skeleton of *P. caninus* from the zone of *Volviceramus grandis* (late Coniacian) in the Smoky Hill Chalk of Phillips County, Kansas. The head and tail are connected by 56 preural vertebrae. The standard length is approximately 166 cm. A total length cannot be determined because rock quarrying activity had destroyed most of the caudal fin rays.

The main criteria for distinguishing between *Pachyrhizodus caninus* and *Pachyrhizodus minimus*, the only other species of true *Pachyrhizodus* known North America, have been the delicate dentition and small size of *P. minimus*. It is now possible to list several ways in which *P. caninus* differs from *P. minimus*. The anterior ceratohyal of *P. caninus* is imperforate and has a notched ventral margin (both are derived states), but that of *P. minimus* bears a large foramen and has a smooth ventral margin. Parts of the intestinal tract of *P. minimus* are frequently preserved as an elongate, convoluted coprolitic mass. This has never been recorded in *P. caninus*. The height of the vertebral centra of *P. caninus* is much greater than the length, but they are nearly equal in *P. minimus*. The ridges and grooves for receiving the uroneurals on the first four preural vertebrae are much stronger in *P. minimus* than in *P. caninus*. The divergence of the caudal lobes varies from 110 to 135 degrees in *P. minimus*, but from 70 to 85 degrees in *P. minimus*. In contrast to most members of the Pachyrhizodontidae, *P. caninus* and *P. minimus* exhibit fusion of the first ural centrum with hypurals one to three.

PTYCHODONTID SHARKS IN THE UPPER CRETACEOUS EAGLEFORD GROUP OF NORTHERN TEXAS

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In North Texas, selachians of the family Ptychodontidae are present in the Upper Cretaceous Britton (Cenomanian), Kamp Ranch (Lower Turonian), and Arcadia Park (Upper Turonian) formations of the Eagleford Group. The Britton Formation represents a shallow marine environment with abundant ammonites and a rich decapod fauna. Two ptychodontids occur in the Britton Formation: *P. decurrens* and *P. anonymus*. The Kamp Ranch Formation is a limestone rich in *Inoceramus* fragments as well as shark and bony fish remains. This deposit is the result of large-scale hurricane storm events that occurred along a low-gradient marine platform. Through the storm, the final backwash transported the benthic elements from the seafloor as well as any pelagic organisms and redeposited them further offshore. One intriguing feature of the Kamp Ranch Formation is the increase in the number of ptychodontid

species, where at least five species made their first appearance: *P. mammillaris*, *P. mortoni*, *P. polygyrus*, *P. whipplei*, and an undescribed *Ptychodus* species. This rapid proliferation of species represents an event that establishes the Ptychodontidae as one of the most abundant selachian groups in the Upper Cretaceous Eagleford Group in northern Texas. These five species are present in the overlying Arcadia Park Formation, which was deposited in a quiet water environment with an invertebrate fauna similar to the underlying Britton formation. The examination of ptychodontid species in these three formations is important, because the taxa may be used as a biostratigraphical tool.

RE-EXAMINATION OF THE DEVONIAN ACANTHODIANS *URANIACANTHUS SPINOSUS* AND *GLADIOBRANCHUS PROBATON*

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Uraniacanthus spinosus and *Gladiobranchus probaton* are Devonian acanthodians originally classified as ischnacanthids, despite the fact that characteristic ischnacanthid jaw bones were not known for either when originally described.

Specimens of *Uraniacanthus spinosus* Miles lack well-preserved heads and all lack evidence of jaws. However, an isolated jaw of an ischnacanthid acanthodian was collected along with the remains of *U. spinosus*. This jaw would not be of concern had the tuberculated, postorbital circumorbital plates of *U. spinosus* been identified correctly. However, tubercles on the postorbital plates were mistaken by Miles for teeth; they were taken as evidence that *U. spinosus* was an ischnacanthid and that the isolated jaw also belonged to the species.

Bernacsek and Dineley later described *Gladiobranchus probaton*, noting its similarity to *U. spinosus*. This similarity led Bernacsek and Dineley, and many since, to classify *U. spinosus* and *G. probaton* as ischnacanthids, following Miles. The lack of preserved jaws in the original specimens of *G. probaton* contributed to this interpretation.

Re-examination of the type material of *U. spinosus* shows that jaws of ischnacanthid type are absent. New, well-preserved specimens of *G. probaton* have toothless jaw bones like those of diplacanthids, and tuberculated circumorbital plates like those of *U. spinosus*. These tuberculated plates which were misinterpreted as jaws in *U. spinosus*, are a characteristic feature of diplacanthid acanthodians. The morphologies of the pectoral and prepelvic spines and pectoral endoskeleton confirm that *Uraniacanthus* and *Gladiobranchus* species are diplacanthids, not ischnacanthids. In fact, *U. spinosus* and *G. probaton* are nearly identical to each other in all comparable features; and therefore, we advocate synonymizing the two genera.

PERIOSTEAL REACTION TO INJURIES OF THE SUPRAORBITAL HORN AND SQUAMOSAL OF AN ADULT *TRICERATOPS* (DINOSAURIA: CERATOPSIDAE)

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Analysis of injuries to the skull of a mature *Triceratops* provides insight into their cause. Skull SUP-9713 was recovered from the Hell Creek Formation (Upper Cretaceous) near Jordan, Montana. When the left and right supraorbital horns are compared, the left horn is missing more than one-third (24 cm) of its original length (approximately 60 cm). Damage appears at the end that remains. On the edge of the damaged area are two opposing conical depressions on opposite sides of the horn that are consistent with the shape of large crocodilian or tyrannosaurid teeth. Because the horn is composed of thick layers of compact bone at the point of injury, the damage appears to have resulted from a bite of considerable force. The injury exposes cancellous bone from the internal portion of the horn. On the surface of cancellous bone are anomalous patches of compact bone that are not ordinarily observed. These overgrowths of compact bone possess multidirectional bone fibers and are interpreted as periosteal reaction to the horn injury.

In addition, three parallel marks appear on the left squamosal of the specimen. The first is 60 mm long, 22 mm wide, and very prominent and is 65 mm from the second mark which is 95 mm long, 6 mm wide, and more superficial. The second mark is 63 mm from the third, which is 90 mm long, 6 mm wide, and faint. The distance between parallel marks corresponds to the inter-tooth distance of tyrannosaurids during the Late Cretaceous. *Tyrannosaurus rex* is the only theropod found in the Hell Creek Formation with an inter-tooth distance of this magnitude. The first mark shows signs of periosteal reaction to injury. At this mark, the bone has grown 4 mm above its regular surface. Bone fibers are expanded and interlace the length of the mark. X-ray analysis of the injuries provides supporting evidence of periosteal reaction. The *Triceratops* appears to have survived these injuries.

LIFE AT AN EARLY PLIOCENE BEAVER POND IN THE CANADIAN HIGH ARCTIC

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A fossil site (78°33'N, 82°22'W) near the head of Strathcona Fiord, Ellesmere island, Nunavut preserves remains of an early Pliocene (about 4-3 Ma) beaver pond occupied by a small beaver (*Dipoides* cf. *D. intermedius*). Evidently this beaver cut many larch sticks and saplings, made dams and feeding piles. Remains of hare-like *Hypolagus* cf. *H. vetus* were nearly as common at the site. Other members of the vertebrate fauna include: fishes; frogs; birds; a new genus of shrew (*Arctisorex polaris*); a mouse like *Baranomys*, a small canid (cf. *Eucyon davisi*); a primitive black bear (*Ursus abstrusus*); several mustelids including the wolverine-like *Plesiogulo*, and a new species of Eurasian badger (*Arctomeles sotnikovae*); a three-toed horse (*Plesiohipparion* sp.) and a deerlet like *Blastomeryx* (*Parablastomeryx*). Although a few of these taxa are derived from mid-continent North America, most have their earliest Asian joint occurrence in coeval deposits of the Yushe Basin, northern China.

Studies of pollen and plant macrofossils indicate that a boreal-forest margin environment with extensive grassy patches surrounded the pond. Larch, alder and birch seem to have been the main trees growing nearby. Some of the wood is charred as a result of forest fires.

Analysis of the diverse beetle fauna (16 extant species) from the peaty matrix indicates that the site was 10°C warmer than present in summer and 15°C warmer in winter. Several freshwater diatoms indicate that the beaver pond was no more than 3 m deep, and that a shift from alkaline to more acid conditions occurred later in the history of the pond. The site yields a rare glimpse of the Pliocene terrestrial biota north of the Arctic Circle.

A NEW DIPLODOCOID (DINOSAURIA: SAUROPODA) FROM THE MORRISON FORMATION OF MONTANA

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Vertebrate fossils from the Morrison Formation (Upper Jurassic, ?Tithonian) of Montana are poorly understood compared to their complements further south. A new, small sauropod dinosaur, discovered in 1999 and represented by a partial skeleton including an incomplete skull, has been recovered from the Morrison Formation of south-central Montana. The taxon is diagnosed by numerous cranial, axial, and appendicular autapomorphies, including coalesced optic foramina, narrow ventral process of supraoccipital, amphiplatyan 'whiplash' caudal vertebrae, and a spheroidal calcaneum. The holotype, Academy of Natural Sciences 21122, displays numerous autapomorphies of the Diplodocoidea; within that clade, however, it displays characters of both the Diplodocidae (*Apatosaurus* + *Diplodocus* + *Barosaurus*)) and the Dicraeosauridae (*Dicraeosaurus* + *Amargasaurus*), including some features (e.g., a postparietal foramen) never previously recorded in a North American sauropod. Preliminary phylogenetic analysis indicates that the taxon is a diplodocoid more derived than rebbachisaurids but in an unresolved trichotomy with the Diplodocidae and Dicraeosauridae. The specimen represents the first well-supported, North American, non-diplodocid representative of the Diplodocoidea. Small sauropods are the most commonly reported vertebrates from the Morrison Formation of Montana, and with a single exception, all have thus far defied ready placement into existing genera. This suggests that the northern end of the Morrison Formation depositional basin, proximal to the retreating Sundance Sea, may have contained a fauna distinct from that recognized from more southerly outcrops.

TROPHIC RELATIONSHIPS OF LATE PLEISTOCENE MAMMALS FROM RANCHO LA BREA

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Most mammalian fossils from Rancho La Brea date between 12-40,000 BP. The skeletal remains are well preserved and, after removal of contaminating hydrocarbons, yield diagnostic stable isotope values. We sampled the bone collagen of both herbivores and carnivores for stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios.

Ruminant herbivores could be distinguished from non-ruminants on the basis of the $\delta^{13}C$ and $\delta^{15}N$ values, which reflect the increase in methane production and autoenzymatic digestion of microbes that are characteristic of foregut fermentation. The $\delta^{15}N$ values for carnivores indicated that *Canis dirus*, *Smilodon fatalis*, and *Panthera leo atrox* competed for a similar prey set, primarily targeting ruminants. Stable isotope values also indicate that ground sloths *(Paramylodon harlani)* had a digestive physiology similar to extant sloths. The $\delta^{15}N$ values of *Mammut americanum* and a subset of *Equus occidentalis* suggest partial reliance on nitrogen-fixing plant taxa, perhaps mosses, distinguishing them from the remainder of the study population.We found no evidence for the presence of C_4 grasses at this site, despite low atmospheric CO_2 concentrations during the late Pleistocene, but do report slight enrichment in $\delta^{13}C$ values consistent with physiological stress on plant communities at the last glacial maximum, ca. 20,000 BP.

SNAKING THROUGH SHAPE-SPACE: GEOMETRIC MORPHOMETRIC APPROACHES TO TAXONOMY AND PHYLOGENY IN ERYCINE SNAKES

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The majority of fossil snake species and their interrelationships have been described on the basis of qualitative descriptions of vertebral shape, which have been criticized as irreproducible and uninformative. In order to quantify sources of shape variability and to determine the utility of vertebral shape in taxonomic identification and phylogenetic reconstruction, this study applies geometric morphometric techniques to vertebral morphology in erycine snakes, a clade that possesses an extensive fossil record throughout the Cenozoic of North America and Europe.

Least-squares Procrustes and relative warp analyses examine the relative contributions of ontogeny, intracolumnar variation, individual variation, phylogeny, and alpha taxonomic identity to vertebral shape variability among extant and fossil taxa. Results reflect higher-order phylogeny in that Erycinae can be distinguished from boine and pythonine taxa, and individual species can be identified on the basis of vertebral shape. However, shape distances within Erycinae do not reflect known phylogeny and may represent ecomorphology. Additionally, ontogenetic change and individual variation are significant sources of shape variability and may confound taxonomic and phylogenetic signals. Some fossil taxa can be identified as unique, but vertebral shape for others falls within the ranges of variability within extant species. This use of geometric morphometrics reduces the number of recognizable fossil taxa, but provides testable methods for reconstructing taxonomy and diversity.

HENRY FAIRFIELD OSBORN AND REVISING THE *OVIRAPTOR* MYTH

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The early 1920s brought the discovery of new fossils from southern Mongolia by expeditions from the American Museum of Natural History. Among these included a toothless

theropod lying near a nest of eggs, in a "grasping" posture; initially, it was assumed that the eggs belonged to *Protoceratops andrewsi* by the relative abundance of *Protoceratops* and the nests versus the single specimen of *Oviraptor philoceratops*, and that the theropod was therefore a predator upon the eggs. Osborn, to whom fell the task of describing most of these fossils, even identified several corroboratory features of the jaw, including a ventral process of the palate (misidentified from a partial ectopterygoid) in the holotype, that were used to support an egg-eating lifestyle. Field work in northern China and in southern Mongolia in the 1980s and 1990s up to now have produced numerous nests of the "*Protoceratops*" type in association with overlying, "brooding" specimens of various oviraptorids; these eggs have been shown to contain at least one embryo of an oviraptorid, rather than a ceratopsian, and indicate the affinity of the nests was originally erroneously assumed. The recent work has led to the creation of an idea that *Oviraptor* was not an egg-"thief" but an egg-"mother", tendering Osborn's theory as an antiquated notion ill-suited to current understanding.

Jaw anatomy in oviraptorids shows the development of several features that indicate dietary specialization to crushing, including an expanded secondary body palate, enlargement of the temporal musculature, and a palatal design that enhances the holding, puncturing, pulverization, and swallowing of an egg or its contents. This indicates that oviraptorids in general may have likely incorporated eggs into their diet often enough to lead to selection favoring this food: other foodstuffs would have been secondary to the eating of an egg. This does not contradict that oviraptorids were good mothers, and they may have preyed upon the eggs of other dinosaurs, of which the Mongolian Late Cretaceous had in abundance.

THE RELATIONSHIPS OF *CETIOSAURISCUS STEWARTI* (DINOSAURIA; SAUROPODA): IMPLICATIONS FOR SAUROPOD PHYLOGENY

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The holotype of *Cetiosauriscus stewarti* consists of a partial sauropod postcranial skeleton from the Middle Jurassic (Callovian) of Peterborough, eastern England. The specimen was found in the marine Oxford Clay in 1898 and represents one of the most complete sauropods from the United Kingdom. The presence of high neural spines over the sacrum, forked chevrons and an apparent "whiplash" distal tail sequence, led several previous workers to conclude that *Cetiosauriscus* is a member of the Diplodocidae or Diplodocoidea. *Cetiosauriscus* therefore has the potential to provide important insights into the early evolution of diplodocoid sauropods, but its phylogenetic relationships have not previously been tested rigorously using cladistic analysis.

The phylogenetic relationships of *Cetiosauriscus* are assessed using the data-matrices of the two largest, currently available, cladistic analyses for the Sauropoda (i.e. those of P. Upchurch and J. A. Wilson). Character data were obtained directly from the holotype specimen, but the distal "whiplash" was ignored because there is no evidence for its association with the former. The analysis using the Upchurch data-set yields 7392 most parsimonious trees (MPTs) of length 745 steps. The application of reduced consensus methods results in a decrease to only six topologies after the deletion of four sauropod taxa. In all six trees, *Cetiosauriscus* is the sister-taxon to *Tehuelchesaurus*, and these two taxa together form a clade with *Omeisaurus*, *Mamenchisaurus* and *Euhelopus*. Analysis of the Wilson data-set yields three MPTs of length 453 steps. Once again, *Cetiosauriscus* clusters with *Omeisaurus* and *Mamenchisaurus*. Thus, both analyses support the view that *Cetiosauriscus* lies outside of the neosauropod clade and is therefore not a basal diplodocoid. The incorporation of *Cetiosauriscus* into cladistic analyses has an important impact on character state distributions and relationships among other sauropods.

THE LATE PLEISTOCENE SEA BIRD FAUNA OF ON YOUR KNEES CAVE, SOUTHEAST ALASKA

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On Your Knees Cave on Prince of Wales Island has produced a bird fauna in excess of 10,000 specimens dating back 40,000+ years. Most seem to have been cached by foxes (*Alopex lagopus, Vulpes vulpes*) that disappeared from the island about 10,000 years ago when the modern rainforest developed. Therefore most of the birds date to the Middle Wisconsin Interstadial, the Last Glacial Maximum (LGM), and the early postglacial interval. Cave sediments have been divided into climatic age zones based on rodent distributions, and bird remains are abundant at all levels.

Because of their migratory habits, birds are not restricted to narrow climatic zones as many mammals are. However, birds can respond quickly to climatic changes because of their mobility. The relative abundance of birds in cave faunas may reflect the location of breeding grounds and fly routes as well as preferences and ease of capture by mammalian carnivores. All these factors may have changed significantly during the climatic extremes recorded at On Your Knees Cave.

A modern bird fauna was found in a cave on Dall Island (>150 bones accumulated by *Mustela vison*) consisting mostly of *Uria aalge, Phalacrocorax pelagicus*, and *Melanitta perspicillata*, plus 14 other species. Birds from On Your Knees Cave with over 100 specimens are *Uria aalge, Cyclorrhynchus psittacula, Fratercula cirrhata, Clangula hyemalis, Phalacrocorax pelagicus*, and *Somateria mollissima*, with 30 additional species.

Four radiocarbon dates on *Fratercula* range from 26,030 to 19,340 yr B.P. (plus one >35,000 yr B.P.). These four dates fall during the LGM and closely match the timeframe of 26 radiocarbon dates obtained on *Phoca hispida*, which is restricted to the LGM. These two species also have a similar distribution in the cave stratigraphy. Other species that dominate the LGM include *Cyclorrhynchus psittacula* and *Melanitta fusca* (with a radiocarbon date of 20,530 yr B.P.). Other species such as *Uria aalge, Clangula hyemalis*, and *Melanitta perspicillata* are found throughout the section and seem to dominate in warmer times.

CONTINENTAL AMPHIBIAN BURROWS FROM THE LOWER PERMIAN SPEISER SHALE OF KANSAS: EVIDENCE FOR DROUGHT-INDUCED AESTIVATION IN PERMIAN TETRAPODS

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Burrows of the lysorophid amphibian *Brachydectes elongatus* occur in a pond deposit within the Lower Permian Speiser Shale (Council Grove Group) of eastern Kansas. Lysorophids are elongate (5 to 150 cm long), nearly limbless lepospondyl amphibians that ranged from the Upper Pennsylvanian coals beds of the eastern United States to the Lower Permian redbeds of the midcontinental and southwestern United States. The occurrence of lysorophids within burrows is restricted to the Permian species. The burrows of *B. elongatus* possess morphological traits that permit their distinction from co-occurring lungfish burrows even in the absence of body fossils, permitting the establishment of a new ichnogenus and ichnospecies.

The pond deposit consists of a 100 m long lens of calcareous green mudstone 10 to 40 cm thick that fills a small paleo-depression within a well-developed paleosol. The burrows occur primarily on the western edge of the pond deposit in three vertically and temporally separated clusters. The clusters consist of up to 45 burrows with concentrations up to 20/m^2. The lysorophid burrows exhibit two types of architecture. Type I burrows are elongate, narrow elliptical tubes 4 to 32 cm long and 2 to 7 cm wide. Type II burrows are short, elliptical tubes 1.5 to 3.5 cm long and 2.5 to 5 cm wide. The burrows of each layer contain a varying number of articulated and disarticulated lysorophid skeletons.

The burrow layers are capped by surfaces with evidence of subaerial exposure and overlain by non-burrowed massive mudstone containing the fossils of charophytes (*Stomachara*), ostracodes (*Carbonita*), fish, and amphibians. This succession indicates that the lysorophids burrowed in response to episodic, perhaps seasonal, droughts on the Permian midcontinental coastal plain. This behavior is analogous to that of the extant aestivating amphibians *Amphiuma* and *Siren intermedia* that inhabit ephemeral rivers and ponds of the southeastern United States.

SAUROPOD DINOSAURS WERE THE COLOSSAL CORKS OF THE MESOZOIC

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This study investigates long-standing hypotheses about sauropod buoyancy and aquatic habits. A general-purpose 3-D mathematical/computational model was developed to study the buoyancy and stability of extant and extinct tetrapods immersed in water. The model determines the downward weight force, the upward buoyant force, and the torques associated with these forces that would act to rotate the body. Starting from an arbitrary initial orientation and depth in water, a model is brought to equilibrium by an iterative process so that all vertical forces and turning moments are balanced. The model incorporates an axial body with variable density, a hollow lung cavity, and all limbs. A model of an alligator can replicate the depths of immersion and body inclinations seen in live alligators that have attained stable equilibrium while floating at the water surface.

Four different sauropods—*Apatosaurus*, *Brachiosaurus*, *Camarasaurus*, and *Diplodocus*—were analyzed and it was found that all four would float at the water surface. Despite having body masses of not less than ten tonnes, these sauropods possessed highly pneumatized skeletons, and this pneumaticity has a profound influence on their buoyancy. The problem of sauropods being unable to breathe while walking along the bottom of a deep lake is irrelevant—they would have been unable to walk on the bottom in the first place. The maximum water depths at floating would commence were also determined for each model and found to be approximately equal to the tops of the ilia: e.g. *Brachiosaurus* at 4.7 m.

The diplodocids—*Apatosaurus* and *Diplodocus*—were found to float with the body tilted up (hind feet deeper than fore feet). The two macronarians—*Brachiosaurus* and *Camarasaurus*—were found to float with their bodies tilted down (fore feet deeper than hind feet). While it appears impossible for diplodocids to have produced manus-only trackways while floating, the macronarians could have done so.

IMPORTANT CONSIDERATIONS REGARDING CONSERVATION AND ETHICS IN MOLD MAKING

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Rubber molds to replicate fossils have long been used in order to "accurately" reproduce casts for research, exhibit display, and education. Many fossils undergo torturous procedures when molded. Poorly thought out mold designs cause tremendous and often permanent damage to the specimen, particularly if the fossil exhibits intricate morphologies (to be discussed during this year's Preparator's Symposium).

Unfortunately, considerations regarding the conservation and ethical aspects of fossils undergoing such procedures are often ignored during the mold making process.
It is IMPERATIVE that appropriate approvals be granted before undertaking ANY mold making procedure, particularly if the specimen has been borrowed from another institution. If written approval is not granted, molding the specimen should NOT be undertaken! If approval's secured, one must understand the procedures and integrity of each specimen PRIOR to molding. A thorough familiarity of the molding compound (tear and tensile strength, working time, etc.) is required, as some specimens would not survive certain products that may adhere more

aggressively than others. Mold separators also have a unique chemistry that can be detrimental to a specimen and should be used cautiously. It is also crucial that the mold maker have a sound working knowledge of the specimen to be molded (morphology, structural weaknesses and strengths, etc.) in order to prevent any damage to the fossil. The ultimate purpose for making the cast, whether research, display or education, must be known prior to mold set-up. If a research quality cast is needed, extra care must be taken in order to obtain the most accurate reproduction of the specimen as possible with little to no distortion. Some materials used during molding are not suitable for high definition casts. However, these materials may be used in molds for display or education casts as the details of a specimen are less important for these purposes.

These and other factors must be considered prior to and during the mold making process, otherwise we, as preparators and lab technicians, are doing a grave disservice to the specimens and the science.

A LARGE HADROSAURINE FROM THE SABINAS BASIN, COAHUILA MEXICO

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In 2001, a large dinosaur was recognized by Juan Pablo Garcia in an excavation in the San Miguel Formation (uppermost Campanian), near the town of Sabinas, Coahuila, Mexico. The bones were excavated by the Association of Amateur Paleontologists of Sabinas in the spring of 2001 and sent to the Geological Institute in Mexico City for study. All of the bones were identified as coming from one individual hadrosaurine dinosaur, and are thought to represent the most complete individual dinosaur yet recovered in Mexico. Identified skull material includes both dentaries, a maxilla, quadradojugal, quadrates, braincase, postorbital, and other skull bones. Post-cranial material includes nearly the entire vertebral column, a partial ilium, pubis, ischium, femur, tibia, fibula, scapula, and coracoids. The ischium is distinctive in being dorsally recurved as in *Hadrosaurus foulkii*. Although lacking the premaxillae, nasals, and frontals, relative proportions of other parts of the skull suggest that the specimen is best compared with *Kritosaurus*as typified by *K. navajovius*. However, the Sabinas specimen is about 20% larger than the holotype. With a femur length of 1.3 m, the Sabinas specimen would have had an estimated length of 11 m and a weight of about 4 tons. A second specimen of similar size, represented by the front of the skull from the Parras Basin near Presa de San Antonio, indicates that the muzzle was deep as in *Gryposaurusi*. Reconstruction of a nasal from the holotype of *Kritosaurus* at the American Museum of Natural History indicates that the circumnarial depression was pulled back to the rear of the nasals as in *Prosaurolophus* and supports the synonomy of *Kritosaurus* and *Naashoibitosaurus*.

THE PHYLOGENETIC INTERRELATIONSHIPS OF THYREOPHORAN DINOSAUR SPECIES (STEGOSAURIA, ANKYLOSAURIA, AND BASAL THYREOPHORA)

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The Thyreophora, including stegosaurian, ankylosaurian, and basal thyreophoran dinosaurs, is currently recognized as a monophyletic group. Several phylogenetic analyses of the relationships among taxa within the Stegosauria or Ankylosauria have recently been published. However, each of these phylogenetic analyses has focused on one major thyreophoran group only, and has included only supraspecific taxa as terminals. Additional problems with recent studies include few characters, use of cranial characters only, compartmentalization, and incomplete state definitions.

To investigate the interrelationships among thyreophoran dinosaurs, 186 skeletal characters, including 113 cranial and 73 postcranial, were gathered from the literature and some specimens for four basal thyreophoran species, 9 stegosaurian species, 44 ankylosaurian species, and the outgroup *Lesothosaurus diagnosticus*. Data for all species was analyzed simultaneously via maximum parsimony methods.

The Thyreophora, Eurypoda, Stegosauria and Ankylosauria are all recovered as clades supported by at least eight synapomorphies each. Jackknife values calculated for these clades are high (over 60%). The established stegosaurian families are both recovered; however, the Ankylosauria fragment into several groups. A monophyletic Ankylosauridae is recovered with the sole exception of the Middle Jurassic *Tianchiasaurus nedegoapeferima*, which falls outside this family and is placed as sister taxon to *Polacanthus* spp. Nodosaurid ankylosaurs form a paraphyletic assemblage of species, including two fully resolved, previously unrecognized clades. These nodosaurid clades, however, have relatively low jackknife values. Further study of thyreophoran specimens may improve their support.

RHINOCEROS HORN ATTACHMENT: ANATOMY AND HISTOLOGY

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Rugosities on dermal bones of the skull have often been used to support inferences regarding unpreserved skin structures in extinct animals. Such associations often seem obvious when examined in extant osteological specimens, where the shape and conformation of epidermal appendages remain intact, but inferences regarding the type and morphology of unpreserved skin structures are not always so clear. Rhinoceros horn provides an example of an epidermal structure whose morphology cannot be readily determined from the shape of its associated rugosity. The horn attachments of two adult white rhinoceros (*Ceratotherium simum*) were examined by CT scanning, dissection, and histological sectioning. The horn proper is an epithelial structure composed of hair-like filaments embedded in a keratinized and mineralized matrix, which in turn is strongly affixed to the dense irregular connective tissue of the dermis. Rhinoceros dermis is quite thick in general, ranging from 1.5-3 cm thick across the skin of the face. The dermis retains much of this thickness beneath the horn, ranging from 1-2 cm thick beneath the rostral nasal horn, and from 2-3 cm thick beneath the caudal frontal horn. The horn-dermis complex is affixed to the bone itself by dense populations of extrinsic fibers derived from the reticular dermis. These fibers penetrate the bone at an oblique angle, and their irregular mineralization gives the cleaned bone surface its characteristic rugose appearance. A more thorough understanding of how this structure affects the morphology of the underlying bone aids in differentiation between horn-induced rugosities and rugosities with other causal associations, such as tendon attachment or secondary dermal ossification. This finer discrimination allows hypotheses regarding unpreserved skin structures to be framed more accurately.

RECONSTRUCTING AMNIOTE PHYLOGENY USING MORPHOLOGY OF THE SKELETON, INTEGUMENT, AND OSTEODERMS

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The phylogenetic relationships among amniotes have recently undergone a resurgence in intensive study, motivated by questions concerning the origins of amniote higher taxa, particularly turtles. The resulting multitude of conflicting phylogenetic hypotheses poses a challenge to molecular systematists and paleontologists to resolve these relationships. In this study, the question of amniote phylogeny is addressed using a combined data set consisting of published osteological, soft tissue, physiological and behavioral data, along with original osteological and histological character data on the integument and osteoderms. Incorporation of new integumentary data contributes information on an anatomical system that has been traditionally underrepresented in morphological systematics. Osteoderms in particular represent an important source of comparative integumentary data, available in both extant and extinct taxa. Taxonomic sampling is increased relative to previous analyses to include multiple genera representing both extant and extinct amniote clades.

Combination of published data sets has allowed for the identification of conflicting data, and produced one of the largest morphological data sets ever compiled for amniotes. Parsimony analysis of the combined data set supports the monophyly of several major clades, including 1) Amniota, 2) Synapsida, 3) Sauropsida, 4) Lepidosauromorpha, and 5) Archosauromorpha. Incorporating characters of osteoderm morphology and integumentary histology provides added resolution within highly nested subsets of each of these clades, including squamates, aetosaurs, and thyreophoran dinosaurs.

The analysis also provides further support for a close phylogenetic relationship between turtles and crown-group diapsids, an unconventional hypothesis that nevertheless is becoming increasingly prevalent through recent morphological and molecular studies. The morphology and histological structure of the integument and osteoderms reveals characters that are phylogenetically informative, facilitating the reconstruction of ancestral states for deep nodes in amniote phylogeny.

THE FOSSIL RECORD OF STURGEONS (ACTINOPTERYGII: ACIPENSERIFORMES: ACIPENSERIDAE)

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The family Acipenseridae (i.e., sturgeons) is the largest group of extant non-teleostean actinopterygian fishes, including 25 extant species classified in four genera (*Scaphirhynchus*, *Pseudoscaphirhynchus*, *Huso*, *Acipenser*). We review the fossil record of acipenserids based on first-hand examination of North American collections, with an emphasis on the Cretaceous and Tertiary of North America. There are three nominal North American fossil species that have been assigned to the genus *Acipenser* (*A. albertensis*, *A. eruciferus*, and *A. ornatus*), none of which can be diagnosed below the family level. Additionally, there is a monotypic fossil genus (*Protoscaphirhynchus*), as well as a well-preserved undescribed taxon, both from the Late Cretaceous of Montana. While the fossil record of sturgeons extends well into the Cretaceous, the quality of the fossils is notoriously poor, usually consisting of fragmentary dermal skull bones, isolated and often broken scutes, and broken pectoral fin spines. There are many specimens of acipenserids from the Late Cretaceous and Paleocene, particularly from the Judith River, Hell Creek, and Tullock formations. There are several known specimens from various Miocene and Pliocene formations as well. We have been unable, however, to find acipenserid specimens from the Eocene and Oligocene of North America.

A PRELIMINARY REVIEW OF THE VERTEBRATE FAUNA OF THE TURNEY RANCH FORMATION (ALBIAN/CENOMANIAN) OF PIMA COUNTY ARIZONA

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An early to middle Cretaceous vertebrate fauna is documented from the Turney Ranch Formation, upper Bisbee Group of southern Arizona, from multiple localities within Mattie Canyon of the Whetstone Mountains. The material recovered so far from this formation consists of fragmentary to partially complete remains of four types of dinosaurs: two theropods, one anklyosaur, and the type specimen of the brachiosaurid sauropod *Sonorasaurus thompsoni* Ratkevich 1998. Also recovered is the 8th? peripheral of a baenid turtle. The Turney Ranch fauna may be unique based on its geographic and temporal location. The Turney Ranch Formation is one of the more southerly Early to middle Cretaceous localities in western North America and is estimated to be equal in time to the Albian/Cenomanian faunal transition of Asian immigrant species of hadrosaurs, tyrannosaurs, and ceratopsians that replaced "Jurassic classics" such as the sauropods, allosaurids, and igaunodonts. The vertebrate fauna of the Turney Ranch Formation retains mega-faunal species that are remnant of the upper Jurassic and early Cretaceous, with as of yet no indication for Asian origin species that are seen at other more northerly localities of the same age. This maybe due to geographic isolation by ancient highlands to the north and west of the Bisbee basin and also from the Bisbee seaway block-

ing possible migration routes from the northeast, until later in the Cenomanian, when the Bisbee seaway receded which allowed for alien species to migrate and replace the Turney Ranch Fauna.

REVISION OF THE DWARFED LEPTAUCHENIN OREODONT *SESPIA* FROM THE LATE OLIGOCENE OF CALIFORNIA AND THE HIGH PLAINS

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Sespia californica is a dwarfed leptauchenin oreodont, first described by Chester Stock in 1930, which is common in early Arikareean (late Oligocene) deposits of southern California. However, the type material was fragmentary and the postcranials were never described. Abundant new material, including hundreds of jaws and maxillae, complete skulls, and partial skeletons, were found during excavations for housing developments in the upper Oligocene Otay Formation in San Diego County. We address three questions: 1) Are the new samples the same species as the type material from the Sespe Formation? 2) Is *Sespia californica* the same as the type of the genus, *Sespia nitida*, from the Arikareean of the High Plains? 3) Do these large samples exhibit any sexual dimorphism? Careful measurements of the relatively undistorted dimensions of skulls and jaws show that *Sespia californica* is significantly smaller than *Sespia nitida* (senior synonym of *S. ultima, S. heterodon, S. marianae, and Megasespia middleswarti*), indicating that *Sespia californica* immigrated from the High Plains (where it first appears in Chron C10r, at 29.5 Ma, in the "brown siltstone" member of the Brule Formation) to California (also at 29.5 Ma, in the upper Sespe Formation in Ventura County, and the Otay Formation in San Diego County). The measurements also show that there is no sexual dimorphism in size, nor was there any evidence of the maxillary "horns" that some have speculated as dimorphic in leptauchenins. Only the upper canines show a slight indication of sexual dimorphism, which is typical in many other primitive artiodactyls, including pigs, camels, and tragulids.

CRANIAL AND POSTCRANIAL CHARACTERS AND THE PHYLOGENY OF PALAEOTHERIIDS (MAMMALIA, PERISSODACTYLA)

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Previous studies have allied the Palaeotheriidae with the Equidae, but a number of authors have debated the composition of this family or described characters that suggest a different phylogenetic position for this family. As with perissodactyl phylogeny in general, much of the discussion of palaeotheriid affinities has focused on dental characters.

Palaeotherium and *Plagiolophus* are the two best-known genera that are consistently recognized as members of the Palaeotheriidae. Examination of cranial and postcranial material of these two genera reveals a number of phylogenetically interesting characters. Results of a preliminary analysis of cranial, postcranial, and dental data for a selection of perissodactyl taxa support palaeotheriid monophyly but include Palaeotheriidae in a basal polytomy with tapiromorphs, equids, and some other early Eocene perissodactyl taxa. While this does not refute the hypothesis that palaeotheriids are closely related to equids, it suggests that other hypotheses deserve greater attention than they received previously.

A SIMILARITY TEST OF EXTANT ARCHOSAUR JAW MUSCLES: CEPHALIC SOFT TISSUES AND THEIR OSTEOLOGICAL CORRELATES.

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Understanding the evolution and homology of archosaur jaw musculature is hampered by divergent morphological specializations of extant groups and further confounded by previous, fragmentary descriptions of soft- and hard-tissue topology, disparate nomenclatures, and a lack of phylogenetically informative characters. A similarity test was conducted to develop hypotheses of jaw muscle homology in extant archosaurs (birds and crocodilians) in order to identify potentially useful characters that can be tracked in fossil taxa via a congruence test. Anatomical techniques, such as dissection and serial sectioning, were coupled with CT scanning and 3D image analysis to identify causal associations between jaw muscles, other relevant soft tissues, and the bones they modify in extant archosaurs and outgroup taxa. In addition to classically used, topological characters (e.g., trigeminal nerve divisions), several new consistent positional relationships (e.g., nervus anguli oris passing between internus and externus muscle groups, caudal ramus of mandibular nerve passing between quadrate muscles and braincase muscles) and particular osteological correlates (adductor tubercle, cotylar crest, lateral mandibular fossa) were incorporated to unite extant archosaur jaw muscles. Changes in crocodilian skull functional morphology led to a complex array of aponeurotic and fleshy muscular attachments that leave a diversity of robust osteological correlates that can be tracked ontogenetically. Major morphological changes in birds, including medial rotation of the orbital process and relevant muscles of the quadrate and medial migration of the mandibular attachment of the pterygoideus muscles, led to marked differences in superficial anatomy while retaining almost identical intermuscular topological relationships to crocodilian muscles. Many of these osteological correlates share common features with structures in extinct taxa implying that they can be successfully tracked in the fossil record and be used to confidently reconstruct jaw muscles and other cephalic soft tissues.

AN INTERBASIN COMPARISON OF SMALL-MAMMAL COMMUNITY DIVERSITY FROM THE EARLY EOCENE (WASATCHIAN) OF WYOMING

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Differences in faunal abundance and diversity among early Eocene mammalian faunas from the intermontane basins of Wyoming are well documented from analyses of large to medium-sized (>5 kg) taxa. Geographic differences among small-body-sized taxa have been suggested, but it has been difficult to determine how differences in collecting methods and taphonomy have skewed those data. To examine faunal differences between basins while controlling for such biases, we compared quarried + screenwashed early Eocene sites from the Bighorn (n=4) and Washakie Basins (n=4), Wyoming, comprising 5000+ specimens.

In both basins, the vast majority (>75%) of mammals recovered represent taxa >500 grams in size and more than 50% of specimens come from taxa >100 g. The remainder represents the full size range of known taxa (up to 350 kg). Insectivores (lipotyphlans and proteutherians) are ~30-35% of all fossils recovered in both basins. However, the relative abundance of the remainder of the fauna differs significantly between basins. In the Bighorn Basin samples, "condylarthrans" consistently comprise ~20% of the faunas and rodents and primates each comprise ~10%. In the Washakie Basin, these relative abundances are consistently reversed, with primates and rodents being much more abundant than "condylarthrans." Other relatively common taxa, e.g., marsupials and multituberculates, vary inconsistently among sites.

Rank abundance curves for all sites follow a broken stick model, indicating evenly distributed faunas, suggesting these sites accurately record differences in relative abundance and that real biogeographic differences exist. These differences may reflect ecologic factors, but may also reflect differences in diversity within groups between basins. In both basins, "condylarthran" and insectivoran diversity is similar. However, primate composition differs substantially, with greater diversity in the Washakie Basin, and preliminary comparisons suggest interbasinal differences in rodent diversity as well. These results highlight the importance of drawing comparisons between comparable data sets and examining differences in relative abundance as well as diversity.

EVIDENCE FOR THE EVOLUTION OF WING-ASSISTED INCLINE RUNNING IN NON-AVIALIAN THEROPODS

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The recent discovery of wing-assisted incline running (WAIR) behavior in primitive modern birds represents an important behavioral "missing link" between cursorial and fully arboreal forms, and allows for a synthesis of "ground up" and "trees down" models of the origin of avian aerial flight. However, anatomical evidence suggests that WAIR characterized a more-inclusive clade than flying dinosaurs (Avialae), and consequently allows some potential insight into the ecology of these groups of coelurosaurs.

The functional correlates with WAIR appear to be: a hindlimb adapted to running; an elongated forelimb capable of lateral and forward excursions (but not necessarily a vertical power stroke); a substantial sternum capable of supporting the muscles necessary for the forelimb stroke; and feathers. These traits are present not only in modern and fossil birds, but also characterize the clade Maniraptora as a whole, as they are present in oviraptorosaurs and deinonychosaurs. The ability to escape predators by seeking refuge in high places would be of benefit to non-aerial fliers, both for small-bodied adults and for juveniles of all maniraptoran taxa. (Indeed, life history patterns inferred by non-avian dinosaur clutch size argue that mortality levels were higher for these taxa than for modern birds or for placental mammals). Some workers have argued that these same anatomical features are evidence for secondary flightlessness in oviraptorosaurs and deinonychosaurs. However, these traits might instead indicate the presence of WAIR rather than the abandonment of aerial flight.

Several maniraptoran clades (*Caudipteryx*, alvarezsaurids, advanced troodontids) are characterized by a reduction of forelimb length and, consequently, would presumably have abandoned WAIR behavior (analogous to the case in modern ratites).

STRATIGRAPHIC FRAMEWORK OF EARLY PLIOCENE LOCALITIES ALONG THE NORTH BANK OF THE CIMARRON RIVER, MEADE CO., KS

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Fossiliferous sediments along the north bank of the Cimarron River in southwest Meade County, Kansas, are up to 34 m thick, and include a basal sand and gravel ("Bishop gravel") at least 9 m thick, overlain by up to 17 m of light- to pinkish-gray, fine-grained sand and silt, with interbedded calcium carbonate layers. These fine-grained sediments are overlain in turn by a second, 8.5 m-thick sand and gravel ("Wolf gravel") that is itself overlain by about 5 m of calcareous silts culminating in a thick caliche. Previously, the sediments below the base of the Wolf gravel were considered by Hibbard to be part of the Rexroad Formation, and those above the base of the gravel to be part of the Ballard Formation; however, ongoing work indicates that these previous correlations are problematic and quite possibly wrong.

Mammal fossils are found at five stratigraphic levels below the Wolf gravel. Prior to our work, only the Keefe Canyon and Fox Canyon localities of Hibbard were known from this area; to date, we have discovered an additional 15 sites. The two gravel units and intervening calcium carbonate layers provide the primary means for establishing correlations between the localities and ordering them in a biostratigraphic succession, with further partitioning possible within that framework based on rodents, particularly the cotton rats. Their presence or absence in the area likely has climatic implications.

HYPSODONTY AND NICHE PARTITIONING IN APLODONTOID RODENTS: DO SMALL HERBIVORES PARALLEL UNGULATES DURING MIOCENE DIVERSIFICATIONS?

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The trend toward increasing hypsodonty and associated diversification in Miocene large herbivores has been the subject of abundant recent research. While the patterns of change in large herbivores are becoming well-understood, few studies have examined evolutionary

changes in small herbivores during the same time interval, essential to building a complete picture of ecosystem dynamics through time. This study examines changing hypsodonty and evolutionary radiation in a lineage of small herbivores, the Aplodontoidea, and asks two questions. First, do small herbivores show the same patterns of ecomorphological change as large herbivores? Second, how does this change affect niche partitioning and competitive interactions within the lineage? I constructed a species-level phylogeny of aplodontoid rodents and used it to study changes in ecomorphology through time within the lineage.

The ecomorphology of aplodontoids undergoes several changes through duration of the lineage which seem to correlate with changes in habitat through the Oligocene and Miocene. While Oligocene aplodontoids are relatively small, brachydont, and postcranially unspecialized, by the early Miocene the clade is dominated by hypsodont forms. middle and late Miocene aplodontoids are all large, fossorial, and extremely hypsodont. These morphological changes parallel those in large herbivores.

Competitive interactions were assessed using patterns of co-occurrence of aplodontoid species drawn from the Miomap database. The relatively low dispersal capability of the modern species would suggest that sister taxa of aplodontoids in the fossil record should occur in close geographic proximity; however, this expectation does not seem to hold. Preliminary analysis of phylogenetic divergence between co-occurring species suggests that the clade generally differs from the expectation inferred from extant aplodontid ecology, and that sister species generally do not occur in close proximity, particularly after their Oligocene radiation. The level of phylogenetic divergence between co-occurring species suggests competition may be preventing sympatry of closely-related species.

USING ISOTOPIC ANALYSES OF HERBIVORE TEETH AS A PALEOENVIRONMENTAL PROXY: A STUDY OF ISOTOPIC PATTERNS IN MODERN GREAT PLAINS BISON

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The isotopic ratios of vertebrate teeth track isotopic variations in an animal's environment, and thus isotopic analyses of fossils may be used to reconstruct paleoenvironmental conditions. The oxygen isotopic ratios of mammalian fossils often reflect the isotopic ratios of local precipitation and have been used to reconstruct paleoclimatic conditions. The carbon isotopic ratios of herbivore teeth reflect the carbon isotopes of dietary plants, and thus have been used to reconstruct paleovegetation gradients (e.g. the C_3/C_4 ratios of grasslands). The relatively high abundance of fossil and subfossil bison makes this taxon particularly useful to researchers interest in using such isotopic proxies to reconstruct Holocene and Pleistocene paleoenvironmental conditions in North America. However, the accuracy of such reconstructions is currently limited because the baseline variability and range of the isotopic signals preserved in modern bison teeth has not been documented in detail. Here we present preliminary results of a study of the carbon and oxygen isotopic variation in bulk samples of tooth enamel from modern bison living in the Great Plains region of the United States. We document the isotopic variability found within individual populations as well as trends observed among bison from different environments. The average oxygen isotopic ratios of bison teeth show a general correlation to the average values of local surface waters. However, the variability of oxygen isotopes within bison populations is often comparable to, or greater than, the variability in average isotopic values found among different populations. In contrast, the carbon isotopic ratios of teeth correlate well with changes in the plant composition (C_3/C_4 ratios) of local grasslands. These results will serve as a baseline for interpreting the isotope signals preserved in fossil bison.

THE TRANSITION FROM NONMAMMALIAN CYNODONTS TO MAMMALS

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The closest outgroups to Mammalia, defined here as the least inclusive clade including Montremata, Metatheria, and Eutheria, are Late Triassic and Jurassic mammaliaform taxa, such as *Morganucodon* and docodonts, which retain an articular-quadrate jaw joint lying medial to the squamosal-dentary jaw joint characteristic of mammals. Still more primitive are the non-mammalian cynodonts of the Triassic, a diverse group of carnivorous and herbivorous forms lacking the dentary-squamosal contact. Which of these were among the closest sister taxa of mammaliaforms is at present controversial, with the favored candidates being the Tritylodontidae, specialized rodent-like herbivores, and the Tritheledontidae (ictidosaurs), aberrantly-specialized carnivorous forms with teeth very different from those of early mammaliaforms. These taxa possess a postcranial skeletal structure very similar to that of early mammaliaforms and much more derived than that of typical Triassic cynodonts. What have, until recently, been absent from the Triassic record are generalized small carnivorous cynodonts lacking a dentary-squamosal contact but possessing teeth and a postcranial anatomy resembling those of early mammaliaforms. Recently described cynodont taxa from the Carnian and Norian of Brazil help to fill this gap. They also support the dichotomy among Triassic cynodonts into the Cynognathia, including *Cynognathus* and the herbivorous Gomphodontia (probably including tritylodontids) and the Probainognathia, including Tritheledontidae and Mammaliaformes as well as the new Brazilian taxa. Within each of these lineages an extraordinary amount of independent acquisition of mammalian features occurs, especially in the postcranial skeleton.

A MORPHOLOGICAL ANALYSIS OF MARSUPIAL EVOLUTIONARY RELATIONSHIPS

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Marsupials have proven to have a complex phylogenetic history, which does not reflect the simple grouping of species by continent. Some marsupials from South America have been shown to be more closely related to Australasian marsupials than to other South American marsupials. Higher-level relationships among Australasian marsupial orders are very controversial, as is the position of the South American microbiotheres among them. We conducted a cladistic analysis to investigate higher-level marsupial systematics. A morphological data matrix was assembled, consisting of a new suite of 149 postcranial characters, and a series of previously published and revised data on the craniodental (76 characters) and soft tissue anatomy (5 characters). Twenty-one marsupial terminal taxa representing all the major radiations of marsupials were investigated, as well as 10 outgroups, including exceptionally well-preserved fossils such as the basal prototribosphenidan *Vincelestes*, the eutherians *Ukhaatherium* and *Asioryctes*, and the metatherians *Deltatheridium*, *Mayulestes*, and *Pucadelphys*. A maximum parsimony analysis was conducted, resulting in one most-parsimonious tree. Relationships among outgroups were congruent with current understanding of mammalian phylogeny. All currently accepted marsupial orders were recovered by the analysis. We confirmed previous results showing the South American "monito del monte" *Dromiciops* nested within the Australasian radiation. Within this australidelphian clade, *Dromiciops* was closely allied with the Diprotodontia. The South American paucituberculates appeared more closely related to the Australidelphia than to the American Didelphimorphia. The marsupial mole *Notoryctes* and the Peramelia were closely allied to each other and in turn were the sister groups of the *Dromiciops* plus Diprotodontia clade. This pattern of relationships left Dasyuromorphia as the most basal offshoot of the Australidelphia. Whereas this tree topology recovers some signal that had been detected by previous studies, morphological and/or molecular, some novel hypotheses are also supported.

CRETACEOUS DINOSAUR TRACKS OF SOUTH KOREA : OCCURRENCES AND PALEOBIOLOGICAL IMPLICATIONS

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Abundant dinosaur fossils including footprints, eggs and nests, teeth and bones have been found from the Cretaceous non-marine deposits of Korea. Among them, dinosaur tracks are the most distinctive, and some tracksites are among the most famous in the world. Until now, 27 dinosaur track localities have been discovered from the Cretaceous strata in the Gyeongsang Basin and several small basins. Ornithopod tracks are most abundant in Korean tracksites, and most of them are identified as *Caririchnium*, a large ornithopod with wide hoof impressions. Most theropod tracks are found in Neungju Basin and they consist of various types of small or medium sized bird-like footprints, and other large footprints. Sauropod tracks are also abundant in the Gyeongsang Basin. The sauropod tracks vary in size, shape, and pattern of trackway, and suggest that diverse sauropods existed at this area. These diverse tracks in South Korea suggest that various dinosaurs frequented the margins of lakes distributed in the southern part of the Korean Peninsula during the Cretaceous.

HEMPHILLIAN TERRESTRIAL MAMMALIAN FAUNAS FROM THE SOUTH-CENTRAL FLORIDA PHOSPHATE MINING DISTRICT

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Large-scale phosphate mining in south-central Florida produces exposures of the very fossiliferous middle Miocene through lowest Pliocene Bone Valley Formation. It contains two distinct Hemphillian faunas, the very late Hemphillian Palmetto Fauna and the early Hemphillian Four Corners Fauna (new name). Specimens from the latter fauna are much rarer and have only been found in a few locations within the entire mining district. The two faunas share no species of land mammals in common, and only six genera, emphasizing the high degree of mammalian turnover during the Hemphillian. We currently recognize 47 species of terrestrial mammals in the Palmetto Fauna, mostly ungulates (22 taxa) and carnivorans (18 taxa). The same two groups, especially perissodactyls, dominate the Four Corners Fauna, which contains only 16 species. Most of these are also present at early Hemphillian sites in north-central Florida, such as McGehee Farm. The Four Corners Fauna contains the oldest record of "*Dinohippus*" in Florida, although over three-fourths of the identifiable equid specimens are hipparionines. Twenty-four species in the Palmetto Fauna are also present in late Hemphillian faunas from Mexico and the western United States, while 13 are endemic to the southeastern United States and two represent species only known from the Blancan in other regions. The high diversity and composition of the Palmetto Fauna ungulates are reminiscent of Clarendonian faunas of the Great Plains, with a broad array of browsing, mixed-feeding, and grazing species. However, browsers are generally rarer than closely related mixed-feeders or grazers; the deer *Eocoileus* is the only relatively common browser in the fauna. Our work excludes from the Palmetto Fauna the following taxa mistakenly included in some older literature: mylodontid and megatheriid ground sloths, *Epicyon*, *Leptarctus*, *Aphelops*, and *Calippus*.

A NEW PHYTOSAUR SPECIES FROM THE TRIASSIC OF WEST TEXAS: NEW INFORMATION ON CRANIAL ANATOMY, TAXONOMY, AND SEXUAL DIMORPHISM IN PSEUDOPALATINAE

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An excellently preserved slender-snouted phytosaur skull from the upper Cooper Canyon Formation (Norian) near Post, Garza County, West Texas provides new data on the

cranial anatomy and taxonomy of the Pseudopalatinae, the youngest and most derived clade of phytosaurs. It represents a new species that is characterized by four diagnostic features: For the first time in a phytosaur, an additional skull element is identified at the anterior rim of the naris between the septomaxilla and the nasal. The supratemporal opening is reduced to a rounded indentation into the skull roof with a characteristically beveled rim. The squamosal resembles that of the type species of *Pseudopalatus* in shape, but is comparatively much shorter and broader. Horizontal medial lamellae of both palatines narrow the gap of the posterior section of the vaulted choanal area, the closest approach to an ossified secondary palate in any phytosaur. In addition, the specimen provides a wealth of new information on the morphology of phytosaur braincases and foramina in general, including unique structures such as a forward projecting triangular process of the prootic and a dorsal extension of the parasphenoid approaching the optical foramen. The presence of an unpaired ossification ('presphenoid') and an unossified hypophyseal gap is confirmed for pseudopalatine phytosaurs.

The supratemporal opening of the new species mediates perfectly between the narrow, slit-like fenestra seen in species referred to *Pseudopalatus* and the fully closed fenestra in dorsal view that defines the genus *Redondasaurus*. Consequently, *Redondasaurus* is regarded as a junior synonym of *Pseudopalatus*, which thus encompasses all North American pseudopalatine phytosaurs.

A second specimen of *Pseudopalatus* of comparable size shows all diagnostic characters, but is distinguished by a robust, lower and wider skull, the presence of a long prenarial crest, and a more robust, close-spaced dentition. The two morphs substantiate previous interpretations of marked sexual dimorphism in species of *Pseudopalatus*

AN EARLY CRETACEOUS THEROPOD FROM SOUTHWESTERN ARKANSAS
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The remains of the right pes of a theropod were collected in the Lower Cretaceous Trinity Group in Sevier County, southwest Arkansas in 1972. These fossils are the first and only dinosaur remains recovered from the state. However, these remains have not yet been adequately described. Characterized by differentiated pedal unguals and a lateraly compressed third metatarsal, the specimen appears to be closely associated with the Early Cretaceous theropods *Nedcolbertia* and *Elaphrosaurus*. The specimen provides further knowledge of a poorly understood radiation of Early Cretaceous primitive coelurosaurians east of the Western Interior Seaway.

ADDITIONS TO THE PUERCAN MAMMALS OF NORTH DAKOTA AND A FRAMEWORK FOR STUDY OF POST-K/T VERTEBRATE RECOVERY
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A dense record of vertebrates of the Lancian North American Land Mammal Age (NALMA; latest Cretaceous), including mammals, occurs in the Hell Creek Formation of North Dakota extending a few meters into the overlying Ludlow Member of the Fort Union Formation. Analysis of these Cretaceous fossils has documented the persistence of vertebrate lineages locally up to the Cretaceous-Tertiary (K/T) boundary. Local extinction and survival across the boundary, however, has been more difficult to assess because of comparatively poorer sampling in the Paleocene part of the section. Until recently, Puercan (early Paleocene) mammals had been recovered locally only from the PITA Flats local fauna, ~8 m above the formational contact, interpreted to be close to the Pu1/Pu2 boundary.

The discovery of Puercan mammals from stratigraphic levels below and above PITA Flats has improved regional temporal resolution. Intensive fieldwork has resulted in the discovery of 41 vertebrate localities in the lower part of the Ludlow. Among these sites is the Wilkening Locality (PTRM Loc. V02017) in sandstone ~2-3 m above the base of the Ludlow at the top of the uppermost Cretaceous as indicated by palynomorphs. Mammals from the Wilkening Locality include forms comparable to *Protungulatum donnae*, *Mesodma thompsoni*, and *Stygimys kuszmauli*, which in stratigraphic context (below PITA Flats) imply a Pu1 age. Above the PITA Flats' horizon, a new locality, Merle's Mecca (PTRM Loc. V99011), is ~11 m above the base of the Ludlow. Mammals from Merle's Mecca include a very large palaeoryctood and a small condylarth comparable to *Loxolophus schizophrenus*, which in stratigraphic context (above PITA Flats), imply a Pu2 (mid Puercan) or possibly Pu3 (late Puercan) age. Merle's Mecca is about 60 m below To1 or To2 (early Torrejonian, mid Paleocene) mammals at the Brown Ranch localities above the T Cross lignite of Clayton in the upper Ludlow. These discoveries add to the biostratigraphic resolution within the lower part of Ludlow necessary to assess patterns of survival and recovery of nondinosaurian vertebrates above the K/T boundary.

ESTIMATING PHYTOSAUR BODY MASS FROM SKELETAL DIMENSIONS USING EQUATIONS BASED ON ALLIGATORS AND OTHER CROCODILIANS
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Phytosaurs were large Late Triassic semi-aquatic predators. Here MBd and snout vent length to the anterior vent limit (SVLA) are estimated from dimensions of the skull and limb bones dimensions for phytosaurs from the Snyder and Canjilon quarries (New Mexico). SVLA is measured to the posterior ischial limit, which approximates the anterior vent limit in Recent alligators. Use of SLVA circumvents problems associated with specimens whose tails are absent or of different relative length than in modern analogues. Retracted nares and elongated rostrum are among traits distinguishing phytosaur skulls from those of alligators. We use equations estimating SVLA and MBd from orbito-cranial length (ODCL), measured from the anterior orbital limit to the posterior skull limit. MBd is also predicted from OVLA (orbitovent length). In alligators (N=37; MBd range: 1.15 to 232 kg) r-values relating MBd and SVLA to ODCL (0.976 and 0.986) were close to those relating MBd and SVLA to skull length (DCL:0.992 and 0.995), as are r-values relating MBd to OVLA (0.991) and SVLA (0.992). MBd and SVLA are also predicted from maximum femur length (MFL: crocodilian equations). MBd is predicted with ALLMASSD, a program which estimates MBd from length and diameter of limb bones in alligators (N=18). For UCMP V2816/27235, an articulated phytosaur skeleton lacking only the tail, MFL predicted 100.4 % of actual trunk length (TrL) and 100.4% of actual phytosaur SVLA (2510.7 mm). TrL equalled estimated SVLA minus estimated alligator DCL for that SVLA; phytosaur SVLA was TrL plus actual phytosaur DCL. Phytosaur SVLA from ODCL was 81.6% (95% CL. 80.3-82.9%) of actual SVLA; in contrast, phytosaur SVLA from DCL was 160% of actual phytosaur SVLA. The accurate SVLA result from MFL gives confidence in the MLF estimate of MBd of 377 kg. Similar MBd estimates came from ALLMASSD (389 kg) and OVLA (416 kg). The estimate from ODCL (143 kg) was about half of these, but much closer than the estimate from DCL (2033 kg), while the estimate from SVLA was 691 kg. Mass estimates from ALLMASSD for phytosaurs ranged from 30 to 394 kg and SVLA from ODCL ranged from 1387 to 2259 mm.

A 3-D DYNAMIC ANALYSIS OF MUSCULOSKELETAL CONTRIBUTIONS TO BODY SUPPORT DURING BIPEDAL LOCOMOTION
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The ability to locomote depends on generating adequate vertical ground reaction forces (VGRF). We developed detailed three-dimensional dynamic models of several bipedal animals (e.g., human, chicken, ostrich, *Velociraptor*, and *Tyrannosaurus*) to quantify their capacity to generate VGRF. Each model is actuated by dozens of muscle groups and includes five rigid bodies: trunk, femur, tibia, metatarsal, and toe segments, connected by joints. Musculoskeletal geometry was derived from phylogenetically-constrained reconstructions and dissections. We used our models to compute the amount of support that is passively provided by the skeleton and actively generated by muscles. We also evaluated how limb orientation and musculoskeletal geometry affect the capacity of muscles to generate support. The human, chicken, and ostrich models all produced results commensurate with experimental data, with some striking similarities to the models of extinct animals.

In *Tyrannosaurus*, our analysis showed that for upright poses the passive resistance of the skeleton to gravity supported as much as 85% of body weight for the most straight-legged poses; however, this dropped below 15% even for slightly crouched poses. Several muscles were identified as the most influential contributors to support: *M. gastrocnemius pars medialis, M. ambiens,* and *M. iliotibialis* 3, which could have generated up to 1.5, 1.2, and 0.92 Newtons of VGRF per Newton of muscle force respectively. Thus a uniarticular ankle extensor produced the most VGRF, followed by multiarticular muscles. Interestingly, proximal uniarticular hip and knee extensor muscles such as *M. caudofemoralis longus* and *M. femorotibialis internus* generated less VGRF, respectively 0.27 and 0.69 Newtons per Newton of muscle force.

Our results show how muscles and the skeleton are more effective in providing support in upright limb orientations. We discuss how this finding compares to anatomical evidence reportedly indicating a more crouched pose. Additionally, our analysis illuminates how specific muscle functions evolved on the line to birds, and how limb support mechanisms vary among bipeds.

PATTERNS OF ENAMEL MICROSTRUCTURE IN DINOSAURS
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The study of non-mammalian amniote ("reptile") enamel, including that of dinosaurs, has been largely neglected, while the enamel microstructure of the teeth of both fossil and extant mammals has been extensively studied. Mammal teeth are usually characterized by distinctive prismatic enamel easily seen in thin sections under polarized light, which is one reason why they have been preferentially studied; most reptiles have non-prismatic enamel whose individual crystallites can be differentiated only by using scanning electron microscopes. While the enamel structure of both ornithischian and saurischian dinosaurs has been previously studied, phylogenetic patterns of enamel microstructure within different dinosaur groups have probably not been adequately discerned because of the small number of individuals sampled and lack of precision in the identification of the taxa studied.

A preliminary survey of teeth from both herbivorous ornithischians and carnivorous saurischians, including *Byronosaurus*, *Velociraptor*, *Tarbosaurus*, *Psittacosaurus*, and *Protoceratops*, is beginning to reveal patterns in enamel microstructure among different dinosaur groups. For example, troodontids are characterized by very thin parallel crystallite enamel with strong incremental lines, while ceratopsians have very thick columnar enamel full of enamel tubules. Because almost all of the teeth examined were removed from the jaws of specimens identified to at least the genus level, the patterns seen are truly representative of the dinosaur taxa studied. Knowing the general structure of enamel within a higher-order taxonomic group of dinosaurs means that isolated dinosaur teeth can be identified more specifically, contributing to taxonomic diversity data for a locality.

EARLY LATE CRETACEOUS VERTEBRATE FAUNA OF THE MIFUNE GROUP IN KUMAMOTO PREFECTURE, JAPAN
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A large number of vertebrate fossils have been recorded from several localities in the Mifune Group of Kumamoto Prefecture. The Mifune Group was subdivided into three forma-

tions, namely the "Basal" Formation, "Lower" Formation and "Upper" Formation. Although these terms are unsuitable for formation names, they were given as the official names by Matsumoto (1939) and have not been revised since then. The "Basal" Formation and the "Upper" Formation are considered non-marine, and the "Lower" Formation is considered brackish and shallow marine deposit. The acanthoceratid ammonite *Eucalycoceras* sp. cf. *E. spathi* is known from the "Lower" Formation, suggesting the middle Cenomanian in age, and it is generally considered that the age of the "Upper" Formation is late Cenomanian to early Turonian.

Several vertebrate sites in the "Upper" Formation yield isolated small bones and teeth and fragments of larger bones. These remains are tentatively identified as the following vertebrate taxa: neopterygian fish, the turtles *Adocus* sp., *Shachemys* sp., *Basilemys* sp., anosteirine, trionychid and *Tienfucheloides* sp. cf. *T. undatus*, neosuchian crocodyliform, azhdarchid pterosaur, and aublysodontine tyrannosaurid, therizinosauroid, velociraptorine dromaeosaurid, ankyrosaurid and hadrosauroid dinosaurs. A fragmentary jaw and teeth of a eutherian mammal have also been found.

This vertebrate fauna is similar to the Bayn Shire and Iren Dabasu faunas of the early Late Cretaceous, and the fauna is clearly different from those of the Early Cretaceous and Campanian-Maastrichtian age. Although early Late Cretaceous vertebrate faunas have been known from Mongolia, China and the Middle Asia, the fact that such vertebrate fossil assemblage was present in Japan suggests that the same fauna had extended to the eastern margin of Asia.

SEQUENCE OF CLOSURE OF NEUROCENTRAL SUTURES IN *CAMARASAURUS* (SAUROPODA) AND IMPLICATIONS FOR PHYLOGENY IN REPTILIA

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A series of *Camarasaurus* (Dinosauria: Sauropoda) specimens in different ontogenetic stages allows determination of the sequence of closure of neurocentral sutures in the vertebral series. Juvenile *Camarasaurus* exhibit highly fused centra and neural arches in the mid- and posterior caudals, no suture lines are seen. However, all presacral, sacral, and anterior caudal (from no.1 to about no.6) vertebrae are unfused, and suture lines between centra and anterior caudal ribs are still seen up to the subadult stage. The time at which the sutures close is likely variable among individuals, but a typical sequence exists: (1st) mid-post caudals, (2nd) anterior caudals of caudal ribs, (3rd) neural arch of anterior caudals, (4th) cervicals (from anterior ones) or sacrum (both neural arch and sacral ribs), and (5th) dorsals. I observed the same pattern in some Archosauromorpha taxa. For example, the order of fusion in mature crocodilians (e.g., *Alligator* and *Crocodilus*) is similar to subadult *Camarasaurus*. The timing of closure is also relatively late in some carnosaurian theropods (e.g., *Coelophysis* and *Godzillasaurus*); on the other hand, the vertebral sutures of extant birds are already closed before hatching. Interestingly, some large-bodied turtles, such as chelids (e.g., *Chelus fimbriatus*) and cheloniids (e.g., *Eretmochelys imbricata*) clearly show visible sutures between the neural arches and centra even in the adult stage; however, juveniles of some small-bodied emydids (e.g., *Terrapene ornata*) have closed sutures. I never saw visible neurocentral sutures in *Sphenodon* or Squamata, even in juveniles of large bodied-taxa (e.g., pythons, komodo monitors, and mosasaurs). These data suggest the pattern and tempo of suture closure are due to phylogenetic position in Reptilia as well as body size, rather than simply the ontogenetic age of individuals.

PRELIMINARY MAGNETOSTRATIGRAPHIC ANAYLSIS OF THE UPPER CRETACEOUS KAIPAROWITS FORMATION, SOUTHERN UTAH

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The Kaiparowits Formation, located within the recently established Grand Staircase-Escalante National Monument of south-central Utah, harbors one of the most important Late Cretaceous vertebrate assemblages in the world; it includes an abundance of turtles, fish, crocodylians, dinosaurs (plus dinosaur egg shell), and mammals. This 850 m thick, structurally uncomplicated unit records relatively continuous deposition of mostly fine-grained fluvially derived sediments along the western margin of the Cretaceous Interior Seaway. Thus, the Kaiparowits Formation is ideally situated, both spatially and temporally, to address questions regarding North American vertebrate biodiversity, Mesozoic mammal biostratigraphy, and latitudinal faunal variations. However, as important as the Kaiparowits Formation is for understanding Late Cretaceous life in North America, its age is known only in a very general sense—a late Campanian age is assumed on the basis of palynomorph and mammalian studies, although conflicting studies suggest the possibility of early Maastrichtian. To refine the age of the Kaiparowits Formation, a pilot magnetostratigraphic study was conducted over ~90 m of this unit. Site mean directions obtained from five class I sites are indicative of normal polarity, whereas 14 additional sites are class III. Although magnetic reversal was not observed over the interval studied, precluding our attempt to temporally refine this portion of the Kaiparowits Formation, the study did result in the determination that 1) rocks of this portion of the Kaiparowits Formation are amenable to paleomagnetic analysis; 2) thermal demagnetization appears to be the most suitable technique; and 3) the normal polarity suggests correlation with chrons C33n, C32r2.1n, or C32n. Given the intentionally preliminary nature of this study, it is hoped that additional upcoming paleomagnetic studies of the Kaiparowits Formation will soon result in a high-resolution temporal framework.

AN ADDITIONAL RECORD OF A POLYCOTYLID PLESIOSAUR FROM THE UPPER CAMPANIAN OF NORTH AMERICA

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A partial polycotylid (Reptilia: Plesiosauria) paddle was discovered as surface float on land administered by the Arkansas Game and Fish Commission, in Hempstead County, Arkansas. The paddle originated from the Marlbrook Marl, ca. 5 to 7 m below contact with the Saratoga Chalk. The Marlbrook Marl is considered Upper Campanian in age based upon ammonite zones in the underlying Annona Chalk and overlying Saratoga Chalk. This specimen and a partial skeleton reported from the Upper Campanian of Saskatchewan represent the two youngest known occurrences of Polycotylidae in North America. Other vertebrate material recovered from this stratigraphic interval includes sharks, bony fishes, turtles, and mosasaurs.

The polycotylid specimen consists of a femur, fibula, centrale, a complete distal tarsal row, two supernumerary ossifications, and numerous phalanges. The femur exhibits four distinct facets on the distal margin, indicating at least two supernumerary ossifications present in the epipodial row. Elements below the epipodial row are extremely foreshortened, more so than in the derived polycotylids *Dolichorhynchops osborni* and *Polycotylus latipinnis*, and much more so than in *Trinacromerum bentonianum*. This condition is remarkable because it expands upon what is known about the progressive foreshortening of polycotylid limb elements through time. This morphological trend can be followed from the earliest known Cenomanian polycotylids, which have comparatively elongate paddle elements, to the culmination of extremely foreshortened elements in this Upper Campanian specimen.

The Arkansas material compares best with the type and referred specimens of *Dolichorhynchops osborni*, both in terms of size and morphology. However, *Dolichorhynchops* is known from the Middle Turonian through the Early Campanian, and thus the youngest known occurrence is ca. ten million years older than the present specimen. The discovery and description of more polycotylid material from the Upper Campanian may reveal that the Arkansas specimen represents an undescribed taxon.

TAPHONOMY OF MARINE VERTEBRATES FROM THE NACO FORMATION (MIDDLE PENNSYLVANIAN), CENTRAL ARIZONA

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A diverse assemblage of chondrichthyan teeth, spines, and dermal denticles is known from the Middle Pennsylvanian (Desmoinesian) Naco Formation in central Arizona, where they occur with an extensive invertebrate fauna of brachiopods, bryozoans, and echinoderms. Study of the vertebrates at one site near Kohls Ranch, Arizona, suggests that these fossils display a taphonomic history independent of the associated invertebrate fauna. The main outcrop consists of four lithologically distinct 1-2 meter thick limestone lenses interbedded with mudstones. Vertebrate material is concentrated within specific bedding planes within only one of these limestone beds. All specimens display rounding and abrasion, and some vertebrates are so highly abraded into "bone pebbles" that their original morphology is completely obliterated. Similar abrasion is not seen in the locality's invertebrate fauna, which includes articulated crinoids, edrioasteroids, and echinoids. Siliciclastic grains that could cause abrasion are extremely rare in the sediments. We hypothesize that most, if not all, of the vertebrate material originated from a near-shore environment where they were abraded by wave action in the sediment. At some point, possibly during a storm surge, these specimens were transported out to more distal marine environments, and deposited in their current location. The taphonomy of this site represents a model for other concentrations of isolated vertebrate elements in marine depositional settings.

ABNORMAL, MULTILAYERED TITANOSAUR (DINOSAURIA: SAUROPODA) EGGS FROM *IN SITU* CLUTCHES AT THE AUCA MAHUEVO LOCALITY, NEUQUEN PROVINCE, ARGENTINA

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All previous reports of abnormal, multilayered Mesozoic eggshells pertain to taxonomically unidentified eggshell fragments or isolated eggs. We report the first systematic study of eggshell abnormalities from *in situ* clutches of a known taxon within Dinosauria, specifically the Titanosauridae. Examination of 393 *in situ* clutches, referable to titanosaur sauropod dinosaurs, from Upper Cretaceous rocks in northwestern Patagonia, Argentina, reveals that six clutches contain both normal and abnormal, multilayered eggs within the same clutch. One complete clutch of 30 eggs contains 27 normal eggs and 3 mutlilayered eggs, distributed in three levels. The three abnormal eggs occupy the highest level within the clutch, are adjacent to one another, and represent the last eggs laid by the female sauropod. All normal eggs within the six clutches exhibit megaloolithid calcite structure, while the multilayered eggs show three distinct types of abnormal morphology. Type I consists of two superimposed eggshell layers of comparable thickness, both with typical megaloolithid eggshell structure. Calcite nucleation sites are present within remnants of permineralized membrane that separates the inner from the outer eggshell layer. Type II morphology displays two superimposed eggshell layers: the inner eggshell exhibits normal structure, while the outer eggshell is thinner, lacks basal nucleation sites, and exhibits unusually large tubercles, compared to normal eggs within the same clutch. In the absence of nucleation sites, the inner eggshell provides a template for the calcite crystalline structure of the overlying abnormal shell, and optical continuity is often apparent between the superimposed layers. Type III morphology consists of three or more superimposed shell layers, with normal calcite structure restricted to the innermost eggshell. The multiple, outer shell layers are laminar and incomplete, often separated by permineralized membrane, or exhibit diminutive surface ornamentation.

A BIOSTRATIGRAPHIC REVISION OF THE PLIO-PLEISTOCENE UPPER SIWALIK DEPOSITS OF THE POTOHAR PLATEAU, PAKISTAN

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Prior biostratigraphic zonations of Plio-Pleistocene deposits in the Upper Siwaliks have been stratigraphically problematic, and have been based on taxa such as *Hexaprotodon* and *Elephas* that make poor index fossils because they have long evolutionary lifespans, low mortality and reproductive rates, and are ecologically restricted. We subdivide the Upper Siwaliks into 29 distinct lithologic beds using high-resolution stratigraphy, and correlate these units across the Potohar Plateau. Using specimens we collected, in combination with those made by Barnum Brown and others in the early 20th Century, we reclassify the Upper Siwaliks into a Strict Overlap Assemblage Fossil Zone for *Potamochoerus paleindicus*, *Sus cristatus/falconeri* and *Equus sivalensis*, and a Partial Range Fossil Zone between the last appearance of *Selenoportax lydekkeri* and first appearance of *Equus sivalensis*. These data are used to biocorrelate the Upper Siwaliks with Plio-Pleistocene deposits in India, Nepal and China which are Pliocene (late Zanclean to early Piacenzian) to early Pleistocene (Calabrian) in age.

THE EVOLUTION OF THE THEROPOD SHOULDER APPARATUS LEADING UP TO BIRDS: AN INTEGRATED APPROACH

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The morphological transformation of non-avian theropod anatomy to yield the avian flight apparatus is one of the most intriguing transitions among vertebrates. The theropod scapulocoracoid is an integral component of this flight apparatus, and its evolution is investigated using a combination of systematically based comparative anatomical and morphometric analyses on fifteen non-avian and avian theropods. The morphological trends revealed via descriptions and comparisons of these terminal taxa are subsequently compared to the results of thin-plate spline analysis, allowing for a more objective assessment of shape changes observed in the scapulocoracoid. Comparisons of terminal taxa allow general morphological trends of the scapulocoracoid to be identified, and for highly autapomorphic forms to be recognized and consequently omitted from arguments of transformation. Thin-plate splines also permit graphical reconstruction of hypothetical ancestral forms situated at the internal nodes within a cladogram by using squared-change parsimony. The transformations inferred for the hypothetical ancestors, which represent more accurately the true line of descent, are compared to the transitions between the terminal taxa.

In order to evaluate changes in the size and performance of the shoulder girdle musculature during this transition, theropod shoulder girdle musculature is reconstructed, based upon phylogenetic and functional inferences, employing comparisons of the crocodilian and avian musculature as the extant phylogenetic bracket. Identification and comparison of osteological correlates of theropod shoulder musculature across theropod groups, and areas of shape change in the scapulocoracoid as revealed by anatomical comparisons, allow muscular changes to be mapped onto structural intermediates leading up to birds.

MORPHOLOGIC VARIATION IN THE DENTARY OF POCKET GOPHERS (*GEOMYS*) FROM HALL'S CAVE, KERR COUNTY, TEXAS

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Previous studies documented that tooth row length in pocket gophers within the genus *Thomomys* is genetically fixed, but diastema length is subject to ecophenotypic plasticity. These characters can be used together as proxies to evaluate evolutionary and ecophenotypic responses to climate change in pocket gopher populations through time (successfully demonstrated in Holocene sediments in Yellowstone National Park). We attempted to use this model to interpret patterns of morphologic change within the pocket gopher assemblage in Hall's Cave.

Hall's Cave is among the best-dated late Pleistocene-Holocene localities in North America, with levels ranging from at least 15,130 ± 170 yr. BP through late Holocene. The pocket gophers *Thomomys*, *Geomys*, and *Pappogeomys* occur in varying numbers throughout the sedimentary sequence at the cave, but *Geomys* is most common throughout much of the deposit. For the *Geomys* record as a whole, calculated tooth row length averages ranged from 4.96 mm (120-125 cm level) to 5.26 mm (160+ cm levels). Diastema length averages ranged from 5.79 mm (120-125 cm level) to 6.36 mm (130-135 cm level). Plots of averages against stratigraphic levels produced a similar pattern for both data sets.

Our initial efforts to interpret the Hall's Cave samples were hampered by a lack of detailed, diagnostic morphologic data on modern *Geomys* populations. In the absence of these data we cannot reliably identify species of *Geomys* from Hall's Cave without invoking modern geographic distributions and assumptions of biogeographic range change to refine our identifications. Our preliminary efforts to generate requisite data suggest that the model built for *Thomomys* may not easily be applicable to other taxa, including the phylogenetically closely related gophers in the genus *Geomys*. We urge caution in applying the *Thomomys* model to any fossil assemblages if data comparable to those gathered for extant *Thomomys* are unavailable for the taxa under consideration. This is especially true for fossil assemblages older than the late Holocene.

CRANIAL ANATOMY OF THE TEMNOSPONDYL *LYDEKKERINA HUXLEYI* (STEREOSPONDYLI: LYDEKKERINIDAE)

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The Lydekkerinidae were small, Early Triassic members of the stereospondyl radiation of temnospondyl amphibians, with representatives in South Africa, Antarctica, India, Australia, Russia and Greenland. The type species, *Lydekkerina huxleyi*, comes from the *Lystrosaurus* Assemblage Zone of the Beaufort Group, South Africa, and is considered the most abundant and well-known lydekkerinid. Various authors have published descriptions of *Lydekkerina huxleyi*, and a suite of supposedly diagnostic characters has previously been identified. However, many of these characters have not been observed directly on the holotype specimen, which consists of a skull with articulated left mandible and some articulated vertebrae. Additional preparation has fully exposed the skull, including the palate and occiput, revealing new aspects of the anatomy of *Lydekkerina huxleyi*. These include, on the skull roof, the presence of a relatively large and medially orientated septomaxilla, and the inclusion of the lacrimal in the narial margin. On the palate, the anterior palatal vacuity shows a possible tripartite subdivision, and fields of denticles are present on the vomer, parasphenoid and pterygoid. On the mandible, the postglenoid area has a prominent retroarticular process and an extended arcadian process separated by a distinct arcadian groove and both an anterior and posterior meckelian foramen are present. This study has allowed for a critical rediagnosis of *Lydekkerina huxleyi* and a reassessment of lydekkerinid species diversity in the Karoo Basin, initial study of which suggests that not all of the currently recognised species are valid.

QUATERNARY FAUNA OF THE DUNGANNON SITE, SCOTT COUNTY, VIRGINIA

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The Dungannon Site, discovered in a roadway stabilization project, consists of Quaternary sediment overlying the Cambrian Rome Formation. It produced seven vertebrate taxa that are strongly indicative of freshwater aquatic environments. The deposition presumably resulted from an impoundment of a valley drainage, but the site is now elevated well above the existing flood basin. While not yet accurately dated (but likely post-Wisconsinan) the paleoecological and geomorphological implications are of interest for interpretation of the development of drainage systems. In particular, the presence of *Schilbeodes eleutherus* (Jordan), the Mountain Madtom, indicates that the site was within the Clinch River drainage at the time of deposition, as it is at present. Fourteen species of terrestrial gastropods enable a paleoenvironmental interpretation, hypothetically comparable to areas north of Virginia.

Geological and paleontological information from sites of this kind could be used to evaluate risks and rates of slumping in geologic hazard areas, and thus could be of value in engineering.

THE PRESENCE OF CLEITHRA IN THE PRIMITIVE TURTLE *KAYENTACHELYS APRIX*

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Kayentachelys aprix is a primitive turtle from the Early Jurassic of Arizona. A recent morphological review of all available *Kayentachelys aprix* material resulted in a number of new anatomical observations. Among these, *Kayentachelys aprix* was found to have clear traces of cleithra, a dermal component of the pectoral girdle. Although these structures were previously noticed in this taxon, they were diagnosed as simple processes of the epiplastra. This primary homology assessment was probably influenced by the morphology of the most primitive known turtle, *Proganochelys quenstedti*. In this taxon, cleithra are also present, but so tightly fused to the plastron that they appear to be outgrowths of the plastron rather than separate structures. In *Kayentachelys aprix* the cleithra clearly demonstrate their identity as independent bones by being loosely attached to both the epiplastra (= clavicles) and entoplastron (= interclavicle) just anterior to the scapula. As these observations match the anatomical relationships of the cleithra of other primitive tetrapods, diagnosing these structures as cleithra is reasonable if topology is used as a primary homology criterion.

The presence of cleithra in *Kayentachelys aprix* is intriguing as it has implications regarding basal turtle relationships and the origin of turtles. As all living turtles lack cleithra, its presence in *Kayentachelys aprix* is suggestive that this taxon may represent the phylogenetic stem of crown turtles. Furthermore, cleithra are present in most anapsid reptiles but absent in all diapsids, making it more plausible that turtles indeed are descendants of anapsid reptiles. Admittedly, the presence of cleithra in primitive turtles is just one character that may be rendered homoplastic by a comprehensive parsimony analysis. *Kayentachelys aprix* and other primitive turtles display numerous other characters, however, that suggest an affinity with anapsids.

THE DIETARY SPECTRUM OF HERBIVOROUS UNGULATE SPECIES AS A TOOL OF HABITAT RECONSTRUCTION

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The first occurrence of tridactyl, hipparionine horses is constrained in Eurasia between 11.2 and 10.8 m.y. *Hippotherium primigenium* is the only species recorded up to now in the early Vallesian–early Turolian of Germany. Two Vallesian populations of *H. primigenium* were investigated in respect of their trophic regimes. One of these populations derives from the deposits of the upper Miocene Rhine river exposed at the locality of Eppelsheim (Germany). The other population (Höwenegg) is represented by lacustrine deposits of a former crater lake about 180 km south of Eppelsheim. Both localities represent two almost contemporaneous Vallesian (MN9) populations of a single equid taxon from different geographic regions within western Germany. Trophic regimes are reconstructed using the mesowear method and the derived extended mesowear method. These analyses lead to the identification of a recent trophic reference taxon for each of the two hipparion populations. The common waterbuck (*Kobus ellipsiprymnus*), a grazer inhabiting reedbeds and also foraging into woodlands, is identified as the trophic analogue for the Eppelsheim population. The reference taxon of the Höwenegg population is the Sumatran rhinoceros (*Dicerorhinus sumatrensis*), a browser, inhabiting mainly hilly country and preferring saplings, fruit, leaves, twigs, and bark as

major food items. The differences in the trophic regimes found for the two populations of fossil horses is interpreted as reflecting the range of possible dietary regimes of this equid species. The trophic signal of *H. primigenium* is therefore interpreted as an ecological signal reflecting properties of the habitat. The paleohabitat of Eppelsheim would then be recognised as representing at least seasonally extended sources of grassy areas as reed flats in the proximity of the Miocene Rhine river. The paleohabitat of the Höwenegg however was most likely immediate part of the subtropical mesophytic forests which covered large parts of central and western Europe, central Asia and southern China during the Vallesian period.

LASER SPECTROSCOPY FOR COMPARATIVE ANALYSIS OF FOSSIL MATERIAL

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Many technologies exist for chemical and elemental analysis of fossil specimens. Most are costly and require specialized processes that usually limit the analysis to a few samples of high interest. An alternative is to determine elemental composition by examination of the light spectrum given off by burning a material.

An industrial infrared YAG (yttrium-aluminum-garnet) laser has been used in many fields to vaporize small samples while recording the visible spectrum of the resulting flame (which reflects the mix of elements present in the sample) with a digital camera for analysis. Such analyses have been used to detect wax and other illegal coatings on the blades of Olympic bobsleds. As applied to a fossil specimen, the described technique records intensity values from 0-255 at 1200 continuous points along the spectrum. These numeric values can be cross-correlated against a matrix of other specimens to determine the percent similarity among them. A "distance" matrix of specimens can be fed directly into molecular evolutionary analysis software, producing a distance tree analogous to DNA trees.

One hundred forty Lance, Hell Creek and White River specimens were subjected to laser ablation of a 2x2x1mm section as an exploratory test of the methodology. Preliminary results show a clear delineation between the Lance and Hell Creek specimens even though they are from the same time period. The White River specimens plot amongst the Hell Creek specimens even though the two formations are stratigraphically, geographically and depositionally distinct. Further testing is planned to determine the technique's potential for differentiation among taxonomic groups and detection of possible mineral halos around articulated specimens.

NOVEL APPROACHES TO SKULL RECONSTRUCTIONS

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The fossil prep lab at the University of Chicago recently completed the skull reconstruction of *Rugops primus*, a new predatory dinosaur from Africa. This project provided an opportunity to expand upon the standard procedures used in restoring disarticulated and incomplete skulls.

After the existing bones of the skull were fully prepared, they were molded in silicone and cast in epoxy resin. Then, a flatbed scanner was used to obtain images of the resin bones that needed to be mirror-imaged. Existing bones were scanned, and the images were reversed in a photo editing program. 1:1 sized printouts of the reversed images serve as photo quality reference for the size, shape and details of the missing anatomy. Hardware cloth was cut to the shape of the missing elements, and covered with epoxy putty for strength. Clay was sculpted over these forms, and detailed with fine tools. The reconstructed elements were wired to the epoxy bones to three-dimensionally restore the skull. Epoxy putty covered hardware cloth was used to create a custom-fitting holder and sculpture stand for the skull. The holder fit over the steel rod of a Bunsen burner stand. A five part silicone mold of the skull was made. To avoid marring the surface of the sculpted plasticene features, clay molding-walls were avoided. Instead, tissue and B72 was used to create dividing partitions for molding.

The mold yields a quality model that incorporates all of the fossil details, and can be painted to match the fossil coloration. A variety of improvised techniques helped the project proceed smoothly; the methods tested here are already being applied to current projects.

THE TAPEJARIDAE—A MONOPHYLETIC GROUP OF PTERODACTYLOID PTEROSAURS

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The Tapejaridae comprises a group of pterodactyloid pterosaurs that was created in 1989 for the taxa *Tapejara* and *Tupuxuara*, both from the Early Cretaceous Santana Formation, Brazil. Since then several more tapejarid remains have been found, improving our knowledge of this clade. Recently, however, the monophyly of this group was questioned. A phylogenetic analysis using the main taxa of the Pterodactyloidea was performed, and confirmed that the Tapejaridae are a natural group diagnosed by the following features: premaxillary sagittal crest that starts at the anterior portion of the skull and extends posteriorly well after the occipital region, large nasoantorbital fenestra that reaches over 45% of the length between premaxilla and squamosal, lacrimal process of the jugal thin, proportionally small pear-shaped orbit with lower portion narrow, and broad tubercle on the ventroposterior margin of the coracoid. At present remains of this clade have been found in the Crato and Romualdo members of the Santana Formation (Aptian-Albian), Araripe Basin; Jiufotang Formation (Aptian), Jehol Group of western Liaoning, China; and in the redbeds (Cenomanian) of the Kem Kem region, Morocco. An incomplete skull found in the Javelina Formation (Maastrichtian), Texas, also shows several tapejarid features and might represent a member of this clade. Several cranial (e.g., supraoccipital extending backwards) and postcranial (e.g., humerus massive medial crest and developed proximal ridge) characters show that the Tapejaridae is well nested within a group formed by Dsungaripteridae and Azhdarchidae, showing a sister group relationship with the latter (e.g., orbit positioned lower than the dorsal rim of the naof; second wing phalanx more than one third smaller than first wing phalanx). A preliminary study of the ingroup relationships within the Tapejaridae shows that *Tupuxuara* is closely related to *Thalassodromeus* relative to *Tapejara*, sharing features such as the posterior margin of the nasoantorbital fenestra very high. The presence of tapejarids in Morocco (Africa) was expected but its occurrence in China needs further investigation.

CORRELATING EARLY CRETACEOUS DINOSAUR SITES USING STRATIGRAPHIC TRENDS IN ^{13}C FROM PEDOGENIC CARBONATES: AN EXAMPLE FROM THE CEDAR MOUNTAIN FORMATION IN UTAH

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Numerous dinosaur sites have been identified in the Cedar Mountain Fm (Barremian?-latest Albian) in recent years. Recognizing the relative chronological order of these sites is critical in reconstructing the paleobiological history of this interesting time interval. Lacking paleomagnetic reversals, radiometrically datable horizons, and a significant microfauna, the Aptian-Albian is particularly difficult to date. We tested for coupling between marine, atmospheric, and terrestrial carbon reservoirs by analyzing the chemostratigraphy of pedogenic carbonate in closely spaced palustrine carbonate beds in sections near Price, Utah (PR2), and at Dinosaur National Monument (DNM16), looking for Aptian-Albian carbon isotope excursions. To better understand the processes responsible for the encoding of this chemostratigraphic record, we have undertaken petrographic and diagenetic investigations of selected carbonate beds in our stratigraphic sections. Evidence for ephemeral ponded water is provided by the common occurrence of ostracods, gastropods, and charophytes indicating emergent aquatic vegetation. Brecciated fabrics are ubiquitous, suggesting that pedogenic overprinting was common to all samples. Only fine-grained carbonates were used in the ^{13}C profiles for each section. Both sections show organized structure that we have correlated to marine Aptian-Albian carbon isotopic curves, supporting the use of palustrine carbonates for continental-marine correlations. Both sites are interpreted as being early Albian in age, with the PR2 site being slightly younger than the DNM16 site.

REMAINS OF A SMALL DIADECTID (TETRAPODA: DIADECTOMORPHA) FROM THE DUNKARD GROUP OF OHIO, WITH CONSIDERATION OF DIADECTOMORPH PHYLOGENY

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A new genus and species of diadectid from the Lower Permian Greene Formation of Ohio is distinguishable from all other members of the group by the presence of conical anterior teeth of the maxilla and dentary, high maxillary and mandibular tooth counts, a lesser degree of molarization of the cheek teeth, a shallow dentary, lack of a labial parapet, and a relatively shallow alveolar shelf that suggests a more shallow tooth implantation than that of other diadectids. The recognition of the new form as a member of Diadectidae is supported by the presence of a heterodont dentition that possesses transversely expanded, molariform cheek teeth bearing: 1) a central cusp flanked by labial and lingual shoulders; and 2) wear facets on the lingual and labial shoulders of the maxillary and dentary cheek teeth, respectively. With the anteroposterior length of the dentary measuring 27.6 mm, the new form is the smallest known diadectid, and comparison of the new form to known ontogenetic series of other diadectid taxa indicates that it does not represent the juvenile remains of a currently known diadectid. Although lacking a deep lower jaw, which is characteristic of herbivores and found in other diadectids, the presence of procumbent anterior teeth, molariform cheek teeth, and wear facets similar to those of other diadectids suggest that the new form, like all other diadectids, was likely herbivorous. A phylogenetic analysis of Diadectomorpha based on a data matrix of nine taxa, including Amniota and Lepospondyli as outgroups, and cranial and postcranial characters has produced a topology of (Lepospondyli (Amniota (*Limnoscelis* (*Tseajaia* (the new Dunkard form (an undescribed diadectid from the Bromacker quarry of Germany (*Desmatodon* (*Diasparactus* + *Diadectes*)))))))), supporting both the monophyly of Diadectidae and the sister-group relationship of *Limnoscelis* to the clade of *Tseajaia* + Diadectidae. With a greater species-richness and wider geographic range relative to other diadectomorph taxa, it is likely that the evolution of herbivory in Diadectidae led to an evolutionary radiation within the group.

TRACKWAYS OF THE MIOCENE HORSE SPRING FORMATION AND A SYNTHESIS OF MIOCENE TRACKSITES IN THE WESTERN U.S.

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Eight track-bearing units are now known from the Miocene of the western U.S., with a combined total of about thirty tracksites. These units are: the Ash Hollow Fm., the Avawatz Fm., the Barstow Fm., the Copper Canyon Fm., the Horse Spring Fm., the Muddy Creek Fm., the Ogallala Fm., and the Ridge Route Fm. Not surprisingly, all of the trackway assemblages are associated with lacustrine facies, and most contain a combination of bird and mammal tracks.

We have been studying the tracks of the Horse Spring Formation, which is exposed in the Lake Mead region of Southern Nevada. The most conspicuous Horse Spring trackways are those made by many types of birds, by camelids, and by canids. No equid tracks or proboscidean tracks have yet been identified in the Horse Spring Formation. In contrast, the Copper Canyon Formation, in Death Valley National Park, contains proboscidean tracks,

abundant equid tracks, and tracks of several other quadrupeds. Paleogeography suggests that the Horse Spring Formation occupied a more arid setting than did the Copper Canyon and Barstow formations, for example, and the ichnofaunas preserved in these formations doubtless reflect these environmental differences.

A preliminary analysis of data from all of the western U.S. Miocene tracksites suggests a working hypothesis that a Miocene lacustrine ichnofacies is recognizable, but that within this ichnofacies there are at least two subfacies. One of these is an arid ichnosubfacies in which equids are conspicuously absent, but camelids, canids, and wading birds are more or less conspicuous. The Horse Spring Formation is an example of this arid ichnosubfacies. The other subfacies is more mesic; it is characterized by a more diverse assemblage of quadruped tracks (but not necessarily bird tracks), and a conspicuous presence of equids.

SYSTEMATIC REVISION OF '*YANDUSAURUS' MULTIDENS*, A MIDDLE JURASSIC ORNITHOPOD FROM CHINA

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'Yandusaurus multidens' is an ornithischian from the Lower Shaximiao Formation (?Bajocian) of Dashanpu (Sichuan Province, China). The name-bearing type (Zigong Dinosaur Museum T6001) is a relatively complete skeleton lacking only the rostral extremity of the skull, most of the mandibles, and the caudal extremity of the tail. The paratype is constituted by a disarticulated and less satisfactorily preserved skeleton.

'Yandusaurus multidens' is recurrently considered to be a junior synonym of *Y. hongheensis*, type-species of the genus, the material of which comes from the Upper Shaximiao Formation (? Oxfordian) of Hongheba (Sichuan Province). However, significant differences exist between the two species. For example, the coracoid of *'Y' multidens* lacks the ridge on the lateral surface and the ventral embayment that are present in *Y. hongheensis*. In addition, the scapula is shorter than the humerus in the former whereas they are equal in length in the latter. Maxillary tooth morphology, enamel thickness, and the degree of tooth wear also differ. The presence of more teeth in the maxilla of *'Y.' multidens* contradicts the hypothesis that this species represents juvenile individuals of the larger *Y. hongheensis*. Consequently, these distinctions appear to be sufficient to warrant a generic distinction between these two species. Moreover, the validity of *Y. hongheensis* is currently questionable, further destabilising the genus.

'Y.' multidens was originally referred to the Hypsilophodontidae on the basis of similarities apparently shared with *Dryosaurus* (a taxon then thought to be a close relative of *Hypsilophodon*). Subsequently, various authors have either supported this referral or regarded *'Y.' multidens* as a fabrosaurid or basal ornithischian. Although *'Y.' multidens* is definitely more primitive than the dryosaurid *Dryosaurus*, its phylogenetic position amongst ornithopods remains challenging. Cladistic analyses suggest that *Agilisaurus louderbacki* and *Othnielia rex* may be the sister taxa of *'Y.' multidens*.

RE-EXAMINATION OF *HARPYMIMUS OKLADNIKOVI* (DINOSAURIA: THEROPODA) OF MONGOLIA AND PHYLOGENY OF ORNITHOMIMOSAURIA

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Harpymimus okladnikovi was discovered in the Early Cretaceous of Mongolia during the Joint Soviet-Mongolian Paleontological Expedition and was described based on selected elements in 1984. *Harpymimus* has been known as a basal ornithomimosaur, but its relationship with *Pelecanimimus* remains problematic because *Harpymimus* has derived skull characters but a primitive hand structure, compared to *Pelecanimimus*. A nearly complete skeleton of *Harpymimus* holotype is restudied and compared with all known ornithomimosaur genera and some undescribed specimens to test the phylogenetic relationships within Ornithomimosauria.

A phylogenetic analysis was performed utilizing 95 characters for ten taxa with two outgroups and produced a single most parsimonious tree. The phylogenetic tree shows that *Harpymimus* is more derived than *Pelecanimimus* based upon skull characters (loss of premaxillary and maxillary teeth) and is a sister taxon to a clade of *Garudimimus* + Ornithomimidae. Two scenarios are possible for hand structure evolution: reversal in *Harpymimus* or convergence in *Pelecanimimus*. Our phylogenetic analysis also resolved the interrelationships of Ornithomimidae. The early Late Cretaceous taxa (undescribed Chinese taxon and *Archaeornithomimus*) form the stem group of a clade of the late Late Cretaceous taxa. The late Late Cretaceous ornithomimids form Mongolian (*Anserimimus* + *Gallimimus*) and North American (*Struthiomimus* + [*Ornithomimus* + *Dromiceiomimus*]) clades. Ornithomimosaur tree topology is congruent with the chronological appearance of its ingroups and suggests that the origin of ornithomimosaurs is in either Europe or eastern Asia prior to the Barremian, and that ornithomimids dispersed to North America during or prior to the Late Cretaceous.

ISOTOPIC RECORDS OF LATE QUATERNARY ECOSYSTEM CHANGE IN TEXAS

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The state of Texas sits at the intersection of steep N-S gradients in temperature and E-W gradients in precipitation. As such, its vegetation and biomes may be sensitive to past and future global change. Poor pollen preservation, and the fact that grass pollen cannot be identified to a low taxonomic level, has led to uncertainty and disagreement about the history of Quaternary vegetation in the region. We explore vegetation change through carbon isotope analysis of Quaternary mammalian fossils. Grasses using the C4 photosynthetic pathway occur in areas with a warm growing season, and they have a very different carbon isotope composition than plants using the C3 pathway (cool climate grasses, and most trees, herbs and shrubs). We focus our study on mammoths, bison and horses. These animals are thought to be grazers (i.e., animals that consume chiefly grass), and so may provide a monitor of the balance between C4 and C3 grasses in Quaternary biomes. We examine fossils ranging in age from greater than 30,000 years old to the Holocene. In addition, we estimate the expected vegetation in different time periods by coupling climate and vegetation models.

Our study has four significant results. 1) Pleistocene horses are not obligate grazers and thus cannot provide solid evidence on changes in C3/C4 balance in the grass flora. 2) Data from these mixed-feeding horses provide no support for the suggestion that forests spread across northern Texas at the last glacial maximum. 3) While there are clear trends in C4 grass abundance across the state, with maxima occurring at both the Gulf coast and on the plains, most regions do not show strong temporal shifts between cool glacial and warm interglacial times. 4) Climate-vegetation models that fail to consider the impact of changes in both atmospheric carbon dioxide concentration and temperature dramatically under-estimate the amount of C4 vegetation in the region.

RATES OF ENAMEL FORMATION IN HERBIVORES AND IMPLICATIONS FOR INFERRING PALEOSEASONALITY

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Oxygen isotope zoning in tooth enamel can never be a 1:1 record of environmental isotope seasonality (e.g., water compositions) for 3 reasons: (1) Air O_2 composition is invariant. This introduces an isotope scaling factor (0.75 to 0.9) between seasonality and tooth records. (2) Each day's uptake of oxygen by an animal is ordinarily a small proportion of its oxygen reservoir. This dampens the magnitude of an isotope record by 5-10%. (3) Teeth mineralize progressively. Each enamel increment thus represents a time-average of the scaled and dampened isotope variability of an animal.

Factors 1 and 2 have predictable limits, permitting correction of fossil isotope records. However, as shown recently by Passey and Cerling, factor 3 (mineralization rates) can have a profound influence on isotope records, with possible damping of 50% or more. If mineralization rates are very different among taxa, then there may be no way of inferring paleoseasonality accurately from fossil records. Mineralization-induced damping depends critically on 2 lengths in enamel: the distance over which enamel matures from its initial appositional state to its final fully crystalline state (l-mat), and the length of enamel laid down during the characteristic time span of a variable environmental signal (l-env). Only 2 determinations of l-mat are available (15-30 mm), and modern teeth are likely the only source of data on l-mat. However l-env is potentially derivable in modern and fossil teeth from isotope zoning profiles and incremental lines. Isotope profiles yield yearly l-env of 40-50 mm for proboscideans and large bovids, 30-100 mm for small bovids, 50-60 mm for equids, and >150 mm for castorids. If 15-30 mm is common for l-mat, then these l-env lengths imply that yearly isotope records are typically damped by ~50% (range=15 to 85%). Incremental features are rarely examined, but daily increments (2-10?m) along enamel fibers can directly yield growth rates. Perikymata (surface striations on enamel) represent variable [daily(?), multiple-day, or weekly] durations and unless calibrated are poor monitors of mineralization rates.

LATE PALEOCENE MIXODONTS FROM THE TSAGAN-KHUSHU LOCALITY, MONGOLIA

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Two mixodont species, *Eomylus zhigdenensis* Dashzeveg et Russell, 1988 and *Sinomylus* sp. nov., were identified from the upper Paleocene Zhigden Member of the Naran Bulak Formation at Tsagan Khushu locality by the authors. The extensive material housed at Paleontological Institute of the Russian Academy of Sciences (including six skulls and over 200 jaw fragments) let the authors revise some of the mixodont taxa known from Mongolia and to describe a new species. The newly established dental formula of *Eomylus* is I1/1 C0/0 P2/2 M3/3. The studied upper tooth rows were identical in M1-2 structure to the holotype of *Eomylus zhigdenensis*. According to our material the lower jaws and teeth of *Eomylus zhigdenensis* completely correspond to the holotype of *Khaychina elongata* Dashzeveg et Russell, 1988 from the upper Paleocene Bugin Member at Khaichin-Ula I locality, Mongolia. Latter species was described based only on the lower jaw remains. Thus *Khaychina* and *Kh. elongata* are junior synonyms of *Eomylus* and *E. zhigdenensis* respectively. *Sinomylus* sp. nov. is represented by skull and jaw fragments, including articulated upper and lower jaws. Being much larger, it is very similar in the P2-M2 structure to the upper Paleocene Chinese *Sinomylus zhaii* McKenna et Meng, 2001. The lower jaws of *Sinomylus* sp. nov. are identical to those that Dashzeveg and Russell tentatively referred to *Eomylus zhigdenensis* (we have articulated upper and lower jaws of *Synomylus*). Having a P2 and an i3, *Sinomylus* is characterized by an intermediate dental formula between Mimotonidae and typical Eurymyloidea I1/2 C0/0 P3/2 M3/3. Upper incisors have well-defined anterior longitudinal groove, which is typical for Mimotonidae and Lagomorpha. Still the absence of the I3 and the structure of P3-M3 and p3-m3 is most similar to representatives of Eurymyloidea, where we place this genus. We believe that the mosaic arrangement of characters reflects a wide morphological diversification of mixodonts at the early evolutionary stages.

ORIGINS AND RELATIONSHIPS OF PINNIPEDS, AND THE CONCEPTS OF MONOPHYLY VERSUS DIPHYLY

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This study summarizes the evolutionary history and phylogenetic relationships of the living and fossil otarioid and phocid pinnipeds, and their extinct relatives. It is based on evidence from the fossil record, comparative morphology, and molecular and cytogenetic investigations. We pay most attention to certain characters that were repeatedly used by different authors to support the hypothesis of pinniped monophyly. Our main goal is to show that a range of characters can be interpreted with different polarity, are very variable, insignificant, or simply convergent. We interpret the pinnipeds to be diphyletic in their origin, at least as far back as late Oligocene time, which is apparently soon after the first arctoid ancestors of each pinniped group invaded the aquatic environment. Therefore, we treat the families Otariidae and Phocidae as being monophyletic. The differences between the proposed hypotheses for pinniped relationship reflect differences in the interpretations of the polarity of characters, their level of analysis, and the extent to which convergence affects the assessment of relationships. Phocids and otarioids now seem to have equally early origins, in the late Oligocene. But the paleontological and biogeographical evidences suggest that they have separate ancestries, with phocids arising in the North Atlantic, being most closely related to musteloids, whereas otarioids arose in the North Pacific and are most closely related to ursids. Anatomical and morphological review of characters that have been often used by supporters of a monophyletic origin reveals that they fail to provide convincing evidence for 'pinniped' monophyly. The process of excluding aquatic specialization has led to an incorrect conclusion about phylogenetic relationships, origins and body size of the early pinnipeds. Numerous features of the pinniped skeletal morphology strongly support a dual origin for the group.

NEW IMPLICATIONS FOR THE CRETACEOUS-TERTIARY ASTEROID IMPACT THEORY BASED UPON THE PERSISTENCE OF EXTANT TROPICAL HONEYBEES (HYMENOPTERA: APIDAE)

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Tropical honeybees had wide distribution in the Late Cretaceous, including the oldest tropical honeybee *Trigona pricsa* from the Latest Cretaceous (Maastrichtian) amber of New Jersey. In the Late Cretaceous, tropical environments extended from Arizona to New Jersey.

In 1980, Alvarez and others proposed that an asteroid impact was the culprit of the Cretaceous-Tertiary extinction event. Alvarez and others proposed that an asteroid impact would have thrown the earth into something comparable to a nuclear winter that may have lasted several years, although this interval has recently been reduced to several months. It has been estimated that during the K-T event, temperatures decreased 7-12°C, bringing the tropics to a more temperate climate. Studies have shown that tropical honeybees have an optimal temperature range of 26-36°C, however, they freeze at 0C, become immobilized at 11°C, and the brood dies below 28°C. Tropical honeybees must have flowering plants (Angiosperms) all year round in order to survive, and thus tropical conditions must have persevered through the K-T boundary. It is this persistence of the tropics that places limitations upon the maximal effect of the impact theory.

DISCOVERY OF A RELATIVELY COMPLETE MAMMALIAN SPECIMEN FROM THE LATE CRETACEOUS OF MADAGASCAR

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The Late Cretaceous (Maastrichtian) mammalian fauna of Madagascar, recovered from the Maevarano Fm., Mahajanga Basin, was previously represented by at least five taxa, each known from nothing more than a fragmentary tooth or two. Even so, the Malagasy sample comprises the second most diverse assemblage of mammals from the Late Cretaceous of Gondwana.

Here I report the recent discovery of a mammalian specimen from the Maevarano Fm. that is much more complete, yet still only partially prepared. It consists of an incomplete skull and articulated skeleton of a cat-sized individual. Despite its immaturity (erupting teeth, unfused epiphyses), it is the largest and most complete mammalian specimen yet known from the Mesozoic of Gondwana. Partial preparation and a preliminary CT-scan reveals a highly derived dentition, with only three or four cheek-teeth in each jaw quadrant separated by a sizeable diastema from procumbent incisors (two upper, one lower). Although exhibiting some primitive characteristics (e.g., epipubic bone, deep zygomatic arch), the specimen bears a host of features (e.g., absence of septomaxilla, well-developed trochlea on distal humerus, absence of emargination along dorsal rim of acetabulum, small and ventromedially-directed lesser trochanter on femur, reduced fibular-calcaneal contact) suggesting that it represents a therian mammal more derived than the Early Cretaceous Argentinian form *Vincelestes*. Significantly, however, it does not represent a form directly ancestral to any of the taxa in the island's highly endemic and imbalanced mammalian fauna.

The relative completeness of the new specimen promises to elucidate a great deal concerning the anatomy, functional morphology, and phylogenetic position of the clade it represents. This specimen will also yield a wealth of information with which to address questions concerning the origin and evolutionary history of Gondwanan mammals. Especially given the unusual morphology of the new specimen's dentition, it appears that the anatomical diversity in mammals from the Late Cretaceous of Madagascar rivals that already documented for crocodyliforms and dinosaurs.

MOLDING AND CASTING *ODOBENOCETOPS*, AN UNUSUAL WHALE SKULL

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Unique skulls/bones are often the only thing that scientists have to study an extinct organism. Sometimes molding and casting of that skull needs to be done so that others may study it. This may put the specimen at risk if the preparator does not know how best to prepare an intricately shaped object for molding. This poster will serve as an aid to the novice mold-maker and may even help the experienced preparator. The disassembled mold and painted cast skull of *Odobenocetops* will be shown here at the Special Symposia for Mold-Making at this year's SVP Preparators Symposia Poster Session. A brief discussion of various mold-making/cast-making materials will be presented at the poster as well.

A NEW SPECIES OF *TCHOIRIA* (DIAPSIDA, CHORISTODERA) FROM DHOUS, MONGOLIA

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A nearly complete skull and partial postcranial skeleton of a choristodere was discovered at Dhous, a site in the Gobi Desert of Mongolia, by the AMNH-Mongolian Academy of Sciences expedition during the 1998 field season. The specimen represents a member of the genus *Tchoiria*, which are moderate-sized choristoderes (~1.5 m), similar in overall morphology to the better-known *Champsosaurus* and *Simoedosaurus*. *Tchoiria* possesses the derived character states of the Simoedosauridae, but also retains several primitive character states, suggesting it is the most primitive simoedosaurid genus.

Several elements preserved in the Dhous specimen are not preserved in the holotype of *T. namsarai* (PIN 3386/1) and allow new comments on the morphology of the genus. The codings for several previously missing characters for *Tchoiria* can be completed. The free atlas pleurocentrum is present, the posterior portion of the supraoccipital is exposed dorsally between the parietals, the number of sacrals is three, and the caudal zygapophyses are vertically oriented. These new codings have no effect on the topology of choristodere phylogeny uncovered by the most recent phylogenetic analysis of the group, which found *Tchoiria* to be the basal genus of the clade Simoedosauridae.

Differences in the number of symphysial teeth, number of maxillary teeth, the anterior extension of the jugal, and the nasal/prefrontal contact indicate this specimen belongs to a species separate from *T. namsarai*. The right half of the mandibular symphysis of the Dhous specimen contains only 12 teeth as opposed to 17 in PIN 3386/1. There are 34 tooth positions preserved in the nearly complete right maxilla of the Dhous specimen, and over 60 in each maxilla of PIN 3386/1. The jugal extends to the anterior border of the lacrimal and the nasals intervene between the prefrontals in the Dhous specimen. The jugal extends only to the posterior border of the lacrimal and the nasals contact but do not intervene between the prefrontals in PIN 3386/1.

NEW MATERIAL OF *ZEPHYROSAURUS SCHAFFI* (DINOSAURIA: ORNITHISCHIA) FROM THE CLOVERLY FORMATION (APTIAN-ALBIAN) OF MONTANA

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Zephyrosaurus schaffi was described in 1980 as a hypsilophodontid based on a single, incomplete specimen consisting of fragmentary skull material, including a well-preserved brain case, and a few incomplete vertebrae. Newly discovered material collected by the Oklahoma Museum of Natural History and the University of the Pacific includes multiple elements from the skull and postcranium of at least seven individuals. The skull material consists of two premaxillae, one maxilla, three frontals and three dentaries. At least one example of every appendicular element is present, with the exception of the pubis and several manual and pedal elements. Known material includes two scapulae, one corocoid, two humeri, one ischium, one ilium, three femora, one tibia and one fibula.

The new material was collected from units V and VII of the Lower Cretaceous Cloverly Formation of south-central Montana. The Cloverly Formation consists of floodplain conglomerates, conglomeratic sandstones, and variegated mudstones that represent overbank deposits laid down in a fluvial phase during the early Albian. Most of the specimens were recovered from overbank deposits. The results of a morphological and phylogenetic analysis of *Zephyrosaurus* will be presented.

QUANTIFICATION OF DIAGENESIS IN FOSSIL LAMNOID SHARK CENTRA

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For vertebrate bones, physical and chemical changes are known to occur rapidly during diagenesis, i.e., within tens to thousands of years. These changes affect crystallinity, organic content, mineralogy, density, major and trace element concentrations, and stable isotopic composition. Despite the potentially profound influence of diagenetic modification on fossilized material, this process is all-too-often poorly understood. In many cases diagenesis is assumed to have a negligible effect on the geochemical signature archived in the fossil record. This study quantitatively examines the processes of diagenesis in vertebral centra of Cenozoic lamniod sharks by determining: (1) the effects of diagenetic recrystallization on both trace elements and oxygen isotopes; and (2) the extent of diagenetic modification. The crystalline structure of bone can be determined by calculating the crysatallinity index (CI) from Fourier transform infrared spectra. The CI reflects the relative sizes of the crystals and the degree that the crystal lattice is ordered. Apatites with larger, more ordered crystals have a higher CI and are more diagenetically altered. Inductively coupled plasma mass spectroscopy (ICPMS) determines the major, minor, trace, and rare earth elements found in modern and fossil shark centra, and the associated sediments. ICPMS allows for the study of concentration changes of these elements through diagenetic processes. Analysis of oxygen isotopes (both phosphate and carbonate phases) in both the bone and associated sediments determine if isotopic exchange of the fossil shark centra has occurred with recrystallization. The quantification of the extent

of diagenetic modification and a better understanding of the effects of diagenetic recrystallization have on trace elements and oxygen isotopes provide an important prerequisite for interpretations of data archived in fossil bone.

NEW CROCODYLIFORM AND DINOSAUR DISCOVERIES FROM THE UPPER CRETACEOUS (CAMPANIAN-?MAASTRICHTIAN) UPPER MEMBER OF THE BAJO BARREAL FORMATION, SOUTHERN CHUBUT PROVINCE, ARGENTINA

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The Upper Cretaceous Bajo Barreal Formation of central Patagonia, Argentina has yielded a diverse continental vertebrate assemblage that includes chelid turtles, crocodyliforms, abelisauroid and tetanuran theropods, titanosauriform and diplodocoid sauropods, and ornithopods. The majority of these forms derive from the Cenomanian-?Coniacian Lower Member of the Bajo Barreal. Here we report new tetrapod discoveries from the uppermost Cretaceous (Campanian-?Maastrichtian) Upper Member of the Bajo Barreal, exposed in the vicinity of Lago Colhué Huapi in southern Chubut Province.

The rostral portions of articulated mandibles characterized by a rostrocaudally elongate symphysis and marked heterodonty indicate the presence of a distinctive mesoeucrocodylian in the Upper Member fauna. The procumbent first dentary crown is labiolingually compressed and denticulate, while crowns 2-4 are ovoid in basal section. Distal crowns are globular with a denticulate distal carina and basal constriction. Dinosaur remains from the Upper Member include a fragmentary skeleton of uncertain affinities and sauropod and ornithopod material. Eighteen articulated procoelous proximal and middle caudal vertebrae and haemal arches represent a derived titanosaurian sauropod similar to *Aeolosaurus*, a genus widespread in Late Cretaceous deposits elsewhere in Patagonia and Brazil. Ornithopod material consists of an isolated ilium pertaining to a derived iguanodontian, possibly a hadrosaur. If accurately identified, the latter would provide increased support for hypotheses of latest Cretaceous faunal interchange between the Americas.

Further paleontological exploration of Upper Member exposures is needed to elucidate the paleobiogeographic relationships of the terminal Cretaceous tetrapod fauna of southern South America.

FUNCTIONAL CONVERGENCE OF ECOSYSTEMS: EVIDENCE FROM BODY MASS DISTRIBUTIONS OF NORTH AMERICAN LATE MIOCENE MAMMAL FAUNAS

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There is a dispute among ecologists as to whether ecosystems are bottom-up (system behavior is the net result of all of the complex internal interactions) or top-down (the behavior is driven by a limited number of key interactive processes) in nature. If ecosystems are primarily bottom-up, then it is unlikely that any two ecosystems will ever behaviorally converge as a simple matter of probability. Conversely, if ecosystems are top-down then the plausible possibility of behavioral convergence exists, since only a small number of factors must come into alignment. This alignment may actually be favored by thermodynamic factors, since some system configurations have higher entropy production than others. Such top-down system convergence explains the ubiquity of hurricane-like atmospheric systems observed on planets beyond the Earth.

Research has demonstrated that body mass distributions of terrestrial animals broadly reflect ecosystem behavior. Thus, comparable but causally disconnected terrestrial ecosystems that demonstrated similar body mass distributions would suggest ecosystem convergence. To look for this possible convergence, I generated body mass distributions in a time series for late Miocene North American mammal faunas (Clarendonian-Hemphillian) from the Gulf Coastal Plains (GCP), Great Plains (GP) and Pacific coastal region (PC), and compared them with data from the modern Serengeti savanna region (with which North American Miocene mammal faunas are often compared). The data show that during the late Clarendonian-early Hemphillian GCP and GP faunas were very similar to each other, but distinctly different from that of the Serengeti, with the PC faunas showing no resemblance to any of the other three. However, during the middle-latest Hemphillian the GCP and GP faunas showed a transformation so as to strongly resemble the Serengeti fauna, while the PC faunas remained distinctly different. These findings suggest that the late Miocene ecosystems of the GCP and GP regions (but not the PC region) converged with that of the Serengeti savanna fauna, and thus that these ecosystems were/are top-down rather than bottom-up in nature.

BODY AND BRAIN SIZE ESTIMATES FROM LONG BONES IN RODENTS: IMPLICATIONS FOR MULTITUBERCULATES.

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Body mass estimates in mammals can be based on long bone measurements. Brain size and encephalization quotients can be calculated from such body mass estimates. We used regression analysis to establish allometric equations between rodent long bone measures, body mass, and brain size.

We derived a sequence of body mass equations using standard multiple regression and stepwise methods. The sample consisted of 56 skeletons representing 25 rodent species from 13 families. Length, sagittal diameter, and coronal diameter measurements were taken from the humerus, radius, ulna, femur, and tibia. Results of stepwise regression showed that the sagittal tibial diameter is the best single estimator of body mass in rodents. The humeral coronal diameter was the next best estimator of body mass. The multiple regression of the femur and tibia together provided the smallest confidence interval for body mass estimation.

We estimated brain size by means of simple logarithmic regression using brain and body weights from our rodent sample used for the body mass estimation. The resulting formula was $Y = 0.347X^{0.460}$ with $r = 0.890$.

We used these equations with the actual dimensions of the femur and tibia of the djadochtatherioid multituberculate *Kryptobaatar dashzevegi* from the Campanian of Mongolia to estimate its body mass. The multiple regression model using all available measurements for the femur and tibia yielded a body mass of 486.71 g (±2.32g). The simple regression model from the tibia sagittal diameter alone yielded a body mass of 194.04 g (±5.63g).

The first estimated body mass provided a predicted brain size of 5.98 g. The second estimated body mass provided a predicted brain size of 3.92 g. Using the predicted brain sizes against an actual endocast volume, we determined two encephalization quotients for *Kryptobaatar dashzevegi*. The tighter confidence intervals of the multiple regression model support the idea that body and brain size estimates are more accurate with multivariable equations.

CONTINENTAL LATE TRIASSIC TETRAPOD BIOCHRONOLOGY: A SOUTHERN PERSPECTIVE

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The Late Triassic is an especially important epoch in vertebrate history, given the first record of major groups such as dinosaurs and mammals. Yet, although attempted since the 19th century, the correlation of terrestrial deposits of that time interval, based on tetrapods, is very poorly constrained. Recent progress towards a global Late Triassic tetrapod biochronology mainly reflects the succession of faunas as seen in some North American continental sequences. This is the case of the Dockum Group, in West Texas, where the proposed superposition of distinct fossil assemblages supports the definition of two LVFs: Otischalkian and Adamanian. Yet, even if appropriate for Western USA, it is ambiguous whether these LVFs can be extended into South Pangea. A particular problem regards the ordination of putatively coeval southern faunas based upon dubious records of Otischalkian and Adamanian index fossils, the taxonomic statuses of which are not clearly understood. This is the case of the Lower Maleri Formation, in India, which was considered of Otischalkian age based on the occurrences of *Metoposaurus* and *Paleorhinus*. Yet, it is uncertain if the metoposaur and phytosaur of that stratigraphic unit belong in those genera, which are still to be comprehensively circumscribed. On the other hand, a younger Adamanian age was proposed for the Ischigualasto Formation, in Argentina, based on dubious records such as those of *Ischigualastia*, in Western USA, and *Stagonolepis wellesi*, in South America. A biochronology based primarily on South Pangean paleofaunas does not support such an ordination. Instead, the Ischigualasto and Lower Maleri Formations are assigned to a single biochronological unit. Based on the fossil record of the Ischigualasto Formation, *Exaeretodon* constitutes an important index fossil of this LVF, whereas the FADs of *Hyperodapedon* and *Jachaleria*, respectively, determine its lower and upper limits. The Ischigualastian is, however, better characterized by the overwhelming dominance of rhynchosaurs (mainly *Hyperodapedon*), and also includes some of the oldest-known dinosaur records.

AN IMPORTANT TRACKWAY SITE FROM THE LANCE FORMATION (LATE CRETACEOUS) OF NIOBRARA COUNTY, WYOMING, WITH NEW INFORMATION ON BEHAVIOR IN *TYRANNOSAURUS REX*.

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Analysis of a trackway site from the Late Maastrichtian Lance Formation of east central Wyoming reveals well preserved trackways from multiple taxa. One set of tracks shows inline movement of from two to six individuals whose tracks are consistent with sub-adult *Tyrannosaurus rex* [*Tyrannosauripus*] (track lengths from 60 to 78 cm.). A separate *T. rex* trackway (track length = 50 cm., width = 54 cm., stride = 356 cm.) from a smaller individual moving at 115° to the group yields a speed of 13 km./hr. at one pace per second.

A very large quadrupedal edmontosaurine trackway (track length = 75 cm., width = 75 cm., stride = 320 cm.) showing a probable tail-drag is preserved on the same slab. The most parsimonious explanation for a quadrupedal tail-drag in this derived hadrosaur is injury, most likely inflicted by a *T. rex*-sized predator.

Also preserved are single prints and a six print trackway attributable to an ornithomimid (track length = 28 cm. width = 19.5 cm., stride = 175 cm.), a smaller tyrannosaurid-like track (length = 36 cm., width = 35 cm.), a side-by-side pair of trackways from an unknown theropod [*Saurexallopus*] (track length = 30 cm., width = 30 cm., stride = 163 cm.), and numerous bird tracks from at least three different species.

A STUDY OF THEROPOD TEETH FROM A LOW-SPECIES-DENSITY HADROSAUR BONE BED IN THE LOWER HELL CREEK FORMATION IN CORSON CO. S.D.

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Theropod teeth can be studied relative to shape, size, cross-section, the position of anterior and posterior carinae, and denticle morphology to identify a specific family, subfamily or species. 95 theropod teeth have been recovered at a site that has yielded over 5500 bones tentatively identified as *Edmontosaurus*. Four teeth were identified as troodontid. The remaining 91 were tyrannosaurid with basal lengths ranging between 4.2 mm and 22.5 mm. The exceptions were two with larger basal lengths of 33 mm and 34 mm respectively.

The purpose of this study was to define the apparent differences in the teeth (related primarily to shape and size) and to determine if those differences represented various juve-

niles of a typical tyrannosaur, or were the differences enough to indicate the possibility of another species of small tyrannosaurid. For the study all the teeth were photographed in lateral view with a macro lens and enlarged to produce a common dimension, in this case a standard fore-aft basal length of 51 mm. All shape comparisons were made from the enlarged photographs. Size comparisons were made by relating fore-aft basal length (FABL) with labial-lingual basal width (LLBW).

Shape comparisons show two groups of teeth based on curvature, and may indicate tooth location in the jaws. Size comparisons indicate several groups of teeth. One group is laterally compressed; the other group more robust. One might hypothesize that not all tyrannosaurid teeth are scaled down versions of adult teeth, and that during ontogeny the teeth become more robust; however that would not explain the presence of small robust teeth and larger laterally compressed teeth.

In conclusion, the evidence suggests that two species of tyrannosaur are present in the bone bed; one most likely *T. rex*, the other a smaller tyrannosaurid.

EVOLUTIONARY INNOVATION OF THE AUTOPODIUM: TESTING DEVELOPMENTAL MECHANISMS OF THE FIN-LIMB TRANSITION

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The origin of the tetrapod limb has been a focus of intensive research. Paleontological and developmental data have yielded three alternative hypotheses concerning the developmental mechanisms of the origin of the autopodium. Its origin has been attributed to (i) a modified metapterygial axis; (ii) a completely novel structure; and (iii) an innovation of structures about a normal metapterygium. Fossil, developmental, experimental, and genetic data are evaluated for these hypotheses. These data are applied to a set of criteria necessary for testing the evolution of developmental mechanisms. The tests support the hypothesis of the autopodium evolving as an innovation of structures about a normal metapterygium while providing evidence to reject the other two hypotheses. Such testing of developmental mechanisms and evolutionary innovation may lead to more accurate definitions of morphology.

A PRELIMINARY PROSAUROPODA PHYLOGENY WITH COMMENTS ON BRAZILIAN BASAL SAUROPODOMORPHA

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Most of the comprehensive phylogenetic studies including prosauropod taxa present inconclusive results. The competing hypotheses not only diverge in the relationships of the supposed major prosauropod clades, but also use different taxa in their analyses, restricting direct comparisons. Three Brazilian taxa could be closely related to basal Sauropodomorpha; within these, *Saturnalia tupiniquim*, *Guaibasaurus candelariensis* are considered as a sauropodomorphs stem-lineage and the unpublished UFSM11069 fill in the prosauropod crown-group. The same features that exclude *S. tupiniquim* from Prosauropoda, include the unpublished Brazilian prosauropod (e.g., anterior portion of dentary, angle of tooth serration, robustness of pes, length of deltopectoral crest of humerus). *G. candelariensis* is considered as a sauropodomorph by having the following characters regarded as synapomorphy to group: the total length of tibia, the ascendant process of astragalus, and total length of ungual of digit 1 of pes, although we consider it to be a juvenile specimen. Eighteen ingroup taxa compose by fourteen prosauropods (*Saturnalia*, *Guaibasaurus*, UFSM11069, *Thecodontosaurus*, *Plateosaurus*, *Massospondylus*, *Euskelosaurus*, *Anchisaurus*, *Sellosaurus*, *Melanorosaurus*, *Riojasaurus*, *Coloradisaurus*, *Lufengosaurus* and *Yunnanosaurus*) and four sauropods (*Vulcanodon*, *Barapasaurus*, *Shunosaurus* and *Brachiosaurus*) were scored for 65 characters. *Herrerasaurus* and *Staurikosaurus* were used as outgroup to Sauropodomorpha. This preliminary phylogenetic analysis suggests that Sauropodomorpha is formed by a stem-group (i.e. *S. tupiniquim* and *G. candelariensis*), and two monophyletic clades (i.e. Prosauropoda and Sauropoda). Prosauropoda is composed of an unresolved clade in a strict consensus approach, probably due to incomplete studies and non-comparable material among the South American prosauropods dinosaurs suggesting more detailed description on this material.

FLAMINGO NEST MOUNDS FROM A CROCODILIAN NESTING SITE IN THE EOCENE WASATCH FORMATION: LINCOLN COUNTY, WYOMING

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Fossil flamingo nest mounds occur in carbonate pond deposits adjacent to the western margin of Eocene Lake Gosiute in the Cathedral Bluffs Tongue of the Wasatch Formation. The nest mounds occur at a density of 1 to 2 nest mounds per square meter with a variety of mound shapes. The most typical examples of these nest mounds are circular in plan view, 30-35 cm in diameter at the base, and in cross-section are 15-20 cm tall with concave sides that narrow toward the top of the mound. The top of the mound is flat and measures 10-15 cm in diameter. The mounds consist of a fine-grained sand matrix containing thousands of randomly arranged caddisfly larval cases, abundant eggshell fragments, and occasional fish bones. Faint shingle-like layering is also visible on the exterior walls of the mounds (in cross-section). The nest mounds are covered by 1 m of massive, gray mudstone that contains abundant eggshell fragments and pulmonate gastropods. The eggshell fragments are 2-3 mm in diameter and the edges are rounded due to abrasion. The eggshell was studied by SEM and by PLM. The basic shell unit consists of a loose arrangement of calcite wedges. This arrangement is consistent with a crocodilian origin. The cause of eggshell abrasion is unknown but may be due to hydrodynamic transport or crocodilian trampling.

Sedimentologic analysis at the site suggests that a small forest was inundated by calcium-rich water. The drowned trees were then encrusted by tufa while microbial mats colonized the bottom of the pond. Abundant caddisfly larvae formed small dome-shaped carbonate-cemented mounds up to 15 cm tall on the microbial mats. Fine-grained sand and mud buried the microbial carbonates. The flamingo nest mounds were constructed from this fine-grained sand, mud and abundant caddisfly larval cases (apparently after partial disappearance of the pond). The nest mounds are encased in crocodilian eggshell-rich mudstone. The crocodilian eggshell was derived from pond-margin nesting sites. The absence of avian eggshell at the site may indicate that the flamingo nest mounds were abandoned before egg-laying or that these were practice nest mounds.

A NEW LATE PALEOCENE "CONDYLARTH" (MAMMALIA) FROM THE SAN JUAN BASIN OF NEW MEXICO AND PHENACODONTID PHYLOGENY

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A new archaic ungulate is described from the Paleocene Nacimiento Formation, northwestern New Mexico. The holotype is a maxillary fragment bearing RM1-3 with small, apical labial cusps, thin cristae, and an elevated trigon, and a dentary fragment bearing a partial Lm3 talonid. Progressive features include incipient hypocones and strikingly blade-like mesostyles. Despite little trace of transverse bilophodonty, the new genus closely resembles the earliest *Ectocion*, *E. collinus*. The traditional consensus derives both earliest Tiffanian *Ectocion* and *Phenacodus* from the earliest phenacodontid, Torrejonian *Tetraclaenodon*. Although in the late Paleocene, the smaller, more cursorial, markedly lophodont *Ectocion* was easily differentiated from coeval *Phenacodus*, few questioned *Ectocion's* inclusion within Phenacodontidae. The new genus is sympatric with youngest San Juan Basin populations of *Tetraclaenodon*, but morphologically antecedent to *Ectocion*. Additionally, once trivialized disparities between *Ectocion* and *Phenacodus* are more pronounced, unambiguously precluding the new genus from phenacodontid *Tetraclaenodon* ancestry. We contend that this separate new genus-*Ectocion* lineage initially evolved strong W-shaped ectolophs and mesostyles, and only secondarily, but rapidly developed transverse bilophodonty. Conversely, the Phenacodontidae initially and more gradually evolved transverse bilophodonty—only the latest taxa secondarily developed uniform labial lophs and mesostyles. Hence, the variable "π-shaped" lophodonty, long used to unite *Phenacodus*, *Ectocion*, and other archaic ungulates was achieved by convergence. Exhibiting no consistent derived phenacodontid traits, the new genus is first evidence of a basal ungulate lineage possibly phylogenetically distinct from Phenacodontidae.

3-D ANALYST AND ARCVIEW APPLICATIONS FOR SPATIAL ANALYSIS OF THE BIG PIG DIG FOSSIL QUARRY, BADLANDS NATIONAL PARK, SOUTH DAKOTA

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In 1993 a chance discovery in the Badlands of South Dakota led to a unique paleontological excavation known as the Big Pig Dig. The quarry has been identified as an Oligocene (Orellan NALMA) watering hole. The fossils recovered from this site show limited diversity but high density within a small area. Due to their high concentration and seemingly random distribution combined with a lack of preferred orientation, traditional field mapping techniques provide limited information for detailed spatial analysis. Data collection with a Pentax Total Station provides a three-dimensional spatial context that can be used for interpretation of many aspects of the quarry. These data combined with the analytical capabilities of ArcView and 3-D Analyst greatly increase the accuracy of any analysis that seeks to identify patterns in any recorded combination of taxon, bone element, and physical position within the quarry with a high degree of certainty. The Pentax Total Station can be used to record the spatial attributes of an individual element. These attributes can then be combined in three dimensions with other recorded data such as taxon and bone element identification. In this way, many attributes of the site can be examined simultaneously and in many combinations. Common Pig Dig fauna such as *Archaeotherium*, *Subhyracodon*, *Mesohippus*, and *Leptomeryx* were included in this analysis by combining various recorded attributes in order to interpret their taphonomic and depositional character while inferring possible relationships with one another and their depositional environment.

ENAMEL DIFFERENTIATION IN NOTOUNGULATES

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The South American notoungulates are a very diverse mammal group existing from the Paleocene to the Pleistocene. Convergent to the Holarctic ungulates, they developed hypsodont and euhypsodont teeth with an enamel microstructure containing radial enamel and Hunter-Schreger bands (HSB).

Although only two enamel types are involved, the schmelzmusters of the different taxa show a great diversity. In contrast to most Holarctic ungulates, the schmelzmusters of some notoungulates even differ between the leading and the trailing edges, which are determined by the direction of masticational forces. Such a differentiation characterizes the rabbit-sized Hegetotheriidae. Both sides are of similar thickness. In both upper and lower molars, the leading edges are formed by radial enamel. The trailing edges are characterized by HSB being intercalated between an inner and outer layer of radial enamel. However among certain similar-sized genera of the typotheres Notopithecinae, Interatheriinae, and Mesotheriinae this differentiation could not be observed.

In the giant Toxodontinae a differentiation between leading and trailing edges was discovered in lower molars but not in the uppers. The leading edge is three layered with HSB in the middle. The trailing edge is somewhat thicker but contains only two layers: HSB as an inner layer and radial enamel as an outer layer.

Interestingly convergent evolution among the South American ungulates is not restricted to the Notoungulata. The Astrapotheria and partially the Pyrotheria developed vertical HSB

similar to the Rhinocerotidae. Therefore the South American ungulates allow the study of parallel evolution with Holarctic ungulates concerning enamel microstructure.

NEW DROMOMERYCIDS (MAMMALIA: ARTIODACTYLA) FROM THE MIDDLE MIOCENE SHARKTOOTH HILL BONEBED, CALIFORNIA, AND THE SYSTEMATICS OF THE CRANIOCERATININS

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The Sharktooth Hill Bonebed in the Round Mountain Silt, northeast of Bakersfield, California, is famous for its rich fauna of marine mammals and fish, but yields few identifiable terrestial mammals. Recent discoveries have recovered several dromomerycid skulls and jaw fragments that were originally misidentied as "*Palaeomeryx*". Although the best skull is from a juvenile (possibly female) and does not have characteristic orbital horns of adult male dromomerycids, it can be identified by its short occipital horn, dentition, and size based on comparison with the dromomerycids in the Frick Collection of the American Museum of Natural History. The new specimen is most similar to *Bouromeryx americanus,* a typical late Hemingfordian-Barstovian taxon. This new material prompted a review of the species-level taxonomy of the Dromomerycidae, which has not been updated since Frick's 1937 monograph. Most of Frick's genera are valid, but the species are grossly oversplit. Using statistical techniques, we significantly reduced the number of species in each genus. All the primitive Hemingfordian species (*marslandensis, sweeti*) and subgenera (*Probarbouromeryx, Protobarbouromeryx*) are synonymized with *Barbouromeryx trigonocorneus* (Barbour and Schultz, 1934). *Bouromeryx submilleri* from the late Hemingfordian is still distinct based on size, but all the remaining late Hemingfordian-Barstovian species (*milleri, parvus, madisonius, pawniensis, supernebrascensis, pseudonebrascensis*) are indistinguishable, and synonymized with *Bouromeryx americanus* (Douglass, 1909). Likewise, the number of species of *Cranioceras* recognized by Frick has been greatly reduced.

CRETACEOUS BIRD TRACKS FROM CHINA: THEIR ASIAN AND GLOBAL CONTEXT

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Cretaceous bird tracks are very abundant in China and other parts of east Asia. Previous reports named four distinctive bird ichnogenera (*Koreanornis, Jindongornipes, Hwangsanipes* and *Uhangriichnus*) from sites in South Korea, two (Aquatilavipes and Laiyangpus) from China and another (cf., *Aquatilavipes*) from Japan.

Cretaceous vertebrate tracksites are known from only about 17 geographic areas in China, some with multiple sites in close proximity. However, recent studies indicate that bird tracks occur at about 12 localities in Anhui, Gansu, Hebei, Laioning, Nei Mongol, Shandong and Sichuan Provinces. Thus, they are very widespread, and more or less co-extensive with vertebrate tracksites. Most Chinese tracks resemble *Aquatilavipes*, though one additional new ichnotaxon is inferred.

Although, all Asian bird tracks resemble those of modern shorebirds (Charadriiformes), the diversity implied by the existing ichnotaxonomy is credible. Elsewhere in the northern hemisphere few ichnotaxa have been named (*Ignotornis* and *Aquatilavipes* from North America, and *Archaeonithipus* from Europe). Only two ichnotaxa have been named from the southern Hemisphere (*Yacoritichnus* and *Patagonichornis*).

Whereas North American bird tracks are associated with coastal plain habitats, Asian ichnites are abundant in inland lake basin settings. Thus, distribution and diversity data raise the question of whether east Asia was a center for avian evolutionary radiation and/or a distinctive paleogeographic setting.

MORPHOLOGY, TAXONOMY AND STRATIGRAPHY OF *ALLOSAURUS* FROM THE UPPER JURASSIC MORRISON FORMATION

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Allosaurus is the most abundant and best-known late Jurassic theropod. However, the taxonomic composition of the genus has long been a subject of debate, with 16 species assigned during the past 125 years. A recent study suggests that there are only two valid species of *Allosaurus* from the Morrison Formation.

The Cleveland-Lloyd Dinosaur Quarry (CLDQ) preserves at least 47 individuals of *A. fragilis*, including a growth series ranging from juveniles (body length < 1m) to adults (body length >11 m). CLDQ thus provides unique insights relating to individual variation within the species. Most skeletal elements exhibit minor variation attributable to ontogenetic and individual differences. In contrast, certain cranial elements typically associated with sexual display and/or species recognition (specifically, the nasals and lacrimals) exhibit a surprising degree of variation. This evidence suggests intraspecific variation must be considered when establishing taxonomic boundaries on the basis of these elements.

Analysis of numerous *Allosaurus* specimens combined with CLDQ variation data support the view of only two Morrison species of *Allosaurus*, distinguishable on the basis of several characters, including the morphology of the jugal. *A. fragilis* (best represented by UUVP 6000) possesses a strongly sigmoidal ventral margin of the jugal, whereas in *A.* sp. 2 (best represented by DINO 11541 and MOR 693) the ventral jugal margin is relatively straight.

The stratigraphic distribution of *Allosaurus* specimens also supports the two species concept. *A.* sp. 2 occurs within the Salt Wash Member and lateral equivalents in the lower part of the Morrison Formation. In contrast, *A. fragilis* is restricted to the overlying Brushy Basin Member. This evidence strongly suggests that these taxa are temporally, as well as morphologically, distinct. Further study of the closely related taxa *Saurophanagax* and *Neovenator* will help determine whether an ancestor-descendant relationship exists between the two species of *Allosaurus*.

RAYMOND ALF MUSEUM OF PALEONTOLOGY: A 70-YEAR LEGACY OF FIELDWORK AND RESEARCH INVOLVING HIGH SCHOOL STUDENTS FROM THE WEBB SCHOOLS

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The Alf Museum is the only museum in the world devoted to paleontology located on a high school campus. The museum was founded by teacher Raymond Alf, who in the 1930's took Webb students in search of fossils. In 1936 they found a peccary skull in the Barstow Fm which they took to Chester Stock at Cal-Tech who described a new genus, *Dyseohyus fricki*. This discovery and a chance meeting with John Clark inspired Alf to become a paleontologist. After studying under Clark's tutelage, Alf returned to Webb and launched the Peccary Society, an innovative melding of paleontology into secondary school education where Webb students were active participants in all aspects of paleontological collecting and research.

Throughout his career Alf concentrated on recovery of fossil vertebrates and by the 1960s had amassed a large regional collection (45,000 specimens). Especially noteworthy were 700 tracks from the Avawatz, Barstow, Coconino, and other formations; the largest collection in the western US. Alf also inspired some Webb students to study vertebrate paleontology; Malcolm McKenna, David Webb, Grant Meyer, Daniel Fisher, and the late Donald Kron. In 1968 a permanent museum facility was constructed and dedicated to Alf. Two exhibit halls were opened (Hall of Life and Hall of Fossil Footprints) and a comprehensive program of public tours began. After Alf's retirement (mid 1970s), Grant Meyer directed museum operations until 1991.

In the last decade, the museum has focused on achieving AAM accreditation (1998) and revitalizing its student-based field research program in vertebrate paleontology. Current projects are centered in Utah (Kaipirowits/North Horn fms) and California (Goler and Barstow formations). With a large number of fossil vertebrates and unique collection of tracks, the Alf Museum is an important paleontological resource for education and research.

***ARCHAEOPTERYX*: TWO WINGS OR FOUR?**

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The Berlin specimen of *Archaeopteryx* displays exceptional preservation of plumage, including feathers of the hind limbs. These well developed leg feathers led to early speculation that they functioned in flight; this hypothesis is reexamined in light of four-winged dromaeosaurids from China. Pretibial, posttibial, and postfemoral feathers are preserved in the slab and counterslab; there is no evidence of metatarsal feathers. The sharp edges, overlap pattern, curved shafts and asymmetrical vanes argue that these are flight feathers, not contour feathers. Their combined area is approximately 10-15% of total airfoil area, and they may have functioned as variable geometry wings, control surfaces and/or Fowler flaps. The presence of hindwings in *Archaeopteryx* and *Microraptor* suggests that the tetrapteryx condition was probably the rule rather than the exception in basal birds. An analogous four-winged condition is seen in some neornithes (e.g. alcids, skuas, procellariformes, anseriformes) where webbed feet act as wings in slow flight. Implications for bird flight origins are discussed. The gliding hypothesis is probably not in doubt (as bats and pterosaurs appear to derive from gliders); so the questions are (1) is the cursorial hypothesis feasible, and (2) which if either hypothesis fits the fossils? The feasibility of hypotheses can be tested against modern biodiversity to some extent. Specialized parachuters and gliders evolved 16-19 times in tetrapods; the twelve extant lineages, all associated with trees, comprise >100 species. Success of gliders demonstrates the feasibility of evolving wings through arboreal parachuting and gliding, but in no case are wings known to have evolved in a cursorial context, raising doubts about whether hypothetical cursorial bird ancestors are evolvable or adaptive. The fossils are consistent with with the arboreal hypothesis: basal birds resemble gliders in possessing scansorial specializations and in abducting all appendages to participate in lift production, as in *Ptychozoon*, *Rhacophorus*, and mammalian gliders.

THE SKULL STRUCTURE OF *SINOMYLUS* (MIXODONTIA)

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Sinomylus sp. nov. is represented by skull and jaw fragments from the upper Paleocene Zhigden Member of the Naran Bulak Formation at Tsagan Khushu locality. As a result of our preliminary study of the skull structure of *Sinomylus* the following characters were noticed: (1) the premaxillary bone is extremely large with a posterodorsal part wedging between the nasal and frontal bones; (2) the foramen incisivum is long and large; (3) the lacrimal bone is limited to the anterodorsal corner of the orbit; (4) the infraorbital canal is relatively short; (5) the postorbital process of the frontal bone is rather long; (6) the zygomatic arch has vertical lateral surface and projects anteriorly further to the anterior border of the orbit; (7) the fossa for the insertion of musculus masseter lateralis and (8) the ventral process of the zygomatic arch are well developed; (9) the foramen palatinum minus is situated between the M1s and (10) the rostral border of the choanae is located at the level of the M2/M3. Character 1 is typical for lagomorphs. Characters 2 and 5-8 are shared by *Sinomylus* and Lagomorpha + Mimotonida and are not found in Rodentia. Characters 1-5 and 9-10 are shared by *Sinomylus, Rhombomylus,* and *Heomys*; characters 2, 4 and 7 are found in *Eurymylus*. This data confirms the referral of *Sinomylus* to Eurymyloidea and supports the evidence of close relationship between Eurymyloidea and Mimotonida and of the monophyly of the group Mixodontia +

Lagomorpha. We suggest including eurymyloids and mimotonids in the order Mixodontia as either suborders or superfamilies. I2/2 C0/0 P3/2-3 M3/3 is a possible initial dental condition in Mixodontia, so such characters as the presence of I3, P2 and i3 in mimotonids, P2 and i3 in *Sinomylus* and i3 in 'gomphostids' are plesiomorphic, and so is the single-layered enamel. The mimotonids gave rise to lagomorphs. A group that includes *Sinomylus* and 'gomphostids' developed parallel to mimotonids. Rhombomylidae and Eurymylidae (including *Eomylus* and *Heomys*) lost the P2 and I3 and were developing in a different direction, converging with rodents.

CLADISTIC ANALYSIS OF THE THRYONOMYID RODENTS: PRELIMINARY RESULTS

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The family Thryonomyidae is known from the Oligocene up to the present. Nowadays, this group comprises of only two closely related species, which are restricted to sub-Saharan Africa. However, various thryonomyids have been recorded in strata of Miocene age, at which time the group has spread out of Africa eastward to Pakistan.

A systematic revision proves that 19 of the species commonly referred to this family should be considered valid: *Thryonomys swinderianus*, *T. gregorianus*, *Paraphiomys pigotti*, *P. occidentalis*, *P. simonsi*, *P. hopwoodi*, *P. shipmani*, *P. australis*, *P. roessneri*, *P. afarensis*, '*P. stromeri*', *Neosciuromys africanus*, *Apodecter stromeri*, *Paraulacodus indicus*, *Paraulacodus johanesi*, *Gaudeamus aegyptius*, *Epiphiomys coryndoni*, *Kochalia geespei*, and *Sacaresia moyaeponsi*.

The result of a cladistic analysis of their relationships suggests that these species form a clade in which the most basal branch leads to *Sacaresia moyaeponsi* from the Oligocene of Baleares islands, but also in which the roughly coeval *Gaudeamus aegyptius* is closely related to *Thryonomys* spp. Additionally, it provides evidence that *Paraphiomys simonsi* should be reallocated to a new genus and motivates the following recombinations: *Apodecter shipmani*, *Apodecter roessneri*, *Apodecter australis*, *Neosciuromys afarensis*, and *Thryonomys aegyptius*.

A phylogenetic definition of the family Thryonomyidae is proposed as an outcome the phylogenetic analysis: *Sacaresia moyaeponsi*, *Thryonomys swinderianus*, their most recent common ancestor and all its descendants (node-based taxon).

EVIDENCE FOR COSTAL PNEUMATICITY IN A DIPLODOCID DINOSAUR (*SUPERSAURUS VIVIANAE*)

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Rib pneumatocoels are described from a new specimen of the diplodocid dinosaur *Supersaurus vivianae*. Previously these structures were known only from titanosauriform sauropods. Six pneumatic dorsal ribs have been excavated and attributed to the remains of a single supersaur individual in the quarry.

A pneumatic foramen is located on the anterior surface proximal to the tuberculum-capitulum juncture. This differs from *Brachiosaurus* where the foramen is located below the head on the most proximal portion of the shaft. The foramen is 51 mm in length and 18 mm at the widest point of the sub-oval opening, and 360 mm from the proximal end of the tuberculum. The pneumatocoel extends 320 mm distal and approximately 175 mm proximal from the foramen, with a maximum cavity width of 270 mm and maximum thickness of 30 mm. Both the tuberculum and capitulum are pneumaticized.

The discovery of costal rib pneumatocoels in a derived diplodocid suggests costal pneumatization evolved at least twice within sauropodomorphs. The widespread distribution of pneumatic pleurocoels within the Sauropoda suggests a developmental mechanism to account for this parallelism. Caution should therefore be taken when using costal pneumaticity as a character in phylogenetic analyses.

A NEW OVIRAPTORID DINOSAUR FROM THE LATE CRETACEOUS OF SHIXIN, NANXIONG BASIN OF GUANGDONG PROVINCE, SOUTHERN CHINA

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Southern China is the first area outside of the Gobi region where abundant derived oviraptorid dinosaurs are found. The new oviraptorid dinosaur herein reported was collected by the Beijing Natural History Museum in 1995 from the Upper Cretaceous Nanxiong Group of Luyuan of Shixin County, Nanxiong Basin of Guangdong Province. The Nanxiong Basin is near the Heyuan Basin, where *Heyuannia* was found, but stratigraphic correlation suggests that the oviraptorid-bearing red beds are younger in Nanxiong Basin than in the *Heyuannia*-bearing red beds in Heyuan Basin.

The new specimen is characterized by a relatively short preacetabular process of the ilium compared to the postacetabular process, a large height/length ratio of the ilium, and ventral margins of the preacetabular and postacetabular processes higher than the dorsal margin of the acetabulum. A unique character is the presence of a large (? pneumatic) opening (its transverse diameter is about one half of the shaft diameter) on the anterolateral surface of the proximal femur. The opening may have contained a complex of smaller foramina and bony struts, similar to that of modern birds, but these delicate struts are not visible. This opening may be the entrance for the air sac diverticula as in birds. The possible pneumatic hind limb bones in the new specimen indicate it is derived and strengthens support for the avialan adaptation of oviraptorosaurs.

CHRYSOCHAMPSA* IS *ALLOGNATHOSUCHUS

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In 1988, Richard Estes described a new genus and species of alligatoroid crocodylian, *Chrysochampsa mlynarskii*, for a specimen from the Eocene of North Dakota. The holotype of *Chrysochampsa mlynarskii* is from "Turtle Valley" below Coffin Butte in Stark County, North Dakota in the Golden Valley Formation, which also yields fossil mammals of early Eocene (Wasatchian) age. Estes diagnosed *Chrysochampsa mlynarskii* as "a taxon distinguished from all other alligatorid species except *Hispanochampsa muelleri*...in the extremely narrow interorbital portion of the frontal and from all alligatorid species by the great posterior width of the frontal with respect to the proportions of the skull as a whole." Although this diagnosis makes no specific comparison to *Allognathosuchus*, in his discussion Estes distinguished *Chrysochampsa* from "*Navajosuchus*" (=*Allognathosuchus*) and "*Wannaganosuchus*" (=*Allognathosuchus*) by their wider interorbital distance, lack of participation of the supraoccipital in the skull table, presence of at least a partial nasal septum and skull shape. He went on to state that *Chrysochampsa* lacks the broad blunt snout and the bulbous, button-like teeth characteristic of *Allognathosuchus*. He also argued that *Allognathosuchus* has perceptible protusion of the nasals into the external nares, not seen in *Chrysochampsa*, and that *Chrysochampsa* has relatively small external nares compared to *Allognathosuchus*. We are unable to replicate these differences, so we take issue with all of the differences that Estes claimed distinguish *Chrysochampsa* from *Allognathosuchus*. Close comparison with the holotype skull of *Allognathosuchus mooki* from the Paleocene of the San Juan Basin, New Mexico indicates no significant differences between *Chrysochampsa* and *Allognathosuchus*. We thus conclude that *Chrysochampsa* is a subjective junior synonym of *Allognathosuchus*, and it is likely that *A. mlynarskii* is a subjective junior synonym of *A. mooki*.

SYSTEMATICS OF THE MIDDLE EOCENE (UINTAN) PROTOCERATID *LEPTOREODON*

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The primitive protoceratid *Leptoreodon* occurs in both southern California and in the Uinta Basin of Utah. Large new collections of *Leptoreodon* have been made in the middle Eocene rocks of San Diego County, California, and allow us to re-examine the systematics of the genus. Early Uintan deposits (Friars Fm. and Uinta B) yield the type species, *L. marshi*, and the large species *L. major*. Both of these species are still apparently valid. *L. major* is slightly larger than *L. marshi*, and the anterior and posterior cingulids of the molars in *L. major* lead to greater interdental spacing between molars. Late Uintan deposits (Mission Valley, Santiago and lower Sespe Fms.) yield the diminutive *L. pusillus*, the common species *L. leptolophus* (known only from San Diego County), and *L. edwardsi* (known only from the Sespe Formation, Tapo Canyon local fauna). Large new samples of *L. leptolophus* show that it can be consistently distinguished from *L. edwardsi* by its gently curved anterior crest of p4; the crest in *L. edwardsi* is sharply inflected. *L. stocki* has also been recognized from the Sespe Fm., but is doubtfully valid. There is slight sexual dimorphism in upper canines, although the sample size of good skulls is still small. This is consistent with the pattern in many other hornless artiodactyls.

THREE ACTINOPTERYGIANS FROM THE BEAR GULCH LIMESTONE (NAMURIAN E2B, SERPUKHOVIAN), AND THE RELATIONSHIPS OF THE PLATYSOMIFORMES.

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We describe a platysomoid actinopterygian whose body form resembles, in its great depth and extended dorsal fins, *Platysomus superbus* from the Lower Carboniferous of Glencartholm, Scotland. With the exception of the slender, delicately toothed premaxilla this species seems to be edentulous in both marginal and palatal aspects. We also describe two sister species of fusiform actinopterygians that are characterized by skull bones and scales which appear to bear a cosmine-like tissue. Their dentitions are predominantly of tumid teeth borne upon coronoid and pterygoid bones, with pleurodont marginal teeth restricted to the premaxillae and anterior fractions of the maxillae. The dorsal fins feature an anterior series of closely set, unjointed, ridge-scale-like rays. Pectoral fins are supported on scaled lobes, and caudal fins are abbreviate-heterocercal. The unique combination of jaw and dental characters of this species pair agree with the dentitions of several, but not all described platysomoid fishes. The platysomoids appear to be a monophyletic group but, as remarked upon by previous authors, they contain a heterogeneous assortment of adaptations.

SUCCESSIVE DIVERSIFICATION OF MESOZOIC MAMMAL CLADES AND ACCUMULATIVE EVOLUTION OF THEIR ANATOMICAL APOMORPHIES

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Two major patterns of temporal and anatomical evolution can be recognized for the Mesozoic mammal clades on the currently available morphological evidence. This assessment on evolutionary patterns is based on a hypothesis of phylogeny supported by a parsimony analysis of 310 osteological and dental characters of 58 taxa of Mesozoic mammals, plus 12 lineages of nonmammalian mammaliaforms and cynodonts. The taxic and temporal macroevolution of the Mesozoic mammals is characterized by seven successive episodes of diversification. (1) Late Triassic divergence of basal mammaliaforms. (2) Early Jurassic divergence of docodontans (if including *Woutersia*) and *Hadrocodium* from the crown mammalian clade. (3) Middle Jurassic splits of shuotheriids, australosphenidans (including monotremes),

eutriconodontans within the mammalian crown group. (4) Late Jurassic diversification of multituberculates, triconodontids, spalacotheriids, dryolestoids, and peramurids. (5) Early Cretaceous diversification of stem boreosphenidans, metatherians, and eutherians. (6) Early Cretaceous divergence of toothed monotremes from stem australosphenidans. (7) Late Cretaceous diversification of stem eutherians (possibly some placental superorders), and stem metatherians.

If mapped on the current phylogeny of Mesozoic mammals, the anatomical evolution from the stem mammaliaforms to crown mammals is characterized by a stepwise, incremental accumulation of apomorphies in the successively derived ranks of phylogeny toward the extant monotremes, and toward placentals and marsupials. This pattern is manifest in the evolution of dental characters, as optimized on the tree. It also holds true for the overall morphological evolution if all dental, cranial, mandibular and postcranial characters are combined in an analysis of total morphological evidence. If calibrated by stratigraphic records, tempo and rate of morphological evolution in Mesozoic mammals show a relatively even pace, which corresponds well with the successive episodes of taxic diversification, and is consistent with the well-recognized pattern of incremental evolution in nonmammalian synapsids.

NEW SKIN STRUCTURES FROM A JUVENILE EDMONTOSAURUS FROM THE LATE CRETACEOUS OF NORTH DAKOTA

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A site in Slope County, North Dakota has produced over 40 well preserved skin fragments as well as cranial and post cranial elements that identify it as a juvenile specimen of *Edmontosaurus annectens*. Among the impressions are tuberculate scales that range from 1 to 5 mm in diameter and are consistent with previously reported skin impressions. However, this specimen has produced six types of skin structures not previously described and include overlapping capped ovoid structures, a 9 cm by 10 cm trapezoidal horn-like structure, and grooved scales all recovered from the caudal section of this specimen. Further investigation and preparation of the specimens will reveal new insights to this unique individual.

VIRTUAL PTEROSAURS: THE USE OF LASER SCANNING EQUIPMENT AND 3-D ANIMATION SOFTWARE FOR EXHIBITION AND RESEARCH

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In the growing age of technology, museums and other research institutions are investigating the uses of virtual images in the study and preservation of their objects. In the realm of paleontology, accurate virtual models provide a noninvasive method for posture and range of motion studies, particularly important in the case of mounted skeletons that cannot be disarticulated for study. Digitized skeletal detail is more accurate than drawings produced by hand and the generation of flesh-outs is easier and more precise than with traditional methods.

Although there are a growing number of methods available for digitization, many of the most common techniques are not cost effective for small museums, such as CT scans, or are potentially injurious to the subjects, such as digitizers that require a stylus to trace the object's surface. In an effort to produce a cost effective and time saving model, hardware and software was utilized that promised to enhance output while shortening production time. Point cloud data from several specimens, including *Quetzalcoatlus* and *Anhanguera*, were captured with a surface laser scanner and then converted into three-dimensional polygonal meshes and NURBS models for importation into a modeling and animation program. Range-of-motion limits were set as constraints within the inverse kinematic (IK) chain of the model, allowing real-time manipulation of the model and precise locomotion studies. The finished model then can be animated and recorded on CD, DVD, or VHS tape for exhibition.

While the technique offers a promising alternative to traditional methods of biomechanical research, one must consider the size limitations of the equipment, access to hardware and software, and the learning curve before selecting the method appropriate to the project. In the end, this technology affords the opportunity for attractive in-house exhibits, specific to institutional research, and free of the constraints imposed by commercially available animation sequences.

MIDDLE MIOCENE LAND MAMMALS FROM PANAMA: EVIDENCE FOR THE AGE OF THE NEOTROPICAL RAINFOREST

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Middle Miocene land mammals referred to the Gaillard Cut Local Fauna are based principally on a collection made by Stewart and Whitmore in the 1960's from Cucaracha Reach, Panama Canal Zone, Republic of Panama. In addition to the Order Rodentia described elsewhere, these land mammals represent three orders (Carnivora, Artiodactyla, Perissodactyla), currently identified as the canid *Tomarctus brevirostris*, Amphicyonidae or Hemicyonidae, oreodont *Merycochoerus matthewi*, protoceratid *Paratoceras wardi*, horses *Anchitherium clarencei* and *Archaeohippus* sp., and rhinocerotids *Menoceras barbouri* and *Floridaceras whitei*. Despite its close proximity to South America, all of the taxa represented in the Gaillard Cut L. F. are of distinctly North American faunal affinities. Given the biochronology of the Cucaracha mammals as they are known from North America, the age of this assemblage is either Hemingfordian or early Barstovian, i.e., within the range from about 19 to 16 Ma. The field relationships indicate a collection from a narrow stratigraphic horizon, i.e., there does not appear to be temporal mixing from different land mammal ages. Accordingly, the Hemingfordian taxa in the Gaillard Cut L. F. are interpreted to represent relictual taxa. The apparent predominance of low crowned herbivores is interpreted to represent forested habitats. Likewise, new carbon isotopic data from herbivore tooth enamel with relatively depleted $\delta^{13}C$ values (as negative as about -16 per mil), approach values found in extant herbivores living in closed canopy rainforest. In conjunction with previous paleobotanical data for the Cucaracha Formation, the data reported here indicate that during the middle Miocene, tropical rainforests existed in what is now Panama.

THE LOMOTOR REPERTOIRE OF PAKICETID CETACEANS: COMBINED EVIDENCE OF GROSS MORPHOLOGY AND SKELETAL ULTRASTRUCTURE.

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A large assemblage of postcranial remains of the earliest fossil whales, the Pakicetidae, has recently been described. These postcranial remains are notable in what they are not—they bear surprisingly few if any anatomic features associated with aquatic locomotion that one would expect in a whale ancestor. Pakicetid limbs are long and gracile, proportionally akin to similar sized cursorial mammals. However, detailed examination of these bones indicates that some long bone diaphyses are osteosclerotic, possessing shafts that are filled with compact bone. Such increased bone density has already been documented in a wide array of extant semi-aquatic and aquatic mammals, marine tetrapods, and all other archaic cetacean families. These ultrastructural changes have been considered to function as ballast—a means of buoyancy control in semi-aquatic taxa. We compare the anatomic and ultrastructural features of pakicetid postcrania to a range of mustelid and ungulate taxa that are known to make substantive use of aquatic substrates, but are not typically considered semi-aquatic (eg., tapir, mink, weasel, chevrotain, water deer). The combination in pakicetids of a primitive gross morphology linked to a cursorial use of the long bones, with bone density consistent with an aquatic niche use suggests that these cetaceans were indeed amphibious. However, rather than swimming, wading likely formed their predominant locomotor mode in water, with interesting implications for the niche of the earliest whales.

THE MORPHOLOGY AND EVOLUTION OF THE TERMINAL PHALANGES IN PALEOZOIC NON-THERAPSID SYNAPSIDS

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Terminal phalanges of non-therapsid synapsids exhibit a certain range of morphological variation within a certain framework of structural design, consistent with the presence of a keratinous sheath. All are characterized by an acuminate outline with varying levels of dorsal and ventral curvature, and the presence of a ventral flexor tubercle. However, the overall shape ranges from flat and broad to sleek and pointed, and there is significant variation in amount of curvature, the dimensions of the surfaces, and the position of the flexor tubercle along the ventral surface. Two functional relationships, one for flexion force and another for pressure, were used to test the hypothesis that there is correlation between basal synapsid phylogeny and the evolution of optimal claw morphology. For the eupelycosaurian genera *Varanops*, *Edaphosaurus*, *Haptodus*, and *Dimetrodon*, there is evidence for gradual improvement of the in-force to out-force (I_i:I_o) lever arm length ratio through an increase in curvature to shorten I_o, and a more distal placement of the flexor tubercle to lengthen I_i. The flexor tubercle also becomes more ventrally pronounced from *Varanops* to *Dimetrodon*. The pressure relationship is improved by decreasing the surface area of the claw in contact with the substrate. The edges of the claw become sharper, the tip becomes more pointed, and the ventral surface narrows down to a keel from *Varanops* to *Dimetrodon*. The claws of the caseasaur *Casea* did not fit this pattern. The ventral surface was flatter and broader than in *Varanops*, but there was a better I_i:I_o ratio due to the position of the flexor tubercle, comparable to that of *Edaphosaurus*. This suggests that the morphology of the terminal phalanges of *Casea* is autapomorphic, possibly associated with its herbivorous lifestyle.

COMPARING PHYLOGENIES: SIMULATION PERSPECTIVE

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A central issue in the field of paleontology is the role of the fossil record in phylogenetic studies: how fossils are used in creating phylogenies, and how they are incorporated into phylogenetic analyses. Debate revolves around the recognition that phylogenetic trees based on cladistics (or any other methodology) provide inferred rather then absolute relationships among the taxa, and the idea that fossils by themselves tend to give us incomplete datasets as compared to extant taxa.

Here we report our findings pertaining to this debate based on a simple phylogenetic simulation with two parts. First, a known phylogenetic tree is created by a simple evolutionary model. We render macroevolution as changes in character states, or acquisition of novelties, over discrete time units. In a given time interval, a taxon can be in stasis, change state(s) for existing character(s), acquire a new character, speciate (by duplicating itself), or go extinct. Based on the initial parameters of the simulation, this creates anywhere between 50-1000 taxa and 50-500 characters, along with the actual ancestor-descendant relationship. Each character is randomly assigned to be scorable both on extinct and extant forms (type I) or scorable just on extant taxa (type II). On the large scale this gives equal representation of each type.

As the second step, four subsets are extracted: (1) Type I and type II characters for all extant species, (2) Type I for all extant species, (3) Type I for all extant species and random 5% of extinct forms, (4) Type I for all extant species and random 50% of extinct forms. Included extinct taxa are sampled by uniform probability. The four subsets are heuristically searched for the shortest tree length. Finally, these trees are compared to the known phylogeny using the Robinson-Foulds method.

REPORT OF NEW CENOMANIAN HADROSAUR (DINOSAURIA: ORNITHISCHIA) POSTCRANIA FROM THE WOODBINE FORMATION OF NORTH CENTRAL TEXAS.

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New postcranial hadrosaur (Dinosauria:Ornithischia) material has been recovered from the Upper Cretaceous (Cenomanian) rocks of the Woodbine Formation in north central Texas. This is the first detailed documentation of hadrosaur postcrania from the Cenomanian of North America. The postcranial material was collected from Woodbine Formation exposures that occur along the shores of Lake Grapevine; southern Denton County, Texas. The material is diagnosed as hadrosaur based upon relative size and morphology, and includes a cervical centrum, a proximal radius, a metacarpal, a femoral condyle, a proximal fibula, a complete tibia and fibula, and caudal centra. This hadrosaur postcranial material is of relatively good preservation, the cervical vertebra is of unusually exceptional preservation for the Woodbine Formation.

The vertebrate faunas of the Woodbine Formation have been reported from the exposures near Dallas-Fort Worth International Airport and Lake Grapevine, Texas. Dinosaurs are documented within the Cretaceous rocks of north central Texas, however many questions remain about these enigmatic animals; as well preserved fossil material is rare in occurrence. The new hadrosaur material recovered from the Woodbine Formation exposures at Lake Grapevine expands what is known of the postcranial morphology of Cenomanian hadrosaurs in North America.

BONE STRAIN IN THE GOAT RADIUS THROUGHOUT ONTOGENY: HOW *IN VIVO* BONE STRAINS RELATE TO BONE GEOMETRY AND TISSUE MICROSTRUCTURE

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For years researchers have examined how the skeletal system accommodates the large size range seen among extant and extinct tetrapods. However, most of these studies have only been concerned with interspecific comparisons. Consequently, little work has examined intraspecific or ontogenetic changes in the skeleton as an animal increases in size and mass with age.

The goal of the present study was to examine how *in vivo* bone strain magnitudes and cross-sectional strain distributions compare across different age groups within a species and how these strain patterns reflect the ontogenetic changes in bone geometry and tissue structure. We obtained *in vivo* bone strain measurements from the cranial, caudal, and medial surfaces of the radial midshaft of young goats at two different ages (4 and 13 wks) over a range of speeds and gaits and compared these with previously published data for adult goats. Strain magnitudes were greater in the radii of adult goats at all gaits despite similar ontogenetic limb loading, suggesting possible differences in bone geometry and/or bone tissue properties among the different age classes. Negative allometric scaling of the midshaft cross-sectional area as well as cranio-caudal and medio-lateral second moments of area likely account for the ontogenetic differences observed in strain magnitude.

To examine the relationship between *in vivo* bone strains and such histological features as bone tissue type, periosteal growth rate, bone porosity, and Haversian system density, the experimentally determined cross-sectional strain distributions were mapped on to histological thin sections. The degree of correlation between the distribution of longitudinal compressive and tensile strains and the above histological features was examined. By measuring these relationships through ontogeny, we determined how the bone tissue responded during growth to the changing mechanical demands placed upon it. Such a relationship between mechanical environment and bone tissue modeling/remodeling has important implications for biomechanical hypotheses concerning fossil species based upon paleohistology.

TELLING TIME FROM FOSSILS: A PHYLOGENETIC APPROACH TO ORDERING BIOTAS THROUGH TIME

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Deriving temporal order from evolutionary relationships has been a topic of much interest to paleontologists. To date, however, most attempts at such analyses have resorted to 'stage of evolution' arguments that suffer from a number of theoretical inconsistencies and/or circular reasoning. A cladistic approach for determining biochronologic order between paleobiotas, based on the phylogenetic relationships of their constituent taxa, is presented and termed Cladistic Biochronologic Analysis (CBA). CBA, which is adapted from vicariance biogeography, analyzes syntaxon information from clades that transcend a number of paleobiotas to determine relative temporal order among these paleobiotas. Its utility is demonstrated on two examples from the Cenozoic fossil record of North America, which differ in spatiotemporal scale. The method successfully recovers correct temporal order between paleobiotas in these examples. CBA is sensitive to large amounts of extinction and poor sampling of the fossil record, however, and sources of error and potential controls for these will be presented. CBA offers a novel approach for biochronologic analysis that is independent of, but combinable with, traditional stratigraphic methods.

LATE PALEOCENE ELASMOBRANCHII FROM THE BASE OF SEROV FORMATION IN WESTERN PART OF THE WEST-SIBERIAN PLATE

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In the area of Transurals (western part of the west Siberian Plate) we studied in detail a various and abundant new association of elasmobranchian fossil remains (Chondrichthyes: Elasmobranchii). There is the first record of the Thanetian elasmobranchians remains in the Middle Transurals territory.

The deposit which contained the shark remains consists of clay with the gravel-pebble beds. It lies in the base of the Serov Formation and also contains an association of the dinoflagellate *Alisocysta margarita* Zone. It allows us to date this deposit as early Thanetian in age, NP8 (*Heliolithus riedelii* Zone).

The elasmobranchian association includes more than 20 shark and ray species: *Notidanodon loozi* Vincent, *Heterodontus lerichei* Casier, *Megasqualus orpiensis* (Winkler), *Jaekelotodus* sp., *Paleohypotodus rutoti* (Winkler), *Striatolamia striata* (Winkler), *Odontaspis winkleri* Leriche, *Isurolamna inflata* (Agassiz), *Otodus obliquus* Agassiz, *Cretalamna appendiculata* (Agassiz), *Dasyatis vochadunensis* Ward, *Pachygaleus lefevrei* (Daimeries), *Triakis antunesi* Noubhani et Cappetta, *Paleogaleus vincenti* (Daimeries), *Khouribgaleus gomphorhiza* (Arambourg), *Synechodus faxensis* Davis, *Synechodus* sp., *Paraorthacodus eocaenus* (Leriche), *Burnhamia davisieri* Woodward, *Myliobatis* sp.

A NEW *XENOROPHUS*-LIKE ODONTOCETE FROM THE CHANDLER BRIDGE FORMATION OF SOUTH CAROLINA

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We report a new species of odontocete from the upper Oligocene, Chandler Bridge Formation. This new specimen (GSM 1098) was found near Summerville, SC, and includes a nearly complete skull, most of the mandible, and the atlas vertebra. Four odontocetes were compared to GSM 1098: *Xenorophus sloanii*,*Agorophius pygmaeus*, *Archaeodelphis patrius*, and *Simocetus rayi*. Of the four, *Xenorophus* is the most closely related to GSM 1098 because both have a large lacrimal exposure in dorsal view, and the premaxilla extends under the supraorbital part of the maxilla. *Xenorophus* has a much broader rostrum and braincase than GSM 1098, and the premaxilla gets narrower posterior to the nasal opening in *Xenorophus*, while in GSM 1098 the premaxilla stays the same width. In *Agorophius*, the supraoccipital extends anteriorly on top of the braincase, which makes it more in dorsal view, whereas the supraoccipital in GSM 1098 is nearly vertical and extends beyond and slightly overhangs the parietals. In *Simocetus*, the rostrum dramatically tapers anteriorly unlike GSM 1098, which has a narrow rostrum that does not change much in width. The vomer of *Simocetus* is very wide, also true for *Agorophius*, and the mesorostral gutter is open dorsally. In contrast, the vomer in GSM 1098 is narrow and the gutter is covered by the premaxillae. In *Archaeodelphus*, the exoccipital is almost the same height as the nasal, which makes the braincase much flatter than the braincase of GSM 1098. With the possible exception of *Waipatia maerewhenua*, GSM 1098 is the earliest record of cranial asymmetry in odontocetes. The asymmetry occurs on the premaxillae anterior to the nasal opening. The left side is shifted posteriorly, and the right side is 130% the width of the left side.

PHYLETIC EVOLUTION IN *OGMODONTOMYS* (RODENTIA:ARVICOLIDAE) FIRST LOWER MOLARS FROM THE MEADE BASIN OF SOUTHWESTERN KANSAS

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Thirteen characters and four indices from six stratigraphically superposed samples of *Ogmodontomys* first lower molars (m1's) from the Meade Basin of southwestern Kansas, spanning an interval of approximately 1.8 million years of the early and middle Pliocene, were measured and analyzed by a variety of statistical techniques. The relative height of the linea sinuosa (crown-root junction) and proportion of enamel atolls on the m1 were also recorded. This information, in concert with previous studies of the schmelzmuster (microhistological enamel banding pattern), shows that a mosaic response in m1 size and shape dominated during the study period. No characters exhibited continual stasis, although extended periods of stasis were noted for some features. The most pronounced morphological changes occurred between the Fallen Angel B and Fox Canyon local faunas, but the most substantial size change (48% when translated to body mass) occurred later, between Fox Canyon and Ripley B. Differences in morphological evolutionary trajectories expressed by samples below the Bishop gravel from samples near the top and above the gravel are interpreted to imply local extirpation of the earlier populations and immigration of later populations. We do not have enough information to determine if the older populations evolved into the later ones or were replaced by a different species; thus the names *O. sawrockensis* and *O. poaphagus* are retained. These results and other information from the Meade Basin rodent database do not support the concepts of punctuated equilibrium or coordinated stasis for our study system.

THE FIRST DIDELPHID MARSUPIAL (MAMMALIA) FROM EUROPE AND ITS SIGNIFICANCE CONCERNING LATE CRETACEOUS BIOGEOGRAPHY

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The first unequivocal record of a Late Cretaceous marsupial from Europe occurs in the type area of the Maastrichtian Stage (southeast Netherlands). An upper molar represents a new genus and species of small didelphid marsupial, occurring nearly 10 million years before marsupials become common in the European Eocene. The specimen occurs in the fossil hash overlying the Lichtenberg Horizon at the base of the Valkenburg Member of the Maastricht Formation (late Maastrichtian, *Belemnitella junior* Cephalopod Zone, ca. 66 Ma) at the base of a transgressive system tract following a thick interval representing a low stand system tract. Surprisingly, the Maastricht didelphid exhibits affinities with North American didelphids, *sensu stricto*, which first appear in the early Maastrichtian Fox Hills Formation of South Dakota. Previously known occurrences of Maastrichtian hadrosaurid dinosaurs, boid snakes, and fragmentary marsupials in Europe suggested a North Atlantic dispersal route with North

America during the Late Cretaceous, and the Maastricht didelphid provides definitive evidence. Paleoclimatic evidence of high-latitude warming and paleogeographic evidence of lower sea level support this dispersal route.

THE IMPORTANCE OF FATIGUE FAILURE IN THE EVOLUTION OF BONE REMODELING

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The success of the calcified skeleton as an evolutionary innovation is obvious, but this organ system also has limitations that have strongly influenced bone biology. One of these limitations derives from the fact that bone is twice as heavy as most other tissues, so that it is advantageous for vertebrates to minimize their bone mass. For allometric reasons, this problem is more severe in larger vertebrates. Another limitation arises from the fact that rigid materials such as bone are subject to fatigue failure—the gradual development of microscopic damage due to load-bearing stresses. Given enough time and loading, such microdamage will accumulate to the point of fracture. A fundamental problem for vertebrates has been the fact that reducing the weight of their skeletons would necessitate increasing the stresses within them, thereby decreasing their maximum fatigue life. This problem was compounded by the little-appreciated fact that, for a given stress, the fatigue strength of any structure is inversely proportional to its volume. Again, species must pay a price for larger bones. This paper explores the implications of these physical principles with respect to vertebrate evolution. It is now known that fatigue damage in bone is one of the principal initiators of bone remodeling, the process by which cells continuously remove and replace small volumes of bone tissue. It is argued here that bone remodeling to remove fatigue damage was an essential biological innovation for the evolution of relatively large, long-lived vertebrates.

FUNCTIONAL MORPHOLOGY AND EVOLUTION OF DOCODONT MOLARS (MAMMALIA) FROM THE MIDDLE JURASSIC OF JUNGGAR BASIN (NW CHINA)

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Field work in the Middle Jurassic (Callovian) Toutunhe Formation southwest of Urumqi in the Junggar Basin (NW China) has yielded dental remains of a new docodont. The lower molars are characterized by an enlarged anterior basin ("pseudo-talonid"), retention of crest b-g, and reduction of cusp e. Correspondingly, a large "pseudo-protocone" (cusp X of Butler´s terminology) is developed in the upper molars. In these "pseudo-tribosphenic" docodont molars a grinding and crushing function is added to the shearing and cutting.

Epoxy casts of an upper and a lower molar were brought to occlusion with the aid of a micro-manipulator and moved towards each other. The stages of mastication were recorded and in the resulting movie the function of the cusps and cutting edges as well as the development of wear facets could be observed directly. During occlusion cusp b of the lower molar fits into the "pseudo-trigon basin" of the upper molar compressing and crushing the food. In the following stage cusp X of the upper molar moves along a transverse valley, formed by crests b-g and b-e at the anterior side of the lower molar, grinding the food items.

Phylogenetic analysis revealed three clades representing two ecological types. The Asian docodonts *Tegotherium, Siberotherium*, and a not yet formally named taxon from the Middle Jurassic (Callovian) of Kyrgyzstan are characterized by the development of an enlarged anterior basin ("pseudo-talonid") and reduction or loss of crest b-g. The Euroamerican taxa *Borealestes, Haldanodon*, and *Docodon* develop two crushing basins in the lower molars. The anterior basin is not enlarged and crest b-g is retained. Their sister-group is formed by the new Chinese docodont and *Simpsonodon*. At the lower molars, the anterior basin is enlarged ("pseudo-talonid"), crest b-g is retained, and cusp e is reduced. The posterior region of the lower molars is covered by complex enamel foldings that enhance the grinding function. They possibly indicate a specialization to masticate tough plant material in addition to turgor-stabilized food like invertebrates or fruits.

TWO NEW AETOSAURS (ARCHOSAURIA, STAGONOLEPIDIDAE) FROM THE UPPER TRIASSIC OF TEXAS AND COLORADO, AND PROBLEMS IN AETOSAUR IDENTIFICATION AND TAXONOMY

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Two new aetosaurs are described from the Upper Triassic of the Dockum Group of Texas and the Chinle Formation of Colorado. The scutes of "New Taxon A" from the Tecovas Formation of Texas show a combination of traits seen in *Typothorax*, *Paratypothorax*, *Stagonolepis*, and *Aetosaurus*. The dorsal paramedians are very wide and have ornamentation with deep pits and fainter radiating grooves, a ridge-like dorsal boss, a ventral strut, and a beveled posterior edge which is strongly thickened. The laterals resemble *Paratypothorax*.

"New Taxon B" is known from the Cooper Canyon Formation of Texas and the Chinle Formation of Colorado. The dorsal paramedians are almost identical to *Paratypothorax*, except that they are not as wide, lack posterior beveling, and have a tab along the posterior edge. However, the laterals have a large horn and plate-like dorsal flange more similar to *Desmatosuchus*. The ventral flange of the lateral scutes are unusual in being highly reduced.

These taxa bear key similarities to other aetosaurs, which questions the validity of identifying isolated and incomplete scutes. Partial scutes from these new taxa might be mistaken for other aetosaurs due to the low number of diagnostic traits used to identify them. Aetosaur scute diversity is poorly understood and probably underestimated, and caution should be taken in assigning scutes to a taxon unless there are many nearly complete scutes from a single individual. As a result of these blurred similarities between scute-based aetosaur taxa, it is also hard to justify assigning even a well represented new species to any particular pre-existing genus. Splitting at the genus level is almost mandated without a better understanding of aetosaur skeletal morphology.

LARGE-SCALE TRANSFER PREPARATION

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Fossil specimens that have undergone weathering often require special treatment to preserve the original position of what are now disconnected portions of bone. Transfer preparation is a technique that can preserve the original arrangement of fragmentary bones or the relations between multiple bones. Using this preparation technique, fossils can be transferred from their original matrix to a stable base such as epoxy. Many small sized fossils have been successfully prepared this way. A partially weathered sauropod vertebral column preserved in unstable matrix was prepared with this method.

MECHANICAL TO CHEMICAL: THE FINAL PREPARATION OF A DICYNODONT FROM THE KINGORI SANDSTONE USING MICROSCRIBES AND DIMETHYL SULFOXIDE

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During an extended preparation process on difficult matrices, the preparator finds new and old tricks for extracting bone from rock. Often a combination of techniques in a particular sequence works better than any one technique used independently. After the preliminary study of a fossil, color-coding with pencils can be helpful for designating the sequence of areas to be worked. On a long-term project, rotation of tasks keeps the worker fresh and alert for new discoveries. Use of dimethyl sulfoxide during the last stages of preparation can soften hard matrix and preserve fine surface detail.

GASTRIC CONTENTS OF A JURASSIC ICHTHYOSAUR

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A specimen of *Baptanodon* (=*Ophthalmosaurus*) was discovered with carbonaceous material preserved with the skeleton. The specimen is from below the lower *Camptonectes* bed in the Redwater Shale member (Oxfordian) of the Sundance Formation, Natrona County, WY. The specimen (UW 34653) is comprised of articulated vertebrae, numerous ribs, parts of two limbs (one partially articulated), and as yet unidentified bone that is within the concretion. A portion of the gastric mass is visible between the left and right ribs within one of the concretion blocks. The remainder was recovered from the lower portion of a badly fractured adjacent block and the underlying soil. The friable, low density mass appears to be from the central or posterior torso. It consists of fractured cephalopod hooklets and fragments of hooklets, loosely cemented by calcite crystals. The hooklets crumble if removed from the matrix, but several different shapes have been identified from intact masses. The contents are comparable to what has been found in ichthyosaurs from the Lower Jurassic of England and Germany. The slender, pointed, conical teeth found in another *Baptanodon* specimen (UW 24216) from a nearby outcrop of the Redwater Shale, would be well suited for a diet of soft cephalopods.

A PROPOSED SYSTEM FOR RECORDING THE POSITION OF SKELETAL REMAINS USING MORPHOLOGICAL LANDMARKS

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There is a lack of a consistent methodology for recording fossil orientations. Therefore, I propose a systematic method for recording the 3D orientation of mammalian skeletons or skeletal elements prior to removal from the matrix. By identifying diagnostic morphological landmarks for every element, a field manual may be compiled and used worldwide, establishing consistencies among comparisons. The morphological data will be collected using a total station and a data collector that are capable of millimeter accuracy, dependent on the skill of the user.

The proposed system will use three to six morphological landmarks per specimen that can be compiled into a field manual. This field manual will contain photographs identifying the landmarks for each skeletal element; allowing the user to quickly identify points in the field for consistent location of fossils. The fossils are located by using a land surveyor's total station and a data collector. This information can then be easily converted to Geographic Information Systems (GIS). This manual provides a consistent means for recording spatial orientation of fossils.

CAUGHT IN DANTE'S INFERNO—STUDYING DINOSAUR TRACKS NEAR THIS SIDE OF HELL QUARRY, WYOMING

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During the summer of 2001, dinosaur tracks were discovered in Elk Basin, Wyoming. The track-bearing horizon occurs in the Upper Cretaceous Meeteetse Formation on the western limb of the Elk Basin Anticline. Outcrops occur in an arcuate belt approximately 12 km long offset by regional faulting. Dante's Tracksite is located approximately 31 km northeast of Powell, Wyoming (near the This Side of Hell Quarry) on public land administrated by the BLM. This is the first reported dinosaur tracksite from the Meeteetse Formation of Wyoming. Since its discovery, nearly 300 dinosaur footprints have been documented in a well-indurated, heavily bioturbated, fine-grained sandstone. Tracks are preserved as casts and molds in a key bed at the top of the Meeteetse Formation. Invertebrate traces associated with the dinosaur footprints include possible sea anemone resting traces, suggesting a nearshore marginal

marine environment with anastomosing channels, mudflats, lagoons and tidal flats. Track morphologies consist of two distinct types of tridactyl prints, those with theropod and those with ornithopod affinities. Research on these newly discovered dinosaur tracks may lead to new interpretations of the ecology and regional depositional environment during the Campanian of northwestern Wyoming. Extensive close-range photogrammetry was conducted during the summer of 2003 using a 35-mm, tripod-based camera and low-level photography from an aerial camera blimp system (ACBS). In addition, preexisting imagery includes large-format aerial photography captured at a variety of scales. The ACBS consists of a 6 meter-long, helium-filled blimp capable of lifting an on-board camera to 76 m above the ground. Photomosaics created from ACBS are used to document locations of the tracks, to analyze trackway trends, and to establish a baseline for future study. As work continues in Wyoming's ichnology-rich Bighorn Basin, state-of-the-art technologies are being utilized to document these previously unknown tracks and tracksites.

CONFIRMATION OF THE SLOTH GENUS *MEGALONYX* (XENARTHRA: MAMMALIA) FROM THE JOHN DAY REGION AND ITS IMPLICATIONS

McAFEE, Robert, Northern Illinois University, De Kalb, IL.

Previous findings of xenarthrans in the John Day Basin have consisted of miscellaneous ungual phalanges, predominantly from the Rattlesnake Formation (late Miocene, 8-6 Ma) and one dubious record from the upper Mascall Formation (middle Miocene, 12 Ma). At best, they have all been safely identified as belonging to the sloth family Megalonychidae. New findings, including a previously unpublished claw and a partial left mandible, finally allow for specimen identification to the genus *Megalonyx*. There are currently two recognized *Megalonyx* species of Hemphillian age (8.5-4.5 Ma), *M. curvidens* and *M. mathisi*. Both species are known from scant records from more southerly locations and with few diagnostic characters. Further analysis and identification of the new material will provide additional diagnostic data for one species or will produce evidence that both species are synonymous. These finds also allow for the previous sloth specimens to be designated as *Megalonyx* and for improved assignment of the material to stratigraphic units.

A NEW INTERPRETATION FOR A CLASSICAL LOCALITY: FOSSIL LAKE, OREGON

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In contrast to the conventional interpretation of the fossiliferous units as lake beds representing various high and low lake levels of pluvial Fort Rock Lake, a volcanic maar is proposed as the primary mechanism that controlled accumulation and preservation of the fossils at Fossil Lake, Oregon. The paleoecology was strongly influenced by the topographic expression, both positive and negative, of the maar. This interpretation offers the promise of resolving the heretofore intractable problem of determining the age of the fossils. A new and extensive collection from the locality has been made by the South Dakota School of Mines and Technology Museum of Geology in which virtually all specimens are tied to a set of lithologically distinct units. Geologic, taphonomic and taxonomic studies of avian specimens from the collection are used in comparing these two different hypotheses for accumulation and preservation of this unique assemblage. Geologic evidence strongly supports the new interpretation, but evidence from the fossils is equivocal and study is ongoing. Further data collection, *e.g.*, field mapping and quantitative collecting methods will be valuable in testing this new hypothesis

MAMMAL AND REPTILE TRACKS FROM THE UPPER PALEOCENE OF ALBERTA

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Two vertebrate trackways are known from the Paleocene of Alberta, and they come from two separate localities. These vertebrate trackways are the only ones found to date from the Paleocene of western Canada and are among the very few Paleocene vertebrate trackways known worldwide.

The trackway of a medium-sized quadruped consists of five prints (three pes, two manus) on a fallen natural cast block that was found along the Red Deer River, near the town of Red Deer, Alberta in 1927 (UALVP 134). The discoverers (Loris S. Russell and Ralph Rutherford) identified the source of the track block as the Paskapoo Formation (upper Paleocene: middle Tiffanian). The trackway was attributed to a mammalian track-maker in two subsequent publications. Recent studies, however, reveal that the prints are more characteristic of a carnivorous reptilian track-maker such as a crocodilian.

A second track-bearing natural cast block (TMP 90.131.01) from a locality on Signal Hill in the city of Calgary was discovered during the preparation of a new residential sub-division in 1990. The large trackslab was discovered in a rock pile, but the block is suspected to have originated from strata belonging to the Porcupine Hills Formation (upper Paleocene: late Torrejonian), which was being excavated at the time. The slab displays the trackway of a quadruped progressing across a mud-cracked surface. The trackway is composed of eleven prints (six pes, five manus) with the pes prints overprinting the manus prints (primary overlap) in all cases. The footprints have many mammalian characteristics and appear to be those of a predatory animal.

USING SYNTHETIC MAPPING DATA TO ANALYZE A HYPOTHESIZED ORELLAN CARNIVORE DEN IN BADLANDS NATIONAL PARK, SOUTH DAKOTA

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Within the lower Scenic Member of the Oligocene Brule Formation in Badlands National Park lies an incredible and laterally extensive bone bed with the name of its founder, The Brian Maebius Site (SDSM Locality Number V-9626). The locality's high fossil density, faunal diversity, age demography, and taphonomy have contributed to previous interpretation of the site as representing carnivore denning activity. The site was revisited during the summer of 2002 as part of a joint salvage expedition between the National Park Service and the South Dakota School of Mines and Technology. The project included fossil collecting and mapping using a combination of detailed hand-drawn grid maps and electronic total station measurements. Due to time constraints, only those fossils that were either taxonomically diagnostic or relatively complete were mapped using the Pentax Total Station (PTS) surveyor's transit and drawn into conventional maps. The remaining fossils were mapped using detailed hand drawings that corresponded to an extensive grid system.

In order to examine possible patterns in the distribution of the fossils that may support or contradict the hypothesis of carnivore denning, the PTS data were entered into ArcView, ArcGIS, and 3D Analyst GIS programs and analyzed in three dimensions. A detailed master map composed of all the hand-drawn site maps was produced and included in the analysis as a visual reference for all of the electronically documented fossils so that each specimen could be viewed within a spatial context. Coupled with the reanalysis of specimens collected prior to 2002, the newly collected specimens have a moderate number of specimens exhibiting carnivore bone modification. However, no sedimentary structures were observed to suggest a possible den site and many of the bones recovered within discrete 'pods' or lenses were complete with no evidence of scavenging. Preliminary analysis of the combined data from the 2002 expedition does not support the hypothesis of a carnivore denning area to the exclusion of other depositional scenarios, although some fossil specimens remain unprepared and further analysis is pending.

THE EVOLUTION AND COMPARATIVE FUNCTIONAL MORPHOLOGY OF FILTER-FEEDING IN THE MYSTICETI (MAMMALIA: CETACEA)

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Mysticetes have evolved a highly specialized mode of feeding. There are three modes of filter-feeding in modern taxa: obligate skimming (Balaenidae and Neobalaenidae), benthic suction (Eschrichtiidae), and engulfment (Balaenopteridae). Skimming, however, is pursued facultatively in certain lineages. Fossil lineages (Aetiocetidae, "Cetotheriidae") are important in understanding the transition to filter feeding as well as the evolution of the three different modes. Characters related to feeding have not been studied from a phylogenetic perspective. Ninety-five characters directly and indirectly related to feeding in mysticetes have been mapped onto a well-supported total evidence tree. Preliminary analysis shows that skimming and perhaps a less efficient form of engulfment feeding are equal candidates for the ancestral mode of filter feeding in the Mysticeti. Some derived "cetotheres" probably fed in a manner similar to balaenopterids, due to similarities in the supraorbital process of the frontal and coronoid process of the mandible. A less efficient form of engulfment feeding, termed "gulping" may have been pursued by certain "cetotheres." Novel filter-feeding methods may have also evolved in certain "cetotheres" such as *Herpetocetus*, which has a posteriorly expanded angular process of the mandible. The evolution of benthic suction feeding in *Eschrichtius robustus* has been acquired recently from a more balaenopterid-like ancestor, as supported from new material from the Pliocene San Diego Formation.

SEMI-ISOLATION AND LOWERED SALINITY OF THE ARCTIC OCEAN IN LATE PALEOCENE TO EARLIEST EOCENE TIME

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Geological and biological evidence indicate a late Paleocene and earliest Eocene transatlantic terrestrial corridor from America to Europe via Proto-Iceland. Simultaneously, Beringia was a high-paleolatitude terrestrial filter bridge. Marine deposits and terrestrial faunal dissimilarity between Europe and Asia support a concurrent marine Turgai break in terrestrial continuity between Europe and Asia. These conditions resulted in the Arctic Ocean temporarily having only one connection to Tethys. Net run-off/evaporation in the Arctic would have favored lowered Arctic salinity, with overflow through Turgai. Until the Atlantic bridge broke, heat transport to the Arctic would have been lower and climate relatively zonal. Following the break, oceanic heat transport northward from the Atlantic would have resumed, reducing the climatic gradient and paleowind dust transport. Arctic winters then became warm enough to support the Eureka Sound Wasatchian and Bridgerian biota of the Canadian High Arctic in isolation from Europe. These events correlate with accelerated North Atlantic seafloor spreading in magnetochron C24R, peak Laramide thrusting in the North American Rockies, worldwide negative ^{13}C and ^{18}O excursions, methane releases, and marine extinctions. Moreover, lowered salinity of the Arctic Ocean would have favored intercontinental dispersal of "Green River" fishes.

A NEW SPECIES OF LLAMA (CAMELINAE, LAMINI) FROM THE BLANCAN AND IRVINGTONIAN OF FLORIDA

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The first lamine fossils, represented by the genus *Pliauchenia* originated in the Great Plains of North America approximately 11 million years ago. They eventually spread south into Florida, which is known for its rich Plio-Pleistocene mammalian fauna. In 1974 a new species of lamine was discovered at the Inglis 1A fossil locality in Citrus County, Florida. In the 1980s and 1990s Florida Museum of Natural History volunteers discovered more of this new llama material from the De Soto Shell Pit fossil locality in De Soto County, Florida. Both fossil localities are latest Blancan or earliest Irvingtonian in age. These are the only two fos-

sil sites from where this lamine is known.

This new lamine bears a striking resemblance to the species *Hemiauchenia macrocephala* with which it is found concurrently. The holotype is a partial mandible with p4-m3 (FLMNH 210707). The dentition is adapted for mixed feeding and is less robust than that of *H. macrocephala*. The majority of specimens yet uncovered are post-cranial elements. The radio-ulnae of this new species is about 1.2 times longer than the radio-ulnae of *H. macrocephala* and 1.3 times longer than that of *Palaeolama mirifica*, another co-occurring lamine species. The limb elements, especially the radio-ulnae and metapodials are long, and slender, giving this llama a very gracile appearance. Little is known of the crania of this new species, besides a few teeth, as none have yet been found.

CRANIODENTAL MORPHOLOGIES OF THE EARLY CRETACEOUS TRICONODONT MAMMAL *REPENOMAMUS*: NEW EVIDENCE FOR MAMMALIAN EVOLUTION

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Several skulls of *Repenomamus*, some associated with lower jaws and skeletons, have been discovered in 3D-preservation from the lowest member of the Lower Cretaceous Yixian Formation of Liaoning, China. With unambiguous occlusal relationships of upper and lower teeth, the dental formula of the taxon is interpreted as I1-3-C-P1-2-(Px)-M1-4/i2-3-c-p1-2-(?px)-m1-5. An abnormal tooth, tentatively denoted as Px, is present in two skulls. CT-scan images reveal replacement of upper and lower incisors, canines, premolariforms and molariforms. Upper molariforms curl medially such that wear facets across the crowns are created by vertical, certainly not transverse, movements of the lower teeth and jaws. Deep pits receiving lower molariforms are present on the palate. The single-boned mandible is robust, lacks the angular process, and has the ossified Meckel's cartilage attached longitudinally along the medial surface of the dentary. The symphysis is unfused, suggesting certain degree of rotational movement of the mandibles. Ear ossicles are considered to be detached from the mandible. Skulls are low, robust, and thick-walled. The braincase is narrow, but the nasal cavity is substantial. The septomaxilla is present; substantial jugal primarily on the medial side of the zygoma; large anterior lamina of the petrosal forming the primary sidewall of the braincase; alisphenoid small; strong occipital condyles projecting posteriorly; cochlea straight externally; fenestra vestibuli small; fossa incudis (epitympanic recess) well-defined and immediately medial to the glenoid fossa; and samll tympanohyal extending from the fossa incudis posteromedially. New light is cast on the tooth formula and replacement, formation of the braincase, transformation of the ear ossicles, as well as mastication of early mammals.

AN ARBOREAL RADIATION OF NON-SAURIAN DIAPSIDS

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Phylogenetic analyses of Diapsida uniformly confirm the monophyly of the crown group Sauria and generally agree on the non-saurian identity of many Paleozoic and Triassic taxa, including Araeoscelidia, Coelurosauravidae, Younginiformes, and *Claudiosaurus*. But for the basal position of Araeoscelidia, however, no firm consensus exists on the structure of the non-saurian diapsid tree. This is arguably the result of limited taxon samples or the use of high-order groups as OTUs in previous studies. A new phylogenetic analysis of saurian and non-saurian diapsids, involving 102 in-group taxa and 522 osteological characters drawn from all regions of the skeleton, sheds new light on this issue.

Notably, a clade containing Drepanosauridae and successively remote sister taxa *Hypuronector*, *Longisquama*, *Coelurosauravus*, and *Wapitisaurus* emerges as the sister taxon of Sauria. *Claudiosaurus* is the sister taxon to the foregoing taxa, and all of these are monophyletic with respect to Paliguana, Younginiformes, and Araeoscelidia. Character analysis strongly supports earlier suggestions that typically saurian features such as the loss of the infratemporal arcade and posterior concavity of the quadrate are present in the common ancestor of Sauria. Indeed, the current analysis places these as synapomorphies of the clade including*Claudiosaurus* and Sauria.

This result also suggests Late Permian niche partitioning between saurians and members of the drepanosaurid-coelurosauravid clade. With the exception of the basal *Wapitisaurus*, the latter clade's members all display arguable arboreal specializations, including integumentary structures for parachuting or gliding and limbs and tails modified for prehensile climbing. Taken with the absence of contemporaneous unambiguously arboreal saurians, this suggests an adaptive radiation of arboreal non-saurian diapsids persisting into the Late Triassic.

NEW GENUS OF PRIMITIVE DIPROTODONTOID FROM THE LATE OLIGO-MIOCENE ETADUNNA FORMATION OF SOUTH AUSTRALIA

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The Oligo-Miocene Etadunna Formation of South Australia is well known for its mammalian assemblages, which contain the first recorded occurrences of several living and extinct endemic species. The formation has been divided into nine stratigraphic members and five faunal zones. However, due to the environment of deposition, whole or articulated specimens are very uncommon. Currently, three diprotodontoids are recognized from the formation (*Ngapakaldia tedfordi*, *N. bonythoni*, and *Pitikantia dailyi*). In 1990, a partial skeleton of a new diprotodontoid genus was discovered.

The postcranial and cranial morphology of the new diprotodontoid shares many cranial and postcranial features in common with the other Etadunna Formation diprotodontoids. The specimen was recovered from Lake Pitikantia, stratigraphic unit 8, faunal zone C (Ngapakaldi Local Fauna). Like *Ngapakaldia*, this new genus possesses a plesiomorphic vombatiform skeleton similar to the phalangeriform possums but with adaptations for a larger size and a plantigrade condition for terrestrial habitus. The terrestrial life-style is clearly seen in the ankle joint, i.e. concave dorsal surface of the astragalus, reduced lateral fibular facet, and the medial tibial knob. However, the manus and pes elements of the new genus are more plesiomorphic than any known diprotodontoid postcrania. These elements are relatively less robust and more gracile suggesting a closer relationship to an arboreal ancestor. Unlike *Pitikantia* and *Ngapakaldia*, the new genus possesses a small but pronounced posterior cuspule on P_3 and I^1 is the largest incisor (plesiomorphic state). Current classification schemes place *Ngapakaldia* and *Pitikantia* in the subfamily Diprotodontinae. However, from an expanded analysis of cranial material based primarily on tooth morphology, the Etadunna Formation taxa including the new genus consistently group together outside and separate from the Diprotodontinae. As a result all of the known Etadunna Formation diprotodontoids should be placed in their own subfamily.

OCCURRENCES OF SUBAQUEOUS TETRAPOD SWIM TRACKS FROM THE MIDDLE JURASSIC (BAJOCIAN) GYPSUM SPRING FORMATION: BIGHORN BASIN, WYOMING

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Recent discoveries indicate that marine carbonates and carbonate-rich siliclastics of the Middle Jurassic (Bajocian) Gypsum Spring Formation contain tetrapod tracks of swimming animals. There are two distinctive vertebrate swim track types, tentatively assigned to crocodilians and to possible bipedal dinosaurs. The swim track horizon is laterally extensive and can be traced throughout the Bighorn Basin, Wyoming wherever the Gypsum Spring Formation crops out.

Importantly, the swim track horizon is located stratigraphically one meter above a well documented, multilayered, tridactyl dinosaur footprint bed. The tridactyl tracks are preserved on multiple surfaces and geographic localities in the northeastern Bighorn Basin. The swim tracks are preserved as "negative relief impressions" on a single exposed flat bedding plane surface. The swim traces are subparallel and parallel "groove" marks or "dimples" that occur either in pairs or (rarely) in threes. Lateral spacing between the sub-parallel grooves is typically a few centimeters. Many traces in the Gypsum Spring Formation are characterized by two parallel 1 cm wide grooves, spaced approximately 3.5 cm apart. Each groove set is approximately 4-8 cm long. Dimples are subequal, or equal, non-linear, indentations sometimes preserved in twos, threes, and rarely in fours. Tracks exhibit "impact rims" and/or "pressure release structures" at the termination of the "grooves" or "dimples." In most cases, the grooves are perpendicular to the bedding plane. However, some arcuate forms have been found. These traces are interpreted to represent toe/claw scratch marks made by buoyed animals briefly touching the muddy substrate bottom while swimming.

These unusual nearly in-line traces reflect a swimming behavior of a dinosaur rather than crocodile. The in-line traces do not seem to be consistent with a sprawling swim pattern, but rather a more erect motion of bipedal (?) swimming. The more arcuate (inclined to the bedding plane) traces may reflect a more crocodile-like sprawling gait swim behavior. Similar traces have been found in Mesozoic track horizons of Utah and Colorado.

PRELIMINARY CLADISTIC PHYLOGENY OF THE EOCENE BRONTOTHERIIDAE (MAMMALIA, PERISSODACTYLA)

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The Brontotheriidae are an Eocene family of North American and Asian perissodactyls, notable for having large bony fronto-nasal horns and body sizes nearing that of elephants. This group achieved diversity levels rivaling and, at times, exceeding that of contemporaneous horses, rhinos, and tapirs. Despite renewed interest in perissodactyl systematics, brontothere phylogeny has been almost totally neglected in past decades. This study is the first attempt at generating a cladistic hypothesis of the Brontotheriidae with the majority of known taxa. Using *Phenacodus*, *Hyracotherium*, and *Pachynolophus* as outgroups, a cladogram was generated based on a matrix of 45 ingroup taxa and 109 cranio-dental characters. *Lambdotherium*, *Eotitanops* and *Palaeosyops* form a paraphyletic assemblage of basal brontotheres. All remaining taxa form a robust clade, supported primarily by upper dental characters related to increased tooth crown height and functional emphasis on shearing by the W-shaped buccal blade of enamel forming the upper molar ectoloph. Brontotheres within this clade have previously been assigned to a dizzying mixture of subfamilies, many of them clearly paraphyletic. Most notably, the Dolichorhininae, a group consisting of several hornless Bridgerian and Uintan taxa, including *Mesatirhinus*, *Dolichorhinus*, *Rhadinorhinus*, *Metarhinus*, is highly paraphyletic. Another Bridgerian taxon, *Telmatherium*, was previously considered the sister taxon to the clade of brontotheres that possess fronto-nasal horns; however several taxa, including *Dolichorhinus*, and Asian Irdinmanhan (Uintan equivalent) taxa, *Protitan*, *Epimanteoceras* and *Dolichorhinoides*, nest more closely to the horned-brontothere clade. The most astonishing aspect of the cladogram topology is that Asian and North American brontotheres do not represent endemic radiations, but are phylogenetically intertwined due to a minimum of seven late early and middle Eocene dispersal events between North America and Asia.

INITIAL REPORT ON PLEISTOCENE VERTEBRATES OF COAHUILA, MEXICO

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Surprisingly, there has been no previous discussion of Pleistocene vertebrates from the northeastern Mexican state of Coahuila, which adjoins Texas along its northern border. This situation is especially unusual since a majority of intermontane basins of the Sierra Madre Oriental contain abundant Pleistocene deposits. The late Cretaceous strata that comprise the ranges in much of this mountain province have yielded numerous marine and nonmarine fossils including dinosaurs.

During the past three years an effort has been made through the Museo del Desierto in the capitol city of Saltillo to collect Pleistocene age vertebrates. As a result, numerous localities have been discovered. Although passing mention was previously made of fragmental horse and elephant (mammoth) bones and teeth from two sites in the state, no specific identifications were given. We have examined and/or collected material from more than 12 localities throughout Coahuila. Taxa we have identified and studied include *Sylvilagus* cf. *leonensis*, *Lepus* sp., *Pappogeomys* cf. *castanops*, *Canis* cf. *latrans*, *Mammut americanum*, *Mammuthus columbi*, *Equus* cf. *conversidens*, *Equus* ?*excelsus*, *Camelops* cf. *hesternus*, *Hemiauchenia* cf. *macrocephala*, *Odocoileus* cf. *virginianus*, *Capromeryx* cf. *mexicana,* and *Gopherus* sp. The most widespread and abundant taxon is the mammoth. All but one site produced this animal.

While some earlier published reports have indicated that climatic conditions during the late Pleistocene were essentially similar to those today in Coahuila, our data suggest otherwise. The horses, camels and mammoth indicate reasonably extensive grassland areas, and localities with deer and mastodon are indicative of wooded areas. These same areas today support only desert shrub and cactus.

BRANCHIOSAURS, LARVAE AND METAMORPHOSIS

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Branchiosauridae are small gill-bearing temnospondyl amphibians from the Permo-Carboniferous of Europe, sometimes implicated in the origin of some or all lissamphibians. Most recent workers have treated them as a single clade of paedomorphic dissorophoids related to the more terrestrial Amphibamidae. Restudy of the original assemblage of *Branchiosaurus salamandroides* from the Carboniferous of N?rany, Czech Republic reveals a more complicated situation. This assemblage appears to comprise a mixture of 'true' branchiosaurids (i.e. relatives of the later well-known *Apateon*), larvae of *Mordex*—an early trematopid, and larvae of *Platyrhinops*—an amphibamid. Some of the characters currently defining Branchiosauridae are found in larvae of other higher Dissorophoidea (Amphibamidae and Trematopidae). The Permian members of Branchiosauridae, as presently conceived, may be diphyletic, comprising paedomorphic relatives (or subsets) of Amphibamidae, Trematopidae and Dissorophidae. Systematic analyses that make either Amphibamidae or Branchiosauridae the closest relatives of Lissamphibia at the expense of the other, may be juggling characters of alternative morphs of the same clade.

A BIRD-LIKE BRAIN IN *ARCHAEOPTERYX* —EVIDENCE FROM HIGH RESOLUTION TOMOGRAPHY OF THE BRAINCASE.

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Archaeopteryx is a key taxon in the investigation of the dinosaurian origin of birds by virtue of a suite of skeletal characters shared with maniraptoran theropod dinosaurs and the modern flight feather configuration shared with birds. The braincase of the holotype London specimen lends itself uniquely to modern investigative methods, since it is preserved 'in the round' and has been separated from the main specimen block. CT scanning and computerized 3-D reconstruction have been used to investigate the detailed anatomy of the braincase and compare it to theropod dinosaurs and birds. Internal and external features of the braincase elements, together with previously unreported elements have been revealed. These have permitted a life-restoration of the braincase, an estimate of the brain shape, size and volume and a reconstruction of the inner ear to be made for the first time. The proportions of the brain lobes show that *Archaeopteryx* brain was bird-like with the telencephalon contacting the cerebellum and the optic lobes displaced laterally; it also retained large olfactory lobes. *Archaeopteryx* has a well-developed lagena in the inner ear and data plotted for semi-circular canal measurements places it well within the range for modern birds.

THE TARSUS OF A NEW DJADOCHTATHERIAN MULTITUBERCULATE FROM MONGOLIA

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The skull, teeth, and basicranium of specimen PSS-MAE 142 were briefly reported at a previous SVP meeting. I will discuss some of the postcranial anatomy of this important specimen and its implications for multituberculate phylogeny. The specimen represents a new taxon that is closely related to *Tombaatar*, which is nested within Djadochtatheria. PSS-MAE 142 includes partially articulated left and right pedes; the left is only missing the distal phalanges and the right pes is complete except for the navicular, mesocuneiform, and phalanges. PSS-MAE 142 is similar to *Kryptobaatar* and *Chulsanbaatar* by having contact between the fifth metatarsal and the calcaneum, thus supporting this character as a multituberculate synapomorphy. In addition, these taxa have a deep and wide peroneal groove, a laterodistally directed peroneal tubercle, and a laterally compressed tuber calcanei. The new multituberculate has some primitive features not previously reported for the group: ventral curvature of tuber calcis, distal end of entocuneiform offset from distal end of mesocuneiform, small calcaneoastragalar facet on the calcaneum, presence of wide fossa between the calcaneoastragalar facet and lateral edge of calcaneum, and calcaneal lateral crest. Provided that this taxon is nested within Multituberculata, most of these characters are optimized as reversals. Both *Kryptobataar* and PSS-MAE 142 do not have a fibular facet on the calcaneum, and this may be a synapomorphy of Djadochtatheria. In addition, the presence of a groove on the dorsal face between the peroneal groove and the cuboid facet is a potential synapomorphy of Multituberculata.

FIRST DISCOVERY OF BRONTOTHERES FROM THE EOCENE OF JAPAN

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Two small brontotheriid perissodactyls were discovered in Japan for the first time from the Nakakoshiki Formation distributed in Kamikoshiki Island, Kagoshima Prefecture. The formation is stratigraphically correlated with the Akasaki Formation in Kumamoto Prefecture, which has yielded an early Middle Eocene mammal fauna including *Trogosus* and *Higotherium* (Tillodontia).

One of the new specimens is a left mandible with unworn P_4-M_3 and fragmentary postcranial bones from a single individual. The lower molars are characterized by brachydont crowns with relatively bulbous cusps, less sharp crests, relatively simple M_3 third lobe, and narrower and shorter trigonid than talonid in M_1 and M_2. The length of the molar series (58 mm) indicates that it is a smaller brontothere than *Microtitan* and *Pygmaetitian* from Asia, but is slightly larger than the smallest brontothere, *Nanotitanops*, from the middle Eocene of China. The primitive dental characters and its small body size suggest that it is most closely related to North American *Eotitanops* of early Bridgerian age. Another specimen is an isolated left P^4 that was found from a stratigraphic level about 300 m higher than that of the mandible mentioned above. The P^4 is apparently larger than that of *Eotitanops*, and is characterized by having the metacone elevated and well separated from paracone, buccally expanded parastyle, straight ectoloph with no metastyle, and broad tooth width. These characters clearly separate the P^4 from that of *Microtitan*, *Pygmaetitian*, and *Nanotitanops*, and rather indicate a close relationship with *Palaeosyops* from the Bridgerian of North America.

Primitive brontotheres in Asia are, in contrast to North America, not commonly known in Eocene mammal faunas, and the early evolution of Asian brontotheres has been poorly understood. The new material from Japan firmly implies the greater diversity of early Asian brontotheres and close affinities with the primitive brontotheres from North America.

A NEW SPECIES OF PROTOCETID CETACEAN FROM THE EOCENE OF SOUTH CAROLINA

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In 1999, Mr. Bill Palmer, a volunteer for the Charleston Museum, discovered a protocetid whale in the Martin Marietta Cross Quarry, South Carolina. The remains consist of both P3's, petrosals, one side of the orbital region, posterior edge of nasals, and a partial cranium. The specimen (ChM PV6950) was collected from the Bartonian Cross Formation. Diagnostic characters that identify this specimen as a cetacean are partially enclosed foramen ovale, anterior process of the petrosal, and supraorbital processes of the frontals. The new species differs from *Protocetus* and *Georgiacetus* by having a bulbous promontorium and a more elongate volcano-shaped internal acoustic meatus. It differs from *Eocetus schweinfurthi* and ChM PV5401 (i.e. Cross Whale) by having an anteroposterior parietal ridge on the medial wall of intertemporal fossa. To determine the affinities of our new taxon, we performed a preliminary phylogenetic analysis of 16 taxa coded for 113 characters. We found two most parsimonious trees; in the first tree PV6950 is the sister-group to the clade including *Babiacetus*, *Basilosaurus*, *Dorudon*, and *Eocetus*. Characters that support its exclusion from Basilosauridae are absence of accessory cusps on posterior premolars and the vertical orientation of the supraoccipital. The second tree indicates a sister-group relationship with *Protocetus atavus*; both taxa lack nuchal tubercles. PV6950 exhibits post-mortem erosion along breaks, which suggests the nuchal tubercles may have been eroded before fossilization. If true, then the first tree is better supported. The new specimen from South Carolina has a petrosal with remarkable preservation, which indicates the most developed peribullar sinus cavity seen in a protocetid to date. In this taxon, the peribullar sinus cavity invades between the tegmen tympani of the petrosal and the squamosal.

RE-APPRAISAL OF THE SKULL OF THE EARLY TRIASSIC ARCHOSAUROMORPH REPTILE *PROLACERTA BROOMI*

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Description of new and re-examination of previously described skulls of *Prolacerta broomi* allows reappraisal of the cranial structure of this early archosauromorph reptile. The ventral margin of the premaxilla is slightly deflected, and there is a relatively large lateral foramen in the maxilla that is bounded anteriorly by the premaxilla; both features are shared with the basal rhynchosaur *Mesosuchus* and the basal archosauriform *Proterosuchus*. Implantation of the marginal dentition is ankylothecodont: the teeth are rooted relatively deeply, bounded lingually by a deep wall of the jaw, and anchored to the jaw by bone of attachment. The pineal foramen varies in size from little more than a scar in the interparietal suture to a suboval opening several millimeters in diameter. Contrary to previous claims, the

skull roof in *Prolacerta* was akinetic, and quadrate mobility (streptostyly) was absent. A phylogenetic analysis of the interrelationships of basal archosauromorphs corroborates the hypotheses of the polyphyly of Prolacertiformes and of a close relationship between *Prolacerta* and Archosauriformes.

DRAMA IN THE PALEOZOIC: A STRUGGLE FOR SURVIVAL

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The discovery of two new reptilian trackways from western Indiana provides new evidence into the feeding behavior of early Pennsylvanian tetrapods. The early Pennsylvanian (Morrowan-Atokan) trackway specimen is from the Mansfield Fm. along the eastern margin of the Illinois Basin, at the Crane (NSWC). Sedimentological study of the locality suggests a coastal tidal flat deposit of well-sorted laminated siltstones. This specimen preserves the trackways of two small individuals traveling together along a non-linear path. The trackway of the larger individual (5.5 cm) is twice the width of the smaller individual and preserves a taildrag. The entire trackway is 129 cm long. The animals appear to have been moving rapidly from the scuffed and attenuated nature of the prints. Although preservation of individual prints is poor, making ichnological identification impossible, enough consecutive printmarks have been preserved to study the trackway. Claw marks, extended rapid movement and the tight curving pattern of the trackway suggest that the track makers were reptilian.

The trackway from Crane provides new insight into behavioral aspects of early terrestrial vertebrates. The scuffed and attenuated prints continue for the entire length of the trackway indicating that the two animals could move quickly for extended distances. The trackmakers also made two tight turns of nearly 180 degrees each over a distance of approximately 0.6 m. These trackway characteristics suggest that some Pennsylvanian tetrapods may have been active, agile land predators. Termination of the smaller footprints suggests the prey was overtaken by its pursuer and eaten. A resting trace at the end of the trackway was made by the larger animal after it captured its prey and stopped to swallow and digest it. The lack of the larger footprints past the resting trace may be due to desiccation and hardening of the substrate as the larger trackmaker rested to bask during digestion as most reptiles are required to do. Reptilian trackways are rare during this time, adding further importance to the track locality.

ANALYSING DOMINANCE IN VERTEBRATE PALEOECOSYSTEMS: A QUANTITATIVE METHOD

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Measuring the percentage abundances of taxa which comprise ancient paleocommunities has been a goal of paleoecology/taphonomy since the inception of the science. Representation of the true percentage abundances of taxa in any study is controlled by 1) the sampling protocol used, 2) variation caused by sample size and 3) a suite of preservational biases which fall into two categories: taphonomic and taxonomic. The first two of these factors can be controlled for easily by the use of indiscriminate, exhaustive sampling of the study area and, given the multinomial nature of the distribution of abundances, by the application of a derived 'worst case' relationship. Calculating the 'optimal case' relationship is possible, but too computationally intensive given the extent of the other biases affecting paleocommunities. From this relationship it can, for example, be calculated that in order for all taxon percentage abundances to be within 5% of their true values 95% of the time, 510 individuals must be collected.

If all of the taxonomic and taphonomic biases affecting a sample were known, and their effects quantified exactly, it would then be possible to determine the percentage abundances of each of the taxa within the community sampled. In reality this is never possible. Although there is a large body of literature studying these biases, the quantifications produced are never exact and there is therefore an extra level of uncertainty which must be incorporated into any such study.

By entering these biases into a computer model it is possible to study the effects of the ubiquitous taxonomic biases (caused by the biology of the taxon in question, e.g. reproductive rate) and more variable taphonomic biases on the accuracy of any estimates of percentage abundance made from fossil assemblages.

As with all modelling approaches, this method ignores some of the complexities of the modelled system in order to highlight some of the underlying controls on that system. It is hoped that comparisons with rigorously sampled field datasets will give more insight into the preservation of abundance in the vertebrate fossil record.

NEW SPECIES OF *LIMNOCYON* (LIMNOCYONINAE, HYAENODONTIDAE, MAMMALIA) FROM THE MIDDLE BRIDGERIAN (MIDDLE EOCENE) OF SOUTHWESTERN WYOMING

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During recent field work by the American Museum of Natural History, a left maxilla (AMNH 140004) of a new hyaenodontid was discovered from a middle Bridgerian (Br-2) locality in the Bridger Formation, southern Green River Basin, Wyoming. The specimen is characterized by a reduced I1 and M2, relatively large parastyles on P3-4, and the presence of a protocone on P3. In all these character states it differs from the similar sized and contemporary *Limnocyon verus*. It differs from the Uintan aged *L. potens* in being smaller, having less blunt teeth, I1 still present, smaller protocones in P3-4, and a less reduced M2. *Limnocyon*, including AMNH 140004, *L. verus*, and *L. potens*, differs from other limnocyonine genera (*Oxyaenodon*, *Thinocyon*, *Prolimnocyon*, and a new, undescribed genus and species from the earliest Bridgerian) by relatively blunt premolars, elongated P1 with relative strong posterior basal cusp, relative short metastyle on M1, and a M2-talon that is as long as the trigon. Dental adaptations of this new *Limnocyon* species imply a slightly more carnivorous diet than its sister-taxon *L. verus*. In order to confirm this tentative paleobiological interpretation the as yet unknown lower dentition will have to be investigated. Additional specimens of this new species may become available by further examination of specimens previously assigned to *L. verus* and by future fieldwork

IMAGING FOSSILS FOR HARD AND SOFT TISSUE SIGNATURES USING ELEMENTAL X-RAY AREA MAPS

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Elemental x-ray area mapping (EXAM) is a non-destructive technique that uses x-ray fluorescence spectrometry to visualize the distribution of elements over an area. Both fossilized hard and soft tissue signatures are visible using this technique. The results can provide a means to locate information and rogue specimens not visible to the naked eye. EXAM images from vertebrate specimens, a fossil fish and a dinosaur tooth, will demonstrate the conventional technique that provides a 2-D image. EXAM images from invertebrate specimens, a trilobite and a Burgess Shale Marrella, will show how the technique can be used to provide 3-D stereoview information.

FRAMEWORK FOR EXPLICIT FUNCTIONAL INFERENCES USING 3D DATA, AND TEST OF PHYSICAL CONSTRAINTS IN VERTEBRATE EVOLUTION

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Functional morphology is an important component of vertebrate paleontology, linking phylogeny with macroevolution, yet its implementation often remains subjective. The last two decades have witnessed a rapid advancement in another component of paleontology, namely phylogenetics, thanks to the wide acceptance of a quantitative framework. It is high time to establish a similarly useful quantitative framework for functional morphology.

As Kevin Padian had conceptualized, inference of function in vertebrate paleontology involves two steps. First, a correlation between shape(s) and function(s) is established using living animals, in which behavior is observable (Step 1). Then, this correlation is used to infer function from the shape of fossilized body parts (Step 2). Step 1 may be achieved in different ways, which can be categorized into three levels. In Level 1 studies, correlation is established intuitively, without quantification (e.g., some ichthyosaurs looked like tunas so they swam like tunas). Level 2 studies involve quantitative data collection, yet resulting numerical correlations lack mechanical reasoning (as in many multivariate analyses). At Level 3, quantitative data are used to test the presence of a correlation that is expected from mechanical principles. The justification of Step 2 ultimately rests on the assumption that physical principles have been uniform through time (thus similar shapes should function similarly). Therefore, Step 1 should also be physics-based to enhance the overall testability of inferences. Such physics-based inferences can then be used to test physical constraints in vertebrate evolution. For these reasons, Level 3 studies are preferred, yet they are rare.

An NSF CAREER project has started to establish a framework for Level 3 studies using 3-dimensional (3D) shape data. A facility containing 3D printer, 3D laser camera, water flume, mechanical test bed, and computer workstation is being established. This facility is used to test the presence of physical constraints behind the evolution of elasmosaurian neck, and to accumulate basic data that can be used by the scientific community.

SKULL ANATOMY OF *LIBOGNATHUS SHEDDI* (PARAREPTILIA: PROCOLOPHONIA) FROM THE UPPER TRIASSIC COOPER CANYON FORMATION OF WEST TEXAS

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Small (1997) described the parareptile *Libognathus sheddi* as a member of the Procolophonia based solely on the holotype, a left dentary (DMNH 20491. The discovery of additional cranial material from the Upper Triassic Cooper Canyon Formation of West Texas has provided new information on the skull anatomy of *Libognathus sheddi* . The additional cranial material from three different individuals was collected from a single locality (MOTT VPL 3874) close to the same stratigraphic level and less than five kilometers from the type locality. The material includes the pre-orbital portion of a skull (TTU 10068), a left maxilla and premaxilla (TTU 10081), and a right dentary (TTU 10069).

This new material has allowed the description of many skull bones of *Libognathus sheddi* which were previously unknown. Small noted there were characteristics in the dentary that were different from other procolophonids such as the anteriorly directed lateral dentary foramen and the anterior projecting coronoid. The new material has also lead to the recognition of other unusual procolophonid characters in the skull. The recognition of a greatly reduced contact between the lacrimal and the nasal and the frontal forming a short lappet along the anterior of the orbit are two unusual characters indicating a derived state for this procolophonid.

A REVISION OF THE EUROPEAN THALATTOSAURS AND ITS IMPLICATIONS FOR THE EVOLUTION AND BIOGEOGRAPHY OF THE CLADE (REPTILIA, DIAPSIDA)

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Thalattosaurs are an enigmatic clade of marine, probably non-saurian diapsids known only from the Triassic Period. In recent years, there were several new fossil finds, especially from China, but a better understanding of the evolution and biogeography of the clade was hampered by the restricted knowledge of the taxa from Europe. The new study therefore con-

centrates on the European representatives, and especially focuses on *Askeptosaurus italicus* from the Middle Triassic of Monte San Giorgio, Switzerland, as well as on *Endennasaurus acutirostris* from the Upper Triassic of Lombardy, Italy; both taxa are thought to be relatively plesiomorphic as compared to the remaining forms.
The anatomical revision results in the correction of many cranial characters and in a more detailed documentation of palate and braincase anatomy, as well as in important corrections regarding the structure of the postcranial skeleton. The new results are used to perform an analysis of thalattosaur ingroup relationships, including all taxa currently considered to be valid. On the basis of 35 characters, *Endennasaurus* and the monophyletic *Askeptosaurus* and the Chinese *Anshunsaurus* turn out to be the sister group of all other thalattosaurs. Among the latter, the Monte San Giorgio taxa *Clarazia* and *Hescheleria* are monophyletic and the sister group of the North American taxon *Thalattosaurus*. The remaining thalattosaurs are positioned basal to this clade, with the Chinese *Xinpusaurus* and the Californian *Nectosaurus* grouped as sister taxa. The palaeobiogeography and the evolution of the clade are discussed in the light of the new analysis, which implies, e.g., that the European Tethyan area must have been inhabited by at least two different thalattosaur lineages, of which one shows close affinities to the taxa from the Pacific region.

PREPARATION OF FOSSILIZED SOFT TISSUE STRUCTURES IN A NEW HADROSAURIAN MUMMY FROM THE JUDITH RIVER FORMATION OF MONTANA

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It has been nearly 100 years since the fossil collecting team of Charles H. Sternberg and sons collected the first popularly known mummified dinosaur, an *Edmontosaurus* specimen currently on display at the American Museum of Natural History. There is no data available that documents the preparation of the extensive integument on this significant and famous specimen. The Sternberg's jealously guarded their preparation techniques and whatever documentation they did record of working on fossilized skin has been lost. A new mummified dinosaur specimen of *Brachylophosaurus*, known as "Leonardo" has been collected from the Campanian sediments of the lower Judith River formation in northeastern Montana and is currently under preparation. This specimen has exceptional preservation of soft tissue structures such as skin, muscle and keratinous features. These offer new challenges in preparation and conservation because there are no standard techniques for preparing fossilized soft tissue compared to bone. The Sternberg family worked in the era of the horse and buggy but modern day technologies now enable us to be creative in conservation techniques applied to fossilized soft tissue structures. Development and documentation of new preparation techniques on this significant specimen are presented.

AN EXCEPTIONALLY PRESERVED MARINE VERTEBRATE FAUNA FROM THE MUWAQQAR FORMATION (LATE CRETACEOUS) OF JORDAN

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Recent field exploration into Upper Cretaceous (Maastrichtian) rocks of the Muwaqqar Chalk Marl Formation of Jordan has yielded an exceptional marine vertebrate fauna. Limestone beds have produced well preserved, nearly complete skeletons of chondrichthyan, teleosts, and marine reptiles. Represented by a cranium, trunk, and tail, the condrichthyan material appears to be a new taxon whose lower-level affinities remain unknown. Among the several teleost skeletons is a new ichthyodectiform that likely belongs to Saurodontidae, based on the long dentary and the edentulous predentary. Marine tetrapods are represented by several mosasaurids, including one well preserved partial skeleton. This new Maastrichtian assemblage from Jordan is the first vertebrate record from the Mesozoic Arabian Carbonate Platform, and underscores the research potential of that area. The fauna shows a marked affinity with that of the Late Cretaceous Interior Sea of North America, in particular that of the Niobrara Chalk of Kansas. Such a fauna may allow for a more detailed reconstruction of the palaeography of this region, and will lead to a better understanding of the dynamics of the Tethyan in the Late Cretaceous.

DEEPENED FLANK SCALES IN TRIASSIC ACTINOPTERYGIANS AS A PHYLOGENETIC SIGNAL

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Deepened flank scales have previously been underestimated in terms of their distribution among fusiform actinopterygians and as a putatively phylogenetic signal. This is suggested by exceptionally well-preserved specimens newly retrieved from the Prosanto Formation (Early Ladinian, Switzerland): the pattern of the squamations of two genera can be matched perfectly with differences in the pattern of skull ossifications, counts of lepidotrichia, and the structure of the caudal fin. To evaluate this phenomenon in a broader context, squamations of all relevant species are analyzed and compared to those of extant analogs.

Putative interdependence and correlations of deepened scale rows with other characters including body size are discussed: counts of deepened flank scales per row are found to correlate negatively with body size in fusiform fishes up to a certain standard length, and occur exclusively in small fishes predominantly in the Middle Triassic. If there is only a single row of deepened scales present, it always persists back to the caudal fin in fishes up to 60 mm in standard length. Fishes possessing deepened flank scales also have fewer longitudinal scale rows than fishes of comparable body size lacking deepened flank scales.

In contrast to extant fishes, there is no interdependence of deepened scales and the presence of features such as spinous rays or spines, thorough ossification of scales, or breakup of geometry of the squamation.

The new finds indicate that counts of deepened scales per longitudinal row probably represent a stable phylogenetic signal. However, why the phenomenon of deepened flank scales peaked in the Middle Triassic remains unknown.

CATASTROPHIC MASS MORTALITY OF A HERD OF YOUNG DIPLODOCID SAUROPODS FROM THE MORRISON FORMATION OF MONTANA

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The Mother's Day Site, located in the Salt Wash member of the Upper Jurassic Morrison Formation in south-central Montana, preserves the remains of a herd of young diplodocid sauropods. The unit containing the bonebed is a muddy fine-grained sandstone, representing a levee or overbank deposit. All of the specimens recovered from the site belong to either juvenile or subadult individuals, as indicated by the small size of the elements and the lack of epiphyseal ossification. Preliminary taphonomic analysis indicates that the Mother's Day assemblage is both monospecific and catastrophic; the only non-sauropod material recovered from the site consists of three isolated theropod teeth which are likely reworked and not directly associated with the sauropod elements. Bone modification features that would indicate some interval of exposure prior to burial (e.g. weathering cracks and bite marks) are not in evidence in the small sample of bones prepared thus far. This lack of bone modification, in conjunction with the monospecific nature of the site, suggests that the assemblage represents a single, catastrophic mass mortality.

Although miring has been previously proposed as the agent of mortality for the Mother's Day assemblage, new evidence suggests that such a scenario is unlikely. Long elements in the quarry are weakly oriented in a NW/SE direction, with a shallow northwesterly dip. This orientation and imbrication is likely the result of a current flowing to the SE. The probable cause for the weak orientation signal is the incomplete decomposition and disarticulation of the carcasses at the time of transport and burial; elements commonly found articulated within the quarry include caudal vertebrae and entire pes units. The presence of preserved soft tissue, in the form of skin impressions, indicates relatively fast burial and shows that the carcasses were not remobilized after burial. Additionally, remnants of skin and other soft tissue would have increased the buoyancy of the bone to which they were attached, explaining the hydraulic inequivalence of the larger elements with the relatively fine-grained sediment of the bonebed unit.

LATE CENOZOIC MAMMALIAN FAUNAS AND AGE OF HOMINOIDS FROM THAILAND

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The Thai and Japanese Paleontological Expedition Team (TJPET) has surveyed the late Cenozoic basins in Thailand since 1996. The late Cenozoic sediments in Thailand have yielded plenty of vertebrate fossils including hominoid fossils. According to previous works, the Neogene Mammalian faunas from Thailand resemble those from the early to middle Miocene of the Siwaliks. TJPET has examined the vertebrate faunas of late Cenozoic sites at Mae Soi, Li Basin, Pong Basin, Mae Moh, Chiang Muan, Had Pu Dai, Sop Mae Tham and Tha Chang near Nakhon Ratchasima in Thailand. At Chiang Muan Lignite Mine 150km east of Chiang Mai, TJPET has found fossils of hominoids, rhinocerotids, suids, tragulids, and *Tetralophodon* cf. *xiaolongtanensis*. The Chiang Muan hominoid fossils are the first record from the Neogene of Southeast Asia. The Chiang Muan mammalian fauna is similar to the fauna of a famous hominoid site Xiaolongtan, Kaiyuan, Yunnan Province, southwest China on the basis of the resemblance of the proboscidean and siud assemblages. The Chiang Muan mammalian fauna suggests a latest middle Miocene or early late Miocene age. TJPET has found new mammalian faunas from a number of sand pits in Tha Chang area near Nakhon Ratchasima. Classification of mainly proboscidean fossils from the sand pits suggests that the mammalian material in Tha Chang comprises the following faunal assemblages. The middle Miocene mammalian fauna consists of amebelodontid gomphothere, *Gomphotherium* and *Prodeinotherium*. The latest Miocene fauna yields *Hipparion*, primitive *Stegodon*, *Stegolophodon* and primitive *Merycopotamus*. The early Pleistocene fauna yields advanced *Stegodon* and *Elephas*. In the Sedimentary facies, the estimated submerged valleys by subaerial erosion and filled with fluvial sand indicate the stable tectonics and frequent riverbed fluctuation from middle Miocene to Quaternary. It is suggested that sediments of each sand pit include only one or two mammalian age assemblage. TJPET is continuing to survey the mammalian faunas, stratigraphy, and magnetostratigraphy in the kate Cenozoic sites of the South East Asia.

CRANIAL OSTEOLOGY IN THE CORDYLIFORMES: NEW PARSIMONY-INFORMATIVE CHARACTERS FOUND USING DISARTICULATED MATERIAL

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Cranial osteology of squamates was recognized long ago as a valuable source for phylogenetically informative data. However, many museum squamate specimens are preserved in alcohol, making examination of osteology difficult. Of the specimens that are skeletal preparations, the vast majority have a completely articulated skull. This type of material makes studying detailed osteology difficult. Disarticulated cranial material provides an unobstructed view of morphologically complex regions, such as the braincase. In my study, I examined disarticulated cranial material and CT scans of several members of Cordyliformes, a group of African lizards whose phylogenetic relationships are in need of resolution, as well as other representatives of major squamate lineages. By studying this type of material, I found sever-

al morphological variations which proved to be parsimony-informative characters in a phylogenetic analysis aimed at resolving relationships within Cordyliformes. These characters include variation of several structures in and around the braincase. Studying disarticulated material and CT scans greatly facilitated the search for new variations in morphology, and the subsequent evaluation of this variation across different squamate specimens. In light of its utility for phylogenetic character analyses, disarticulated cranial material should be better represented in museum collections and be included in more squamate systematic analyses. New data are necessary to resolve the current systematic status of Cordyliformes, and disarticulated cranial material provides an excellent source for these data that is applicable to both recent and fossil taxa.

WHY DOES *XENOSMILUS* LOOK LIKE A PANDA?

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Xenosmilus, from the Pleistocene of Florida, shows a combination of morphological characters that make it unique among saber-toothed predators. The association of a narrow skull, scimitar-tooth canines with short crennulations, short legs, plantigrade hind feet and a robust body form suggest that this animal has habits different from those of previously known sabertooths. Although these predators have been described as "bear-like," the postcrania of *Xenosmilus*, surprisingly, more closely resemble the giant panda, *Ailuropoda melanoleuca*. Our work suggests that *Xenosmilus*, like *Ailuropoda*, assumed an upright stance frequently. For pandas the ability to stand bipedally frees the forelimbs to hold onto and strip bamboo stalks, while for *Xenosmilus* forelimbs were important for holding onto large, struggling prey. This comparison is further supported because of a "thumb" evolved from a carpal bone in *Ailuropoda*, and the presence of a large thumb and claw in *Xenosmilus*.

NEW TECHNOLOGY FOR AN OLD SITE: USING SURVEY GRADE GPS AND TOTAL STATIONS TO ESTABLISH A PERMANENT CONTROL NETWORK AND A TOPOGRAPHIC MAP OF THE PLEISTOCENE-AGE SITE IN SALTVILLE, VIRGINIA

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First described by Thomas Jefferson in 1787, the Pleistocene-age site at Saltville, Virginia has been actively worked for decades. A survey team from East Tennessee State University visited the site with the goal of using new technology to establish a permanent horizontal and vertical control network, mapping existing conditions, and training students and researchers to use total stations for locating specimens. The existing control network in Saltville consists of multiple grid systems established by earlier research teams. Many of these grid systems are arbitrary in nature with few associations between sites within the Saltville valley. The three goals of the East Tennessee State University survey team are as follows: 1) Using GPS technology and the Virginia State Plane Coordinate System, the survey team installed a permanent, highly reproducible horizontal and vertical control network. The horizontal and vertical network met the Federal Geodetic Control Committee's accuracy standards. Locating fossils within a common system facilitates future research efforts by relating them to other specimens found in the Saltville valley; 2) After completion of the network, the survey team created a topographic map of the research area including location of previous research pits, older control grids and existing topographic features. The map created by this survey can be imported into computer systems, such as GIS, to assist in site analysis; and 3) The final initiative of the survey team is training students and researchers at the Saltville project to use total stations to locate fossils. The course consists of both classroom and field exercises associated with operating a survey instrument and using the new control network. In the classroom, students are taught the basic knowledge and techniques necessary to collect data in the field. The results of this course provide new tools for both researchers and students to use at other sites.

A NEW SPECIES OF MOSASAUR FROM THE FOX HILLS FORMATION OF SOUTH DAKOTA

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In 2002 the Timber Lake and Area Museum acquired this yet to be described mosasaur from the late Helen Ross who collected the specimen from the lower Fox Hill Formation in Western South Dakota in 1993.This exquisite mosasaur skull was prepared for exhibit by Steve Haire. It was unveiled at the T L & A Museum in July. The collection site was relocated in September and at that time additional cranial material (its snout) was collected. This new material was equally well preserved but free of the sandstone matrix affording a more detailed examination of the internal jaw structure.

A few unassociated post cranial mosasaur bones and bone fragments have been found in the vicinity and in the formation. Since its deposition was in the fine sand of the shoreline of the Cretaceous Seaway there is very little distortion.

Our objective in preparing a poster presentation for the SVP meeting will be to attract professional study of the "Ross mosasaur" which we feel represents an extremely late (about 68 mya) and very large variety that could prove to be not only a new species but also a new genus. The poster presentation will include photographs of the "Ross mosasaur" at its time of discovery and in its present state both the portion on exhibit and the end of the snout not yet prepared. There will also be a schematic stratigraphic column for the location.

Judging from the size of this animal's head, this mosasaur may have exceeded 10 meters in length. If complete the mandible would be nearly a meter in length. The width of the skull is about 40 cm and the height is about 50 cm. The orbital opening is about 20 cm. The crowns on the larger teeth are 7 cm long. The teeth of the "Ross mosasaur" are smooth. The vertical fluting present on many species are not evident on this specimen. However, there are distinct facets. Tooth replacement mechanics are well illustrated on this specimen. Generally the frontal bone is broad and short, similar to the *Progathodon overtoni*. There seem to be 14 teeth in the dentary which would be consistent with the genus *Progathodon*.

MIOCENE PALEOSEASONALITY INFERRED FROM EQUID TEETH AND INTRA-TOOTH ISOTOPIC PROFILES

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This research uses intra-tooth isotopic variability measured in hypsodont equid teeth from the Miocene Siwalik sediments of Pakistan to determine paleoseasonality of precipitation. The purpose of this investigation is to determine whether *Sivapithecus*, a Miocene hominoid, lived in habitats that were characterized by a seasonal rainfall regime, and if so, what kind of forest was associated with this regime. Forest type, such as evergreen, semi-evergreen, moist deciduous, and dry deciduous, is largely determined by length of the dry period. Reconstruction of the rainfall regime therefore allows inferences of forest type in the fossil record. Seasonal rainfall regimes can be determined from oxygen stable isotopes, for oxygen isotopes track amount of rainfall in tropical regions. Sampling oxygen isotopes along the length of an equid tooth, which takes over a year to develop, provides a record of seasonal isotopic changes in body water, which in turn reflect drinking water and ultimately precipitation.

Reconstructed precipitation regimes from Siwalik equid teeth spanning 10.0-6.3 Ma resemble the wet monsoonal environments of southern China today, where the dry season lasts five to six months. These results suggest that the Asian monsoon was probably in place by 10.0 Ma, and that throughout the record sampled, the Siwaliks experienced heavy monsoonal rainfall for at least several months, with five-to-six months of dry season per year. Enrichment of oxygen values among tooth profiles over time probably indicates a decrease in rainfall that was sufficient to drive a transition in vegetation from moist- to dry-monsoonal forests.

These results suggest that *Sivapithecus* lived under a seasonal regime with dry periods of five- to-six months, longer than the maximum of four months that most great apes experience today. Therefore either *Sivapithecus* had habitat requirements different from those of modern apes, or alternatively, Siwalik forests under a monsoonal rainfall regime differed in the spatio-temporal availability of fruit compared to modern analogues, thus providing habitat that could support a great ape.

A NEW SPECIMEN OF *ARIZONASAURUS* FROM THE MOENKOPI FORMATION (LOWER MIDDLE TRIASSIC) AND ITS IMPORTANCE TO PSEUDOSUCHIAN DIVERGENCE

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The upper Moenkopi Formation (lower Middle Triassic) of northern Arizona has yielded isolated skull elements, centra, and girdle elements that traditionally have been referred to the Rauisuchia and the Poposauridae. A recently discovered skeleton referable to *Arizonasaurus babbitti* shows that most of these archosaurian remains belong to one taxon. The new skeleton of *Arizonasaurus* is nearly fifty percent complete, including a partial skull, and represents one of the best and earliest pseudosuchian specimens in existence. Characteristics of the skeleton of *Arizonasaurus* show that it belongs to a poorly known group of Middle Triassic archosaurs called the ctenosauriscids. A phylogenetic analysis of twenty-four characters used the best known rauisuchids (*Postosuchus*, *Saurosuchus*), poposaurs (*Poposaurus*, *"Chatterjeea"*) aetosaurs (*Desmatosuchus*), crocodyliforms (*Terrestrisuchus*), *Marasuchus* (bird-line archosaur) and *Euparkeria* as the outgroup of Archosauria to investigate relationships of ctenosauriscids (*Arizonasaurus*). These data suggest that ctenosauriscids are closely related to poposaurs, and that poposaurids and ctenosauriscids are derived rauisuchians. The pelvis and skull of *Arizonasaurus* are especially important in clarifying the relationships of the poposaurs, rauisuchians and ctenosauriscids. The systematic position and age of *Arizonasaurus* also show that nearly all the pseudosuchian archosaurs must have evolved by the Early Triassic, and that the bird-crocodile divergence occurred in or before the Early Triassic. The Moenkopi fauna to which *Arizonasaurus* belongs provides an important transition between Early Triassic and Late Triassic faunas.

FISH COMMUNITY DYNAMICS, GROWTH OF YELLOW PERCH, AND CORRELATIONS WITH CLIMATE AND FIRE IN AN EARLY HOLOCENE LAKE IN NORTH DAKOTA

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An early Holocene postglacial lake located in the Missouri Coteau region, near Buchanan, North Dakota, has produced one of the best-preserved fossil assemblages ever reported including plants, insects, amphibians, and fish. The fossil fish recovered include complete specimens of yellow perch *Perca flavescens* (Percidae), brassy minnow *Hybognathus hankinsoni* and blacknose shiner *Notropis heterolepis* (Cyprinidae), banded killifish *Fundulus diaphanous* (Fundulidae), and brook stickleback *Culea iconstans* (Gasterosteidae). These fish are being examined to gain a better understanding of long-term patterns in fish population dynamics in relation to climate, which is poorly understood. The relative abundance of each fish species has been contrasted over approximately 1500 years and preliminary results indicate oscillating population levels. These oscillating abundance patterns show several marked declines in abundance that are correlated with periods of charcoal deposition (i.e., fire events) at the site. Abundance pattern oscillations could also be the result of temperature changes.

We used extant yellow perch growth to interpret Early Holocene ambient temperature. Ageable skeletons of fossil yellow perch were used to contrast growth patterns of fossil and extant yellow perch and to estimate ambient mean annual temperature (MAT) of the site. Total

length and MAT data for 20 populations of extant yellow perch, ranging in latitude from the Central Manitoba, Canada to South Carolina, USA, were analyzed to develop a new MAT index. Preliminary analyses show that three fossil yellow perch skeletons recovered from 47°N had total lengths-at-age values similar to that of extant yellow perch from the cooler climate of central Manitoba (55°N). Using regression equation parameters and total length data from fossil yellow perch, a MAT of approximately -0.1°C has been calculated for the Early Holocene site, while the contemporary ambient MAT is 4.5°C. A more thorough study of fossil yellow perch growth and temperature may provide insight into the fluctuations of fish abundance occurring in other fish species at the site.

THE HOLOCENE ECOLOGY AND DISTRIBUTION OF NORTHERN FUR SEALS

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Radiocarbon and faunal analyses suggest northern fur seals (*Callorhinus ursinus*) are the dominant pinniped species in late Holocene coastal archaeological sites from southern CA to British Columbia (BC), whereas today, northern fur seals (NFS) breed almost exclusively on offshore islands at high latitudes (>50ºN). In our prior work exploring the enigmatically high abundance of NFS in mid-latitude sites we recognized the need to answer three questions: 1) Did mid-latitude NFS feed offshore, as NFS do today, or did they forage in nearshore waters where they would be more accessible to human exploitation? 2) Were NFS from mid-latitude sites immigrants from high latitudes, as many mid-latitude NFS are today, or were they year-round residents? 3) If NFS were mid-latitude residents, where were their breeding colonies located? With respect to the last question, ongoing archaeometric studies suggest that NFS had rookeries on the coasts of CA, WA, and BC. We used natural variations in isotopes to investigate feeding and migratory behavior of Holocene NFS. We measured $\delta^{13}C$ and $\delta^{15}N$ values of NFS bone collagen from sites ranging from the western Aleutian Islands, AK to southern CA. Isotopic work revealed three conclusions about NFS. $\delta^{13}C$ values for NFS are always more negative than values for associated harbor seals, showing that NFS foraged offshore across this entire range. Second, NFS cluster into three subgroups: a CA group with high values, a WA/BC/AK group with intermediate values, and a western Aleutian group with low values. Finally, all pinnipeds from Duncans Point, CA have extremely high $\delta^{15}N$ values. We provisionally interpret this to reflect locally intense upwelling of ^{15}N-enriched water. More important from the standpoint of NFS ecology, the fact that nearby NFS populations do not have high values suggests that individuals at these CA sites did not migrate extensively up and down the coast. When coupled with the archaeometric evidence, these data suggest that NFS had mid-latitude rookeries during the late Holocene and a substantial fraction of their global population resided at mid-latitudes.

MASS SETS FOR INTERACTIVE COMPUTATION OF BODY SEGMENT DIMENSIONS AND BIOMECHANICAL ANALYSIS OF ANIMAL LOCOMOTION

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We designed an interactive software tool that uses three-dimensional B-spline solids to visualize and estimate biomechanically important parameters for animal body segments. Although the tool is most useful for assessing the importance of unknowns in extinct animals, such as body contours, muscle bulk, or inertial parameters, it is also useful for non-invasive measurement of segmental dimensions in extant animals. Points measured directly from bodies or skeletons are entered and visualized, and then the B-spline solid is fitted to enclose these points, allowing quantification of segment dimensions. The model has a flexible click-and-drag interface that allows body segment dimensions to be either interactively deformed (by warping the solid) or specified quantitatively (e.g., expanding the solid boundary by some percentage or a specific distance beyond measured skeletal coordinates). It then displays any resulting changes of segment mass, center of mass, and moments of inertia. Objects representing volumes of reduced density can be embedded to represent lungs or air sacs within body segments.

The tool was validated by reconstructing an ostrich body from a defleshed skeleton and comparing the estimated dimensions to separately measured values from the original carcass. We then used the tool to calculate the segmental masses, centers of mass, and moments of inertia for an adult *Tyrannosaurus* with measurements taken directly from a complete skeleton, and compared these results to other estimates, using the model to conduct sensitivity analysis of unknown parameter values. Next we analyzed the interaction between segment dimensions, limb orientation, and joint moments during single-legged stance. Segment moments of inertia are commonly ignored in biomechanical analyses of animal locomotion, but we show that they can be highly influential when the center of mass of the trunk segment is anterior to the hip joint, particularly in larger animals.

THE PES OF CENTROSAURINE CERATOPSID DINOSAURS: NEW INFORMATION FROM A COMPLETELY ARTICULATED SPECIMEN

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For nearly a century, the phalangeal formula of the centrosaurine foot has been listed as 2-3-4-5-0. This formula was initially based on a reconstruction of a presumably complete but partially scattered foot attributable to *Brachyceratops*. Due to the lack of articulated pedal materials for the group, this formula was assumed to be both correct and applicable to other members of the group. Through the twentieth century, a succession of citations of this formula has resulted in its acceptance as the actual versus reconstructed formula. Recent recovery and examination of a completely articulated pes attributable to a centrosaurine (possibly *Styracosaurus*) from the Late Cretaceous (Campanian) Dinosaur Park Formation of southern Alberta, Canada suggests that this phalangeal formula is incorrect. The specimen is a completely intact and articulated pes down to the unguals of each digit. The phalangeal formula of this foot is 4-4-3-3-0. Such a drastic change in the phalangeal formula may have serious implications regarding not only the posture, but ultimately, the locomotion of the centrosaurines specifically, and the neoceratopsians in general.

THE POSTCRANIAL SKELETON OF THE GHOST RANCH *POSTOSUCHUS* WITH SPECIAL CONSIDERATION OF THE MANUS

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The Ghost Ranch *Postosuchus* is a well-preserved rauisuchid from the Upper Triassic *Coelophysis* Quarry, Rock Point Member, Chinle Formation, Ghost Ranch, New Mexico. The *Coelophysis* Quarry is world-renowned for the abundance of well-preserved skeletons of *Coelophysis bauri*. The Ghost Ranch *Postosuchus* (Carnegie Museum of Natural History, CM 73372) is presently located on block C-4-81 and is housed at the State Museum of Pennsylvania (Harrisburg) for a temporary exhibit.

The Ghost Ranch *Postosuchus* is nearly complete postcranially with no associated skull material. This specimen is one of two known articulated *Postosuchus* and one of only two rauisuchians with a nearly completely known and articulated manus. The manus length is approximately 30% that of the pes. The proximal articular ends of the metacarpals imbricate tightly and digit I is associated with a large mediolaterally compressed ungual.

The most controversial element of *Postosuchus* is the structure of the manus. Preparation of the Ghost Ranch *Postosuchus* indicates manal morphology and dimensions different than the paratype manus of *Postosuchus kirkpatricki* and only in certain respects similar to the manus of the North Carolina *Postosuchus*. Metacarpals I and II of the Ghost Ranch *Postosuchus* do not show a groove and flange relationship such as that found between the proximal articular ends of the same metacarpals in the North Carolina *Postosuchus*. A distinctly grooved metacarpal I is unique to the North Carolina *Postosuchus* and strongly deviates from the pleisiomorphic reptilian manus. Structural differences between the manus of *Postosuchus* specimens suggests evolving manus morphology within this genus.

HEARING IN EOCENE WHALES (CETACEA, MAMMALIA)

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During the evolution of whales the ear had to change from receiving airborne sound to waterborne sound. In modern odontocetes this task is accomplished by radical changes in the ear morphology. The tympano-periotic complex is isolated from the skull by air sinuses. The medial side of the tympanic bone (involucrum) is pachyosteosclerotic, and the lateral wall (tympanic plate) is very thin. The lower jaw receives and guides sound through a fat body in its mandibular canal up to the tympanic plate. The malleus is synostosed to the tympanic plate, and the ossicular chain transmits sound to the inner ear. The tympanic membrane is an elongated ligament attached to the malleus, mainly functional in equalizing pressure in the middle ear cavity.

In pakicetids, the earliest whales, the periotic bone still had a bony connection to the skull, but the tympanic bulla already had an involucrum and a thin tympanic plate. A small mandibular foramen in the lower jaw, a tympanic ring in the tympanic bulla, and a fossil incus of *Ichthyolestes* indicate that the sound path to the inner ear passed through the external auditory meatus to the tympanic membrane and the ossicular chain, which were of the terrestrial mammal type. With this ear, pakicetids were able to hear in air, and in water they apparently relied on bone conduction, similar to modern pinnipeds, and lacked directional hearing.

The tympanic bulla of middle Eocene remingtonocetids and protocetids resembled that of modern dolphins, but the periotic bone was still connected to the skull although already partly surrounded by air sinuses. This suggests that directional underwater hearing was at least partly possible. A large mandibular foramen and a well-developed sigmoid process occur in these families. Also, the malleus of *Indocetus* is derived. The sound path in remingtonocetids and protocetids passed through the lower jaw and the tympanic plate, which had functionally replaced the outer ear canal and the terrestrial tympanic membrane. Taken together, the modern odontocete sound path evolved early in cetacean evolution, although apparently Eocene cetaceans did not echolocate.

NEW SPECIMEN OF THE MIOCENE MUSTELID *STHENICTIS* FROM THE MIOCENE OF INNER MONGOLIA, CHINA

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A lower jaw of the mustelid *Sthenictis* was recently recovered from the middle Miocene Tunggur Formation, Inner Mongolia, China. In size and morphology, it is slightly larger than *Sthenictis bellus* from the late Hemingfordian Sheep Creek Fm. of Nebraska, and *S. junturensis* from the early Clarendonian Black Butte l.f. of the Juntura Fm., southeastern Oregon. It is slightly smaller and less robust than *S. dolichops* from the early Barstovian Olcott Fm., Nebraska, *S. robustus* from the late Barstovian (Valentine Fm.) of Nebraska, and *S. lacota* from the Clarendonian of South Dakota. It is most similar to an undescribed new specimen (F:AM 25235) of *Sthenictis* from the Burge fauna (late Barstovian) of Nebraska, which is

probably a new species. Thus, the Mongolian specimen suggests that *Sthenictis* migrated from North America to Mongolia in the middle Miocene. This is yet another example of how mustelids, although rare, are valuable indicators of migrational trends between Eurasia and North America, and also good biochronological indicators.

CLOSING THE AFRICAN GAP: A NEW CRETACEOUS VERTEBRATE FAUNA FROM TANZANIA

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Recent Cretaceous vertebrate discoveries from Gondwanan landmasses, including South America, Antarctica, Australia, India, and Madagascar, have generated considerable data relevant to Southern Hemisphere vertebrate biogeography at the close of the Mesozoic. In some cases, fossils support Cretaceous Gondwanan cosmopolitanism, but in other instances Cretaceous faunas conform better to the hypothesis that Africa was isolated and had a relatively endemic fauna during much of the Cretaceous. These contrasting views are limited in one critical respect: relatively few fossils are known from terrestrial deposits on mainland (particularly sub-Saharan) Africa during the latter part of the Cretaceous. Thus, in many cases, biogeographic hypotheses rest on negative evidence where continental Africa is concerned.

To address this African Gap we conducted a four-week reconnaissance survey in Cretaceous-age deposits in Tanzania during summer 2002. This research was conducted in the virtually unexplored Mbeya Region of southwestern Tanzania, in deposits of the Red Sandstone Group. A number of productive vertebrate-bearing sites were discovered, and one particularly rich locality yielded a surprisingly diverse terrestrial/freshwater fauna. Vertebrate taxa recovered include osteoglossomorph teleosts, turtles, crocodiles, titanosaurid sauropod and both avian and nonavian theropod dinosaurs, mammals, and dinosaur (sauropod?) eggshell. Of particular interest is the presence of both articulated sauropod dinosaur remains, and small, isolated jaws and teeth, indicating the diverse preservational potential of the field area.

Initial comparisons suggest that at least some of the Tanzanian vertebrates are closely related to taxa from other Gondwanan landmasses, implying that continental Africa may have been part of a cosmopolitan Gondwanan faunal backdrop and not a center of endemism during the Cretaceous. Furthermore, the discovery and identification of such a diverse vertebrate assemblage underscores the importance of East Africa in general, and Tanzania specifically, for refining existing biogeographic hypotheses concerning Gondwana during the Cretaceous.

SCALING AND ECOMORPHOLOGICAL TRENDS IN THE EVOLUTION OF THE PLESIOSAUR LOCOMOTOR SYSTEM

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In this study we investigate the evolution of body size and locomotion in the Plesiosauria, a diverse clade of Mesozoic marine reptiles. We document and interpret evolutionary patterns in plesiosaur locomotor proportions and body size using measures of limb and girdle elements from well-preserved plesiosaur specimens. Size increase is a significant trend in the clade as a whole, and in constituent plesiosaur subclades. Several allometric trends, including changes in propodial and girdle proportions, appear concomitant with this size increase and are interpreted as responses to the physical constraints of large body size. Other trends in the locomotor system appear to be ecomorphological, perhaps tied to differences in hunting style. Pliosauromorph taxa are interpreted as high-acceleration, high maneuverability hunters, while plesiosauromorphs are interpreted as low-acceleration, high-efficiency cruisers. These ecomorphological patterns evolved convergently in several clades of plesiosaurs, and are significantly correlated with both body size and relative head size. These findings are independent of, but agree well with, previous work on plesiosaur flipper aspect ratio. Several lines of evidence therefore indicate that the aquisition of differently-sized prey items was an important factor in the evolution of the plesiosaur locomotor system.

THE POSITION OF WHALES AMONG MAMMALS: INCORPORATING NEW DISCOVERIES INTO CONTINUED COMBINED ANALYSIS

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Important new discoveries of fossil cetaceans have been argued to impact our understanding of cetacean phylogenetics, in particular, to clarify aspects of the much publicized conflict between molecule-based analyses and morphology-based analyses. The bases for these phylogenetic arguments, however, are often relatively limited cladistic analyses that include few characters and taxa. Some recent analyses have even been subsets of previously published cladistic analyses. When new analyses bypass but do not integrate so much published information, the resulting cladograms have only been weakly tested, making their significance hard to interpret. Molecule-based phylogenetic analyses have put forth the hypothesis that whales are nested among artiodactyls and closely related to hippopotamids. By contrast morphological support for any special relationship between hippopotamids and whales has been less forthcoming, however, some anatomical systems remain poorly explored. Simultaneous analysis of osteological data from cranial, dental and postcranial data partitions, as well as soft tissue data, combined with molecular sequences will best address controversial questions such as artiodactyl monophyly and the position of the extinct clade Mesonychia. Newly collected data from scanning electron microscopy of sperm represent a previously unexploited source of soft tissue character data for cladistic analysis. It has been suggested recently that dental characters are nonindependent and therefore less useful for mammalian phylogenetics than other characters such as molecules. This generalization, however, requires a variety of assumptions about the evolution of dental characters for which there is little evidence. As morphological cladistic matrices grow in size it becomes increasingly important to document character descriptions and character states with labeled illustrations rather than simple verbal descriptions. Labeled illustrations eliminate some of the ambiguity associated with morphological character descriptions thereby reducing the need to recollect data each time an investigator undertakes a new cladistic analysis.

EPAXIAL MUSCLES AND TENDONS IN ARCHOSAURS: THEY'RE NOT JUST FOR DUCK-BILLS ANYMORE

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In an attempt to better understand ossified tendons in extinct dinosaurs, epaxial musculature and tendons of living archosaurs (various bird species and *Alligator mississippiensis*) were dissected. The general pattern of tendons associated with the M. transversospinalis of alligators and the *M. longissimus dorsi* of birds were found to be conserved across living archosaurs. Moreover, these tendons commonly ossify in avian species that experience intratendinous ossification in other parts of the body. This finding has major implications for using the hadrosauriforme ossified tendon lattice as a synapomorphy. Given these data, functional interpretations of the lattice must be reevaluated. From a paleobiological perspective, reconstruction of the epaxial muscles, anatomical placement, and myotendinous/osteotendinous attachments of hadrosauriforme ossified tendons were described using first order inferences (extant phylogenetic method).

The histology of tendons across living archosaurs appears to be plesiomorphic in regards to the general tissue structure found in vertebrates. From a phylogenetic perspective, intratendinous ossification appears to be a character that occurs sporadically throughout Dinosauria. Histologically, there is little difference between the ossified tendons of dinosaurs (including birds), save pachycephalosaur tendons. Ossified tendons from living birds appear to be much less developed in terms of haversian bone formation than those found in extinct ornithischians. Developmentally, intratendinous ossification begins earlier in hadrosaurs (and probably all ornithischians) than it does in birds, though the developmental process appears the same.

Once anatomical and histological data are combined with the behavioral ecology of extant archosaurs, the functional argument for ossified tendons looses potency. This research indicates that intratendinous ossification probably occurs throughout Dinosauria for physiologic reasons rather than biomechanical stresses. Thus, intratendinous ossification in dinosaurs may be a classic example of adaptation, where the feature seen as adaptive is present prior to its exploitation.

EVOLUTIONARY TRANSITIONS IN THE ORIGIN OF BIRDS

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The emergence of birds from other theropod dinosaurs affected virtually every aspect of their behavior and biology. These transitions did not occur suddenly or in lockstep. Many features associated with birds or their flight preceded the appearance of *Archaeopteryx*, and even more such features evolved later. Growth rates were already high in bird ancestors, and these support high basal metabolic rates. Birds became small by shortening the duration of rapid growth found in their dinosaurian relatives; they became miniaturized adults. Sometime before the evolution of Neornithes, avian growth rates secondarily accelerated to near present rates. Feathers evolved in Maniraptoriformes and soon were turned to many functions, including thermoregulation, patterning, brooding, and eventually flight. The development of feather types in living birds generally parallels the apparent evolution of feather types in theropods. At their new smaller size, the feathers in the immediate ancestors of birds had significant aerodynamic advantage. This, coupled with the unique kinematics of the forelimb extension of maniraptorans, contributed thrust to the wing stroke and fostered the evolution of flight. During and after this transition, the emphasis in locomotory modules progressively shifted to greater reliance on the forelimb, though the hindlimb continued to be important for nearly all birds. It is striking that despite the behavioral and ecological diversification of birds, their bones still ossify in an invariable order.

There is yet no evidence for arboreal habits in the first birds. Small birds and their relatives may have run up the sides of trees and other structures, but there is no evidence for quadrupedal climbing, and no evidence that birds passed through a gliding stage on the way to powered flight. Although both precocial and altricial growth patterns have been reported in non-avian dinosaurs, basal crown-group birds are precocial, and they are ground-nesters, as the first birds must have been. Tree-nesting and its associated altriciality appear to be highly derived features of Neognathae.

IDENTIFICATION OF HYPSODONT HORSES FROM THE MIDDLE MIOCENE BARSTOW FORMATION BASED ON ISOLATED CHEEK TEETH

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Two genera and three species of hypsodont equids are recognized from the Barstow Formation, *Acritohippus stylodontus*, and two species of an unnamed genus, "*Merychippus*" *intermontanus* and "*Merychippus*" *sumani*. Each genus can be distinguished through cranial morphology, but isolated cheek teeth are most common. Thus, a study was undertaken to see if each genus and species could be recognized based on upper cheek teeth.

Acritohippus stylodontus exhibits typical "pliohippine" skull morphology. The dorsal preorbital fossa (DPOF) is shallow and unpocketed, and a malar fossa is present. The upper cheek teeth of *A. stylodontus* have an unworn crown height of ~35 mm. The protocone unites with the protoconule by 30% of wear (~25 mm), and the enamel fossette complexity is simple. The upper cheek teeth of *A. stylodontus* have an occlusal area of 530 mm^2 or greater.

"*Merychippus*" n.gen. is recognized by a large, pocketed DPOF which includes the infraorbital foramen, and has no malar fossa. The upper cheek teeth of "*M.*" *intermontanus* have an unworn crown height of ~50 mm. The enamel fossettes are more complex than those of *A. stylodontus*, and the protocone unites with the protoconule by 30% of wear (~35mm). "*M.*" *sumani* is differentiated from "*M.*" *intermontanus* by an unworn crown height of ~40 mm, more complex enamel fossettes, and a protocone that is isolated up to 60% wear (~18 mm).

A. stylodontus has a range from the Green Hills Division Fauna through the Second Division Fauna. "*M.*" *intermontanus* occurs in the Second Division Fauna, but does not become abundant until well into the Barstow Fauna. "*M*" *sumani* is found in the Green Hills Division Fauna, the Second Division Fauna, and the Barstow Fauna, but decline in abundance with increased occurrence of "*M.*" *intermontanus*. The decline of "*M.*" *sumani* coupled with the increased abundance of "*M.*" *intermontanus* up section suggests a speciation event recorded within the Barstow Formation.

DINOSAUR DEPOSITS OF KOREA: STRATIGRAPHY, PALEOENVIRONMENTS AND PRESERVATION

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Dinosaur remains including bones, tracks and eggs, are common in the Cretaceous non-marine deposits of Korea. Among the remains the tracks are predominant. The dinosaur bones occur mostly in the Lower Cretaceous floodplain calcic or vertic paleosols and channel deposits. The dinosaur tracks occur mostly in the Upper Cretaceous deposits, and one of the track sites is found in the Campanian to Maastrichtian deposits. The tracks are usually preserved in dry mudflat deposits which experienced calcareous pedogenesis. The widespread preservation of pedogenic calcretes in the dinosaur track deposits indicates that climate during their formation was seasonal and arid. It is thus inferred that repeated deposition by sheet-floods on mudflats of a perennial lake, which was used by dinosaurs as a persistent water source during droughts, and the subsequent development of calcareous pedogenesis were the main causes of the extensive preservation of dinosaur tracks. Recently, dinosaur eggs and clutches have been discovered from the Cretaceous deposits in Boseong, Sihwa, and Goseong. Among them Boseong sites are distinguished by the preservation of intact clutches. The general depositional environment of the Boseong egg-bearing deposits is a distal alluvial fan. Dinosaur eggs are preserved in vertic and calcic paleosols. In summary, the Cretaceous dinosaur deposits in Korea show selective occurrences in stratigraphy and depositional environments according to the fossil types. The dinosaur tracks are preserved mostly in the Upper Cretaceous marginal lake deposits. The bones occur mostly in the Early Cretaceous floodplain deposits. Most of the eggs are present in the Late Cretaceous alluvial fan deposits. Regardless of fossil types, most of the dinosaur remains in Korea are preserved in calcic paleosols. Consequently, dinosaurs inhabited alluvial fan, fluvial plain, and lake margin environments of Korean Peninsula throughout the Cretaceous under semi-arid climate, and the calcareous pedogenesis is deemed to have resulted in the preservation of the dinosaur remains.

A JUDITHIAN MICROFAUNAL LOCALITY IN ELK BASIN, PARK COUNTY, WYOMING

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Lithostratigraphic correlatives of the Montana Group are recognizable in Elk Basin, Park County, Wyoming. The Crosby Site, in the uppermost Judith River Formation equivalent, has produced *Myledaphus*, *Lepisosteus*, Theropoda, Hadrosauridae, Ceratopsidae, Crocodylia, and Chelonia, along with small amphibian, reptilian, and mammalian specimens as yet poorly identified. The fossiliferous stratum is a coarse dark-colored sandstone at the top of a thick sequence of strata dominated by cross-bedded sandstones typical of the marginal marine deltaic deposition of the Judith River Formation. The overlying Bearpaw Formation equivalent (marine) is approximately ten meters thick at the site.

The site provides a faunal sample from a southerly location, but typical of Judith River lithology, for comparison with the type area and other Montana localities and their Canadian correlatives. Contrasts to the Ellisdale Site (Marshalltown Formation of New Jersey) which is also marginal marine and of Campanian age, are attributed both to the subcontinental separation and the position of the latter site on a continental margin.

EVOLUTIONARY HISTORY OF THE ANKYLOSAURIA (DINOSAURIA: ORNITHISCHIA)

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Recently, there has been much discussion on ankylosaurian phylogeny, and several cladistic analyses have been published. However, the resulting cladograms all differ in their topologies and there is little consensus on the interrelationships of several taxa and on the monophyly (or otherwise) of several ankylosaurian ingroups. In addition the majority of these analyses contain only a limited number of taxa, mostly coded from the literature, and often consider only a small selection of the available character data (e.g. inclusion of cranial material only). The analysis presented here included all valid ankylosaur taxa, the majority of which have been examined firsthand, and is based on cranial, postcranial and dermal armour characters. These data were analysed using PAUP*4.0b10, producing 156 MPTs (CI=0.5382, HI=0.4618, length 288). Character re-weighting (using the RC index) reduced this to 15 MPTs. A reduced consensus analysis was then conducted in order to prune unstable taxa, and decay and double decay analyses were also undertaken. The Polacanthidae was found to be only very weakly supported and the enigmatic Gondwanan taxon *Minmi* was placed outside of the clades Ankylosauridae + Nodosauridae. Concordant with some recent analyses, the basal ornithischian *Scelidosaurus* is the sister taxon to the Ankylosauria. At present *Cedarpelta* falls outside of the Ankylosauridae + Nodosauridae: this is probably partly due to the immature nature of the specimens and to a large amount of missing data. The resulting trees were examined to assess the phylogenetic distribution and evolution of various character states, including the appearance and arrangement of dermal armour and the form of the scapulocoracoid, and to comment on the palaeobiogeography of various ankylosaurian clades. The 50% majority-rule tree was fitted to a stratigraphic range chart and this was compared to palaeogeographic maps of the Mesozoic. From this it can be seen that the earliest members of the Ankylosauridae are Asian and that there was a dispersal event to North America sometime in the middle Cretaceous.

GEOCHEMISTRY OF DINOSAUR BONES FROM THE CRETACEOUS HASANDONG FORMATION OF THE GYEONGSANG BASIN, KOREA

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Numerous Cretaceous dinosaur fossil bones, eggs, and footprints have been found in Korea during the past several years, demonstrating that the Korean peninsula was one of the most densely populated dinosaur habitats. We have conducted various geochemical analyses to test the possibility of direct age determination from the bone fossils, to determine the required conditions for bone preservation, and to evaluate diagenetic alteration of the bone chemistry and report some of the results here.

Electronprobe x-ray compositional maps reveal that porous original bone textures are well preserved, frequently filled with calcite. However, such spaces within the Galsari bone sample remain unfilled with calcite. Instead, thin films of aluminosilicate minerals are coated on the inner surfaces of the pores and filled the micro-fissures. It seems early diagenetic precipitation of aluminosilicate minerals made the bone less permeable and prevented them from calcite filling.

Sr-Nd-Pb isotopic compositions obtained from the bone fossils and their host sedimentary rocks show systematic variations. Even though the bulk analyses of host sedimentary rocks reveal relatively wide range of Sr isotopic compositions, reflecting diverse provenances, acid leachates show far less variations with relatively low $^{87}Sr/^{86}Sr$ values very similar to the bone fossils. Such low Sr isotopic compositions cannot be explained by the derivation of sediments only from the Precambrian basement gneisses and the Jurassic granites exposed wide around the Gyeongsang basin, but need a component with lower $^{87}Sr/^{86}Sr$ such as volcanics with significantly depleted mantle signatures. Isotopic compositions of Nd and Pb also support the addition of such depleted mantle component. It is noteworthy that there are closer similarities of isotopic compositions between the bone fossils and leachable components of their host sedimentary rocks than among bone fossil themselves, which strongly suggest that Sr isotopic compositions of the fossil bones reflect diagenetic alterations.

REVISED TAXONOMY OF THE LATE TRIASSIC AETOSAUR *DESMATOSUCHUS* (ARCHOSAURIA: CRUROTARSI) FROM THE SOUTHWESTERN UNITED STATES

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Episcoposaurus haplocerus was first described by E.D. Cope in 1892 from Carnian deposits of the Tecovas Formation in Texas. Twenty-eight years later E.C. Case described *Desmatosuchus spurensis* from the same area and horizon. Gregory synonymized the two taxa in 1953 resulting in the creation of the combination *Desmatosuchus haplocerus*. Since this time numerous specimens from the Late Triassic of the southwestern United States have been assigned to this taxon including specimens from the Norian age Post Quarry of Texas described by Small in 1985. This has led to the speculation that *D. haplocerus* has an extended temporal range, appearing in the late Carnian and extending to at least the mid-Norian (the Adamanian and Revueltian LVF). In Arizona *Desmatosuchus* has only been found in Carnian age deposits equivalent to the Tecovas Formation.

A new specimen of *Desmatosuchus* from the Lower Petrified Forest Member (Chinle Formation) of northeastern Arizona shows that the lateral dermal armor of all *Desmatosuchus* specimens from Arizona is identical to that of the Texas specimens from the Tecovas and distinct from Norian specimens of Texas and New Mexico. Thus the *Desmatosuchus* specimens from the Post Quarry appear to represent a new species. This new taxon can be distinguished from the Arizona/Tecovas specimens by the increased spinescence of the lateral armor with the lateral spikes of the cervical and posterior dorsal region being more elongate and recurved.

"Desmatosuchus" chamaensis from Upper Chinle deposits of New Mexico is not a valid species of *Desmatosuchus*. Instead it is a *Paratypothorax*-grade aetosaur akin to *Paratypothorax andressorum* and several undescribed taxa from Arizona and Texas and represents a new genus. As a result the temporal range of *D. haplocerus* is not as extensive as previously believed and is constrained to the Carnian (Adamanian LVF). Suggested occurrences of *Desmatosuchus* in North Carolina, Algeria, and Madagascar are based on scrappy, undiagnostic material and cannot be substantiated.

MAPPING ECOMORPHS ONTO SAUROPOD PHYLOGENY

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Contemporary cladistic analyses, the discovery of numerous new taxa, and advances in the functional inferences of locomotion, cervical mobility, and feeding have

greatly improved our understanding of the evolution and diversity of sauropod dinosaurs. For this integrative study, locomotor patterns, neck types, and skull and dental shapes were mapped onto an updated version of the Upchurch (1998) phylogeny of sauropods, producing the following observations:

1)Most ecomorphic discriminators appear repeatedly in different lineages. For example, ventral inclination of the skull relative to the occiput occurs within Diplodocidae and Brachiosauridae, and extreme cervical elongation, with increased vertebral count, occurs within Diplodocidae, Brachiosauridae, and Euhelopodidae.

2)Distributions of various ecomorphic discriminators do not always overlap. For example, elongate, sloping skulls occur within both the Titanosauroidea and the Diplodocidae, but those occurrences correlate with varying degrees of cervical elongation, and each of the two clades exhibits distinct tooth morphologies and dental battery configurations.

3) Some ecomorphic discriminators recur within two or more lineages with disjunct geographical distributions, an example being the presence of long, horizontally inclined necks within the Asian Euhelopodidae and the primarily American/European/African Diplodocidae.

Despite being constrained by a highly distinctive body plan, sauropods display considerable ecological diversity, which does not clearly reflect the overall phylogenetic or biogeographic history of the group. Instead, sauropods reflect a complex mosaic of ecomorphs which is a classic, albeit morphologically canalized, example of an adaptive radiation. Although its fossil record remains incomplete, the primarily Cretaceous lineage of Titanosauroidea appears to undergo its own ecomorphic radiation following the extinction of the other sauropod clades.

DESCRIPTION OF A NEW IMMATURE SPECIMEN OF *DEINONYCHUS ANTIRRHOPUS*, (SAURISCHIA, THEROPODA)

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Specimen MOR 1178 was excavated from the basal portion of Unit VII of the Cloverly Formation in a Lower Cretaceous site within central Montana. By comparison of the elements of its pes, lt. pes IV-5, rt. pes I-1, lt. pes IV-4, lt. pes III-4, and lt. pes III-1, with similar skeletal elements as found on the holotype YPM 5205, the fossil remains of this small theropod have been identified as *Deinonychus antirrhopus*. Though in some cases fragmentary, other skeletal elements include a lt. coracoid, rt. scapula, mid-section of a humerus, mid-section and partial distal end of a femur, lt. semi-lunar carpal, lt. manus I-2, proximal end of a rt. fibula, tarsal, proximal end of a rt. 2nd metatarsal, fragment of coossified sacral neural arches with a remnant of the neural spine lamina, several partial vertebrae, (1 distal caudal, 2 mid-caudal, 1 proximal caudal, 1 mid-dorsal, cervico-dorsal, cervical (C6?), and the axis) fragment of a possible sternal plate, dentary fragment, squamosal fragment, 1 partial tooth, ilium fragments, as well as some other as yet unidentified fragments. The unfused nature of the neural arch of a cervical vertebra (C6?) led to the determination that the growth stage of this specimen was that of a subadult. When compared to the more mature AMNH, YPM and MCZ specimens, there appears to be a considerable degree of variation in the relative size of the various skeletal elements of MOR 1178. In particular, the limb morphology of this specimen indicates a pattern of growth development that may differ from OMNH 50268, as well as from what has been observed in the juvenile growth stages of other more familiar theropods. Along with the derived character of the curvature of the manus II-3 ungual, the confirmation of this limb morphology may indicate some unique aspects to the possible juvenile behavior of this genus.

USE OF RARE EARTH ELEMENT SIGNATURES AND TRACE ELEMENTS IN VERTEBRATE FOSSILS TO DETERMINE PALEOENVIRONMENTAL CONDITIONS

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Concentrations of rare earth and other trace elements were measured in vertebrate fossils from marine, lacustrine, and terrestrial deposits in the upper Cretaceous Pierre Shale (South Dakota), Pleistocene Fossil Lake (Oregon) and other localities. REE signatures and concentrations of some other TE in fossils result from early diagenetic conditions in which fossilization occurred. Modern waters show systematic variations in REE signatures as a function of redox, pH, sorption, alkalinity, and other factors. If REE signatures in fossils are related to those of waters from which the REE were diagenetically obtained, then REE signatures and their stratigraphic variations can be used for interpretation of paleoenvironmental or early diagenetic conditions and trends. Visualization of REE signatures is enhanced by plotting representative light (Nd), middle (Gd), and heavy (Yb) REE in ternary diagrams. The ternary diagram allows the basic shape of the REE pattern to be represented.

REE signatures in Pierre Shale fossils relate to differences in mixing of oxic, shallow seawater and anoxic, deep waters. If mixing differences are interpreted as depth differences, then the lower Sharon Springs was deposited in deep, anoxic water, with gradual shallowing upward. The Gregory was deposited in shallow water, and the overlying Crow Creek, DeGrey, and Verendrye Members in progressively deeper marine waters. These interpretations are generally consistent with those based on faunal diversity and lithological interpretation of the members.

Changes in REE signatures within Fossil Lake sediments are interpreted as resulting from evolution between neutral pH and alkaline (high pH) waters resulting from climatic changes during the Pleistocene.

REE signatures from other fossil localities are also interpreted in paleoenvironmental terms and are consistent with other data interpretations.

WHO SAYS DROMAEOSAURS COULDN'T FLY?

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Conventional but obsolete phylogenetics continue to place the most bird-like avepod theropods basal to the *Archaeopteryx*-modern bird clade, even though Cretaceous dromaeosaurs, troodonts, oviraptorosaurs and therizinosaurs had advanced flight-related characters absent in *Archaeopteryx*, and became less avian as they evolved; classic indicators of loss of flight more advanced than that of the Urvogel. Obvious flight adaptations (oversized sternal plates, folding arms, pterosaur or bird-like tails) are usually explained away as exaptations, and pennaceous feathers are supposed to have evolved before flight. The discovery of sinornithosaurs (= microraptors and cryptovolians) with fully developed arm plus leg wings verifies that basal dromaeosaurs were aerial as the neoflightless hypothesis predicts. Presented as glider protofliers, in all regards sinornithosaurs were either as flight adapted as *Archaeopteryx*, or more so (much larger sternum, ossified sternal ribs and uncinates, strongly bowed outer metacarpal and flattened central finger that anchored outer primaries that were longer relative to the hand, alula feathers, swept back distal pubis which streamlined the body).

Sinornithosaur flight performance was intermediate to *Archaeopteryx* and *Jeholornis*. A similarly intermediate phylogenetic position probably applies to long tailed dromaeosaurs and troodonts, short-tailed oviraptorosaurs were close to or a little more derived than *Confuciusornis*. Large heads bearing serrated bladed teeth, raptorial fingers and sickle claws indicate sinornithosaurs were arch predators. Spherical femoral heads allowed the hindwing to be held horizontal, it could not strongly flap and may have been folded during normal powered flight, being deployed for soaring and/or for extra lift and drag during final approach to prey. Whether dromaeosaur hindwings were the basal avian condition or an independent adaptation is unclear, the dromaeosaur-like jeholornid tail suggests that pterosaur-like tails were the basal avian norm.

POSTCRANIA OF EARLY EOCENE *APHELISCUS* AND *HAPLOMYLUS* (MAMMALIA: "CONDYLARTHRA")

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Apheliscus is a relatively rare late Paleocene-early Eocene hyopsodontid "condylarth" whose postcranium has been unknown except for a single specimen described by Matthew in 1915. That specimen—very fragmentary and poorly preserved—provides little insight into either the locomotor habits or the phylogenetic position of the genus. A new skeletal association of *Apheliscus* from the early Eocene Willwood Formation (Bighorn Basin, Wyoming), along with additional reassociated postcranial elements from several Bighorn Basin quarries, permit interpretation of the postcranial morphology of *Apheliscus*, and reveal dramatic differences from *Hyopsodus*, the only other hyopsodontid known from substantial postcranial remains. Whereas the postcranium of *Hyopsodus* shows a mixture of terrestrial and scansorial features, forelimb and particularly hindlimb elements of *Apheliscus* indicate specialized cursorial or saltatorial locomotion. These specializations parallel those of contemporary leptictids, finding a close modern analog in the macroscelidean *Rhynchocyon*. The postcranial morphology of *Apheliscus* argues against a close relationship to *Hyopsodus*, and suggests that Hyopsodontidae, as defined on the basis of dental morphology, may be polyphyletic. *Apheliscus* also shows no convincing postcranial similarities to pentacodontid pantolestans (as represented by *Aphronorus*), another group to which it has sometimes been allied. The tarsus of *Apheliscus* shares derived features, however, with the tarsals of the louisinine hyopsodontid *Paschatherium* and with tarsals tentatively referred to *Haplomylus*. Several of these characters also appear in members of the Macroscelidea, consistent with the hypothesis that the origins of that order may be found among taxa currently placed in Hyopsodontidae.

THE ANATOMY OF THE MASTICATORY MUSCLES IN TWO STREPSIRRHINE PRIMATES AND INFERENCE OF MUSCLE ATTACHMENT AREAS FROM OSTEOLOGICAL MATERIAL

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Paleobiologists often use surface features on the skull to infer the attachments of masticatory muscles. These muscles are of interest partly because muscular variation often reflects variation in the pattern of masticatory movement. Combined with dental morphology, this pattern can be used to infer diet and other aspects of adaptation in extinct taxa. Closely related extant taxa are commonly considered to be the best models for inferring behavior in extinct taxa. Extant strepsirrhines are good analogues for the earliest true primates, especially Eocene adapoids. Prior to this study, few strepsirrhines have been examined with respect to the detailed anatomy of their masticatory muscles. Furthermore, the correlation between bony features and true muscle attachments has seldom been examined.

Dissection of two strepsirrhine primates, *Nycticebus coucang* and *Lemur catta*, has yielded information on the architecture, homologies and force production capabilities of their masticatory muscles. Fascial planes and abrupt changes in fiber orientation divide the jaw-closing muscles into eight separate units; within each, there is some functional and geometric heterogeneity. Pinnation and physiological cross-sectional area (PCS) were estimated for each unit. The medial pterygoid is very pinnate; the deep masseter and deep temporal are also pinnate relative to the other muscles of mastication. The PCS of the superficial temporal, deep temporal and superficial masseter together represent more than half that of the entire masticatory musculature.

An estimation of jaw muscle attachment from bony surface morphology was compared to the true areas of attachment. Some muscle attachments were more reliably estimated than

others. Aponeurotic and tendinous attachments can be estimated accurately, whereas fleshy (direct) attachments are less reliably estimated. Several subtle bony features not initially observed actually correspond to muscular borders. Knowledge of these subtle features, coupled with finer histological techniques, may enable inference of areas of jaw muscle attachment in comparable, well-preserved fossil primates.

POSTCRANIAL ANALYSIS AND FUNCTIONAL MORPHOLOGY OF LATE HEMPHILLIAN CARNIVORA FROM NORTH CENTRAL OREGON

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This study describes locomotory adaptations and prey-capture techniques of one of the most diverse Hemphillian carnivoran faunas in the United States, from Oregon. Fossil genera are compared with extant genera of known locomotor type: *Canis, Vulpes, Ursus, Bassariscus, Procyon, Taxidea, Martes, Mustela, Gulo, Felis, Lynx, Acinonyx, Panthera,* and *Equus* using specific postcranial measurements to determine locomotor type (arboreal, cursorial, or fossorial). Length of m1 was used graphically to determine body size. Postcranial measurements include several on the distal humerus, proximal radius, and proximal ulna reflecting amount of pronation-supination of the manus; on the astragalar trochlea, reflecting amount of movement allowed of the pes; and metapodial compactness, reflecting cursorial ability. Eight fossil genera of Carnivora and their locomotory adaptations are discussed including: *Canis, Agriotherium, Bassariscus, Pliotaxidea, Martes, Plesiogulo, Barbourofelis,* and *Pseudailurus*. Body size was used to exclude a fossil genus from a certain locomotor type (arboreal or fossorial). Measurements from the humerus in fossils of *Canis, Pliotaxidea, Martes, Barbourofelis,* and *Pseudailurus* reflect those of extant locomotor types. Locomotor type could not be determined from the humerus for *Agriotherium, Bassariscus,* and *Plesiogulo* due to the lack of fossils. Measurements from the radius and ulna show felids to have the highest amount of pronation-supination and fossorial animals to have the least, with cursorial animals intermediate. These results are counterintuitive and require further investigation. Measurements from the astragalus and appression of metapodials in fossil *Canis, Bassariscus, Martes,* and *Barbourofelis* reflect extant locomotor types. Locomotor type could not be determined from the astragalus for *Agriotherium, Pliotaxidea, Plesiogulo,* and *Pseudailurus* due to the lack of material. For each genus studied, modern lifestyles were reflected in the fossil bones of related taxa, suggesting that the ancient lifestyles were similar to extant lifestyles of related taxa.

THE CHINESE VAMPIRE AND OTHER OVERLOOKED PTEROSAUR PTREASURES

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Previously considered indecipherable, the crushed skull elements of the newly discovered Chinese anurognathid pterosaur, *Jeholopterus ningchengensis*, yield new information on the unusual feeding strategy of this extinct flying prolacertiform. Vampirism is indicated by a suite of characters. Two hypertrophied maxillary fangs are buttressed posteriorly by a hyperrobust palate arranged to transfer stabbing shocks laterally and posteriorly. The gape is greatly increased by a quadrate that not only leans anteriorly, like that of a rattlesnake, but the articular surface bends posteriorly. Plus the jaw line is curved 90° from premaxilla to quadrate. After fang insertion, such a curve permitted the blunt rostrum to roll forward, locking the fangs beneath the victim's epidermis for unshakable adhesion. The dentary teeth are small and closely spaced for gripping without penetrating a pinched mound of dermis oozing blood. Presumably blood was ingested via tongue lapping. Unlike other pterosaurs, the hyper-extendable and flexible manual claws were capable of parallel insertion into a wall-like substrate, in this case, dinosaur skin. Pedal digit V was longer than in any other pterosaur, apparently to increase puncture leverage for anterior claw penetration, like a church key can opener. The sharp terminal phalanx of pedal digit V could be injected posteriorly for unshakable pedal adhesion. The atypically flexible tail was tipped by a bundle of hairs. A slender plume-like parietal crest extended as far as the pelvis. Both could have been used to distract flies while *Jeholopterus* was otherwise immobilized during feeding. A sister taxon, *Anurognathus*, has primitive versions of these characters. Another sister taxon, *Batrachognathus*, shares robust limbs, a small sternum and large eyes, but does not have large claws, or fangs. It appears to have been a more benign feeder than the nightmarish *Jeholopterus*.

A COMPLETE REDESCRIPTION OF THE FRENCH *COMPSOGNATHUS* WITH SPECIAL CONSIDERATION OF THE ANATOMY OF THE HAND

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Re-examination of the Canjuers *Compsognathus corallestris* from the Portlandian limestones of the Tithonian of southern France provides us with new cranial and postcranial information that allow a new interpretation of the genus *Compsognathus*. The skull is long and slender, with a reconstructed maximal length of 100mm making up 22% percent of the presacral vertebral column. Twenty-three presacral, five sacral, and thirty-one caudal vertebrae are preserved in situ. The pubis slightly surpasses the femur in length and its pubic boot shows no anterior extension but a pronounced posterior one. A large obturator process and a distal expansion into a small foot characterize the ischium. The ilium is slightly convex dorsally and the anterior iliac process seems to have been shorter than the posterior one.

C. corallestris possessed three functional digits in the hand. Most of the manual elements are fragmentary. Only the proximal halves of the right metacarpals I and II, and the proximal extremity of phalanx I-1 of the left manus are preserved. Metacarpal I-III of the right and left manus, as well as five additional phalanges are known from their impressions in the calcareous matrix. These impressions are well defined and their corresponding elements were mostly articulated before they were lost. Metacarpal I-III are comparable to the same elements in other theropods, e.g., *Ornitholestes*, *Deinonychus* and *Archaeopteryx*, in possessing a short and stout MTI, a stout and long MTII, and a slender, long and somewhat curved MTIII. The right carpus preserves the radiale, distal carpal one, and distal carpal two. Distal carpals one and two do not build a semi-lunate carpal, as there is a well-defined suture separating the two elements from each other.

Anatomical and morphological characters displayed in the Bavarian specimen of *Compsognathus* are nearly identical to the same characters in the Canjuers specimen. Differences can be attributed to different ontogenetic stages of the two specimens. Therefore, this study supports the idea that *C. corallestris* is a junior synonym of *C. longipes* from Bavaria.

THE ROLE OF SYNSEDIMENTARY CARBONATE CEMENTATION IN THE PRESERVATION OF DINOSAUR TRACK SITES: AN EXAMPLE FROM THE DAKOTA FORMATION

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A dinosaur track-bearing sandstone and several paleosol horizons within the Late Albian Dakota Formation in the Nebraska-Iowa region have been analyzed in order to elucidate their paleoenvironmental conditions and diagenetic history. The track host sandstone was deposited as a bar complex in a fluvial-estuarine setting, while the mudstones were deposited within the central estuarine bay. Paleosol development was limited to interfluve positions. The track host horizon marks a transition between these depositional settings and is likely a parasequence boundary within the Muddy Cycle. Petrography shows pervasive early calcite cementation of the track host sandstone. High minus-cement-porosity (> 47%) indicates lithification prior to loading by overlying strata. Blocky poikilotopic calcite cements indicate precipitation in phreatic environments. Cathodoluminescence petrography reveals two temporally distinct calcite zones in track site strata, and four cement zones in equivalent strata from a nearby section. Oxygen and carbon isotopic compositions of cement zones and approximately coeval paleosol sphaerosiderites are used to assess the diagenetic history and paleogroundwater evolution. Earliest calcite cements precipitated in a zone of mixing between meteoric and marine pore fluids. Later calcite cements precipitated in groundwater systems dominated by meteoric fluids. Paleosol sphaerosiderites serve as isotope proxies for meteoric groundwater recharged by local paleoprecipitation. Comparison of these values with those from the track-bearing sandstone horizon delineates the geochemical evolution of coastal groundwater. Track site cementation resulted from changes in groundwater flow in response to a relative sea level rise. Subsequent cementation occurred as shoreline progradation produced an apparent sea level fall. Ultimately, we conclude that the preservation of dinosaur tracks at this locality is in response to local depositional controls on groundwater evolution. We argue that track preservation is often achieved by precipitation of early diagenetic cements.

NEW MULTITUBERCULATE MAMMALS FROM THE LATE CRETACEOUS KIRTLAND FORMATION, SAN JUAN BASIN, NM

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Ongoing fieldwork in the Naashoibito Member of the Kirtland Fm. is resulting in the recovery of a diverse mammalian fauna from microvertebrate localities, the Alamo Wash local fauna. The Naashoibito fauna is probably correlative with those of the Lancian North American Land-Mammal "Age."

Multituberculate mammals recovered include *Essonodon*, a Lancian index taxon. *Essonodon* is significantly more common in the Naashoibito than in any more northern fauna. At least four additional multituberculate taxa are present. One of these is tentatively identified as *Mesodma* sp. nov., similar to but not conspecific with *M. archibaldi*. We refer another to Cimolodontidae gen. et sp. nov. A third small, apparently new, taxon is currently too incomplete for meaningful assignment. A single upper anterior premolar indicates the presence of a larger multituberculate that may have been in the size range of *Cimolodon nitidus*. Incisors are commonly recovered; none found so far have the restricted enamel characteristic of some early Paleocene lineages. The average size of multituberculate teeth recovered from the Naashoibito is smaller than that of teeth recovered from the contemporaneous Hell Creek and Lance Formations. This may reflect different taxonomic composition and taphonomic factors. It may also reflect Bergmann's Rule, since the *Essonodon* specimens are smaller than those reported elsewhere, although morphologically identical to *E. browni*.

Within the North American Western Interior, mammalian faunas of the preceding Judithian Land-Mammal "Age" and of the subsequent Puercan differ taxonomically with latitude. Evaluation of latitudinal variation in faunal composition during the latest Cretaceous has been hampered by the lack of diverse mammalian faunas from the southern Western Interior. Our findings thus far suggest that in the latest Cretaceous there was similar north-south variation in mammalian faunas. We propose that as a result of southern endemicity, multituberculate diversity of the Western Interior in the time period preceding the end-Cretaceous extinction has been underestimated.

A JUVENILE ALLOSAUR WITH PRESERVED INTEGUMENT FROM THE BASAL MORRISON FORMATION OF CENTRAL WYOMING

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Recent excavations at the Meilyn Quarry near Medicine Bow, Wyoming have produced a large adult allosaur and a new specimen interpreted as a juvenile of the same species. They

were recovered 11 meters above the base of the Morrison Formation within a fine-grained sandstone with depositional features indicating an ephemeral fluvial system. Taphonomic indicators, including a high degree of articulation and skin impressions, argue for little to no fluvial transport and the presence of soft tissues at the time of burial.

Disarticulated cranial material includes both dentaries, surangulars, prearticulars, splenials, hyoids, jugals, quadratojugals, quadrates, squamosals and pterygoids, right articular, maxilla, palatine and vomer, left postorbital and prefrontal, and a partial braincase. Most of the vertebral column, ribs and gastralia are represented, except the atlas, axis and some mid-caudals. Limb materials include shoulder girdles, forelimbs and the right hindlimb. The left side of the body preserves a 30 cm2 skin impression consisting of small scales 2-3 mm in diameter. This suggests that juvenile allosaurs possessed scaly integument. This represents the most derived tetanuran to retain this character, otherwise present in more basal theropods such as *Carnotaurus*.

Overall length of the specimen is estimated at 4 m with a hip height of 1 m and skull length of 36 cm, suggesting that this animal is a juvenile. Furthermore, size-independent morphological characteristics—including open cranial and postcranial sutures, forelimb and hindlimb proportions, and juvenile bone surface texture—are also indicative of a juvenile specimen.

Comparisons with juvenile and adult allosaur material from the Cleveland-Lloyd Quarry, and material of a new allosaur (DINO 11541), suggest that this new specimen is not *Allosaurus fragilis*, based primarily on a relatively flat ventral jugal margin, and the shape of the caudal neural spines. These characters together with a wide obturator notch on the pubis of the adult specimen are consistent with characters present on DINO 11541, suggesting that these two animals belong to a distinct species of *Allosaurus*.

A NEW SAUROPOD TRACKSITE FROM THE UPPER JURASSIC MORRISON FORMATION WITH PRESERVED SKIN AND FOOT-PAD IMPRESSIONS

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A newly discovered sauropod tracksite from the Upper Jurassic Morrison Formation in Shell, Wyoming, provides new information about sauropod foot morphology, locomotion dynamics, and resultant substrate deformation. Several track-bearing horizons are preserved in crevasse-splay deposits associated with channel sandstones and paleosols dated at 155 to 144 Ma. Individual trackways appear to be wide-gauge and, as such, are likely attributable to titanosaurs.

Tracks occur as convex hyporelief and concave epirelief casts on the undersides of sandstone beds and range from 20 to greater than 100 cm in diameter and 10 to 60 cm deep. Exposed cross-sections reveal lobate- to asymmetrical lobate-shaped impressions with clear deformation of immediately underlying beds. Variations exist among prints of the same size and shape, reflecting changes in substrate consistency and differentially preserving 0 to 5 digits (pes) and rare skin and foot-pad impressions.

Skin impressions appear as symmetrical to elongate hexagonal surfaces ranging from 0.75 to 1.2 cm along the principal axis, separated by depressions with V-shaped profiles. This pattern of repeated polygonal units in relief is consistent with that of an infilled track with scale impressions, rather than a mudcracked surface.

A NEW GOBIOSUCHID CROCODYLIFORM TAXON FROM THE CRETACEOUS OF MONGOLIA

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We report a new fossil crocodyliform taxon found in the Cretaceous Red Beds of the Zos Canyon (Mongolia). This new form shares numerous derived characters with *Gobiosuchus kielanae*, also known from the Late Cretaceous of Mongolia (Bayn Dzak locality). However, it is distinguished from *Gobiosuchus kielanae* by the presence of six autapomorphic characters. Some of these are unusual morphologies for a crocodylomorph and concern the presence of a well developed spiked armor (e.g., retroarticular process with a well developed ornamented posterolateral spike-like process and presence of extremely well developed keels on dorsal and lateral cervical osteoderms, the height of which is approximately as long as the lateromedial extension of the dorsal osteoderms).

The phylogenetic relationships of *Gobiosuchus* and the new taxon are evaluated through a parsimony analysis of 193 characters scored across 50 taxa. In all the most parsimonious hypotheses, the new taxon is depicted as the sister group of *G. kielanae*, forming a strongly supported clade diagnosed by 14 unambiguous synapomorphies (e.g., palpebrals fused to each other and the frontal, excluding it from the orbital margin, external surface of ascending process of jugal exposed posterolaterally, dorsal surface of posterolateral process of squamosal ornamented with three longitudinal ridges, dorsal surface of osteoderms ornamented with anterolaterally and anteromedially directed ridges, cervical region surrounded by lateral and ventral osteoderms sutured to the dorsal elements, presence of appendicular osteoderms, and closed supratemporal fenestra). This clade is positioned basally among crocodyliforms, although it is apparently more closely related to mesoeucrocodylians than to protosuchids (i.e., rejecting the monophyly of a large clade traditionally referred as “Protosuchia”).

The phylogenetic context of this new form, together with previously known taxa, provides another insight into the diversity achieved by late appearing basal crocodyliforms of Central Asia, as recorded in Upper Cretaceous beds of Mongolia.

PALEOPHYLOGEOGRAPHY AND PHYLOGENETIC RECONSTRUCTION

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Paleophylogeography is the study of phylogenetic and geographic history within species using fossil data. Whereas phylogeography of extant taxa is studied using molecular markers, paleophylogeography is limited to quantitative morphological data. As with genes, morphological traits have a variety of evolutionary rates that differ trait to trait and group to group. And as with genes, a particular trait will only be useful if it evolves quickly enough for divergence to have accumulated, but slowly enough not to have been unduly ‘saturated’ by evolutionary reversals. Multivariate traits are often superior for paleophylogeographic work because, *ceteris paribus*, the probability of exact evolutionary convergence decreases with dimensionality; however, univariate traits, *ceteris paribus*, diverge more quickly and may provide better resolution for some problems. New research on mammals indicates that linear measurements of teeth and skulls evolve at a rate that is amenable for studying taxa separated by 1,000s to 10,000s of years, multivariate measurement of molar shape is appropriate for taxa separated by 10,000s to 1,000,000s of years, and discrete presence-absence traits are appropriate for divergences of 1,000,000s to 10,000,000s of years.

With conspecific samples, the probability that an older and younger sample may belong to the same ancestor-descendant lineage is high enough to warrant explicit testing. Traditional discrete-character cladistic analysis is not adequate in this case because its nested data can only resolve relative recency of common ancestry; for discrete traits, stratocladistics is the only method currently available. For quantitative traits, either multivariate or univariate, a number of techniques are available, including maximum-likelihood and Bayesian analysis. Multivariate shape data are particularly amenable to these techniques through analysis of the scores of population means after superposition and rotation to orthogonal axes. Tree support can be assessed by bootstrap techniques in which the members of each population are resampled, population means recalculated, and reordination and tree construction iteratively performed.

TAXONOMY AND SYSTEMATICS OF THE HOLOTYPE OF *HADROSAURUS FOULKII* (DINOSAURIA, ORNITHOPODA) FROM THE LATE CRETACEOUS OF EASTERN NORTH AMERICA

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Hadrosaurus foulkii, the first dinosaur in the Americas known from relatively complete remains, is the type of the family Hadrosauridae. The holotype of this historically significant taxon has been reexamined to ascertain its systematic position and phylogenetic importance. *H. foulkii* is diagnosed on the basis of two autapomorphies: the presence of a hook-like preacetabular process on the ilium that thins dorsoventrally and has a dorsal edge that arches 180 degrees anteroventrally, and the possession of an ischial shaft that arches dorsodistally, forming a dorsally concave profile. A phylogenetic analysis of 105 characters that includes *H. foulkii* and 19 hadrosaurids (8 hadrosaurines, 6 lambeosaurines, and 5 non-hadrosaurid iguanodontians) was performed on PAUP 4.0b10, using a branch-and-bound search under both ACCTRAN and DELTRAN parsimony options. The strict consensus cladogram of 3111 most-parsimonious trees (length = 191, consistency index = 0.64, retention index = 0.74) is very poorly resolved, indicating *Hadrosaurus foulkii* as part of a large polytomy composed of euhadrosaurian taxa, with some internal differentiation into higher clades (i.e., *Maiasaura*, *Brachylophosaurus*, *Lophorhothon*, *Gryposaurus*). However, the majority rule consensus tree indicates that *Hadrosaurus foulkii*, *Kritosaurus australis*, and Euhadrosauria have an unresolved relationship with each other, but are otherwise the sister-group to *Telmatosaurus* within the context of the Hadrosauridae.

BIOGEOGRAPHY AND DIVERSITY PATTERNS OF NORTH AMERICAN RHINOCEROSES

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In the process of a systematic revision of the North American Rhinocerotidae, a number of striking biogeographic patterns emerged. During the late Eocene, only one species (*Trigonias osborni*) is common, but there are rare specimens of *Subhyracodon mitis* In the Oligocene, North American rhino faunas were very low in diversity and homogeneous, with only one species each in three genera (the common *Subhyracodon*, plus the rare *Amphicaenopus* and *Penetrigonias*) in the Orellan and Whitneyan. Although these faunas are largely known from the Great Plains, rare occurrences in the Gulf Coast and California confirm this pattern. By the Arikareean, the diversity was reduced to one lineage (*Diceratherium*), but there were two sympatric species of *Diceratherium* in many locations in North America. They include the large *D. armatum*, and the smaller *D. annectens,* each of which shows sexual dimorphism in large quarries such as the Frick 77 Hill Quarry in Niobrara County, Wyoming. With the invasion of *Menoceras* in the latest Arikareean, diversity increased briefly as several species of both genera coexisted (along with the rare immigrant *Floridaceras*), then decreased following the extinction of *Floridaceras* and *Diceratherium*. In the middle-late Miocene, most North American faunas produce at least two rhino genera, typically a browser (an aceratherine, such as *Aphelops* or *Peraceras*) and presumed grazer (a teleoceratine, such as *Teleoceras*). However, rhinos were very rare in Miocene faunas of the Rockies and Great Basin (compared to horses and camels in those faunas), while they were extremely abundant in contemporaneous deposits from the Great Plains. Unique endemic dwarfed species were found in the Gulf Coastal Plain, and the Santa Fe Group of New Mexico also produces a unique short-nosed species of *Teleoceras,* which may have had a tapir-like proboscis (like that of the cadurcodont amynodont rhinos).

DOES LAMNOID TOOTH TERMINOLOGY NEED REVISION?

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For nearly a century the lamnoid tooth terminology developed by Leriche with minor modifications by Applegate (1965) and Compagno (1988) has been used successfully by paleontol-

ogists and ichthyologists in describing these teeth. Siverson (1999) and Shimada (2002) proposed changes in the identifications of the intermediate and anterior teeth of these sharks. Although as with any tooth terminology, such as that of mammals, misidentifications occur in the literature, the usage of Leriche's terminology is not in a state of confusion as stated by Shimada (2002). Specimens of Recent sharks provide evidence that Siverson's and Shimada's changes in terminology are not justified.

THE ADAPTIVE SIGNIFICANCE OF CRANIAL KINESIS INVESTIGATED USING FINITE ELEMENT ANALYSIS

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Finite Element Analysis (FEA) has the potential to test hypotheses of adaptation and constraint in skeletal constructs. This paper presents one such analysis, which investigates skull construction and the adaptive significance of cranial kinetic joints, particularly with respect to stress dissipation, in theropod dinosaur crania. A comparative approach is taken, and the crania of three taxonomically disparate theropods, *Coelophysis*, *Allosaurus,* and *Tyrannosaurus rex*, are investigated.

This preliminary study uses 2D lateral aspect FE-models of crania and as test cases. The accuracy of 2D results is tested against results produced for a 3D model of *Allosaurus* crania. To avoid potential errors in muscle and condylar force estimation and posterior expansion of the skull, a region from anterior snout to the anterior edge of the temporal fenestrae is considered. Estimated bite forces taken from the literature are applied to the teeth of these digital models. Stress and strain distribution patterns and vector orientations are recorded for 'solid' skulls. Kinetic joints are then introduced at the postorbital-jugal contact and the jugal-maxilla contact to create regions of mobility. Stress distribution patters are recorded once more.

The results confirm the hypothesis that the introduction of kinetic joints reduces stress about the region of mobility. However, stress and strain are concentrated to other regions of the crania, often to a higher magnitude, and therefore with a presumably detrimental effect to cranial performance. These results are preliminary and future work will focus upon the introduction of soft tissues, dynamic force application and 3D models. Nevertheless, here I present the immediate effect of the introduction of cranial joints in terms of mechanical performance. This analysis hints that the evolution of cranial joints proceeded in a correlated manner to minimise stress concentrations. The adaptive significance of kinesis in theropod crania raises questions concerning the evolutionary pressures and the mechanical performance of the skull during the transition from non-avian to avian dinosaur.

A NEW TOOL FOR PALEOPATHOLOGICAL ANALYSIS: DEVELOPMENT OF A DESCRIPTION-BASED CLASSIFICATION SYSTEM FOR PATHOLOGICAL BONES

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Diagnosis of atypical bone morphology in fossil material presents inherent challenges. Considerations of diagenetic pseudopathology aside, because bone response to disease or trauma is a combination of two processes (bone production and bone destruction) two different diseases may result in the same pathological appearance. In addition, different taxa (or even different individuals) may respond to the same pathogen in a different manner. An additional complication is the central assumption underlying paleopathology: that ancient bone diseases and modern bone diseases are identical. This uniformitarianism is a necessary working condition in analysis of ancient pathology, although it flies in the face of evidence about microbial evolution and varied host immune response. All of these factors do not undermine the value of paleopathology, but do warrant caution when interpreting the etiology of abnormal bone. Since diagnosis of a specific disease on dry bone may not always be advisable, paleopathological studies should address a spectrum of possibilities through differential diagnosis, which allows consideration of multiple working hypotheses.

In addition to those detailed above, additional paleopathological problems include the following: (1) Medical terms are often interpretation-based, rather than descriptive; (2) Diagnoses are almost always based upon human disease patterns and data, without consideration of other taxa; and (3) A single diagnosis is commonly sought, without fair consideration of other possibilities. Development of a description-based classification system is one step towards resolving some of these issues. We propose a web-based resource for paleontological paleopathology that features a key for narrowing diagnosis: a description-based scheme inductive reasoning protocol. This will be specifically tailored to the needs and abilities of the nonspecialist. A glossary of non-human as well as human pathology terms and diseases with related photos will be included.

COTYLOSAUR PHYLOGENY AND THE INITIAL DIVERSIFICATION OF AMNIOTES

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A phylogenetic analysis of cotylosaurs confirms the sister-group relationships between diadectomorphs and amniotes. Diadectomorpha forms a clade, with *Limnoscelis* being the sister-taxon to the clade of *Tseajaia* and a monophyletic Diadectidae. Although the composition of the Cotylosauria, Diadectomorpha, and Amniota has changed repeatedly during the last century, their present structure and pattern of relationships are strongly supported by several cranial and postcranial synapomorphies. The late appearance of diadectomorphs in the fossil record relative to its amniote sister-taxon results in a long unrecorded history for the group.

Studies of Pennsylvanian (late Carboniferous) cotylosaurs includes reassessment of the taxonomic identity of the oldest known amniotes *Hylonomus* and *Protoclepsydrops* from Joggins, Nova Scotia, of the enigmatic *Cephalerpeton* from Mazon Creek and Linton, Ohio, and of other "captorhinomorphs". Cotylosaur phylogeny also confirms the basal dichotomy of amniotes into synapsids and sauropsids, with a subsequent dichotomy of sauropsids into parareptiles and eureptiles, but results in the erection of long ghost lineages for several amniote taxa. The presence of long ghost lineages of diadectomorphs, parareptiles and eureptiles creates interesting challenges in the studies of not only the origin of amniotes, but also the initial pattern of diversification of amniotes.

UNUSUAL PRESERVATION OF THE 3-DIMENSIONAL ORGANIZATION OF FIBERS IN DINOSAUR BONE TISSUE

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Bone is a load-bearing skeletal structure composed mainly of fibrous collagen stiffened by calcium phosphate. The fiber organization and its relationship to the anisotropic mechanical properties of bone is of considerable importance to understanding the functional behavior of the tissue under the varying loads on skeletal elements. However, the details of this organization are still incompletely known, even for modern mammals.

We describe an unusual type of preservation for some dinosaur bones in which the courses of fiber bundles can be seen in their 3-dimensional geometry. Polarizing microscopy of both modern and fossil bone tissue allows discrimination of gross differences in the angle with which the fibers intercept a given plane, but does not reveal the directions of the fiber bundles within that plane. In optical thin sections of some dinosaur bones, however, we have found fine parallel structures which reflect fiber directions. These structures do not appear to be cracks because they are roughly circular in cross-section. Their directions are consistent with what one sees under polarizing microscopy: they tend to be aligned longitudinally (parallel with the long axis of the bone) but near vascular canals they tend to be more transversely oriented. In these sections, unlike views of fibrillar organization under crossed polars, one can observe precise fiber directions. For example, changing patterns of fiber directions around vascular canals can be traced over long distances in longitudinal sections. In transverse sections, by focussing and defocussing, one can see the trends of numerous adjacent fiber bundles in 3 dimensions. These data can lead to an understanding in greater detail of the organization of fibers in different taxa and in different regions of bone.

THE PALEOBIOGEOGRAPHY OF TRIASSIC SAUROPTERYGIA

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Triassic stem-group Sauropterygia, which include placodonts, pachypleurosaurs, and basal eusauropterygians, are known from three faunal provinces. These are the Western Tethyan, the Eastern Tethyan, and the Eastern Pacific provinces respectively. The most complete record is from the Western Tethyan province (Europe and circum-Mediterranean localities); Triassic sauropterygians are very rare in the Eastern Pacific Province (Western North America); important new faunas have recently been discovered in the Triassic of the Eastern Tethyan province (Guizhou Province, Southeastern China). Given their restriction to nearshore habitats or shallow epicontinental seas, it is unlikely that stem-group sauropterygians had the capacity for trans-oceanic dispersal. Dispersal along coastlines may have been an important component of their biogeographical history, as is indicated by 1) phylogenetic affinities of the faunal elements from the Eastern and Western Tethyan provinces; 2) the immigration of sauropterygians into the Anglo-Germanic basin at the transition of the Lower to the Middle Triassic; and (3) the population of the Alpine Triassic by sauropterygians after the evolution of the appropriate intraplatform basin habitat during the Middle Triassic. Conversely, trans-Panthalassan relationships of pistosaur sauropterygians appear best explained as a consequence of vicariance due to the accretion of exotic terranes at opposite margins of the Pacific Basin. A vicariant event resulting from the opening of the southern branch of the Neotethys may also account for the sister-group relationships of nothosaurs from the northern Gondwanan shelf and the Anglo-Germanic basin.

AN EXPERIMENTAL APPROACH TO IDENTIFYING AND INTERPRETING DERMESTID (INSECTA, COLEOPTERA) BONE MODIFICATION

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The fossil record preserves many examples of post-mortem bone modification, including surface weathering, breakage, trample traces, tooth traces, and insect traces. These features, although not always linked unequivocally to the trace-maker, can provide a valuable tool for reconstructing paleoecology and paleoenvironment. Careful description and interpretation of bone modifications are of paramount importance for accurate taphonomic reconstruction.

Bone modification specifically attributed to insect activity has been noted in several fossil localities. However, insect-related bone alterations need to be studied from an experimental perspective before we can fully appreciate their paleoenvironmental and paleoecological significance. We report here preliminary results of an experimental study of bone modification by dermestid beetles (Coleoptera: Dermestidae). The dermestids are the most commonly cited insect linked to traces in fossil bone. A series of experiments were performed under controlled conditions using four dermestid beetle colonies. Food availability, food type, and substrates were varied in the four colonies. Preliminary results reveal that a variety of different trace morphologies may be produced, ranging from discrete oval-shaped borings through cortical bone to large, irregular excavations in trabecular bone. Spongy marrow cavities of large limb elements were utilized more than any other type of bone. In addition, narrow sub-vertical burrows and small circular borings were constructed in the substrate of dermestid colonies floored by sand and wood, respectively. Interestingly, the traces observed in this study appear to differ from those traces attributed to dermestid beetles in fossil studies. The most significant aspect of this study is the observation that bone utilization appears to be strongly medi-

ated by resource availability. Specifically, bone modification was most pronounced under conditions in which both food and substrate (for pupation/shelter) were limited. Thus, the nature and extent of dermestid traces may serve as an indicator of a stressed habitat where food availability and nesting substrates are limited.

QUANTITATIVE DESCRIPTION OF SAUROPOD TRACKS–A GEOMETRIC MORPHOMETRICS STUDY

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A geometric morphometric analysis of shape variation in a sample of 22 sauropodomorph footprints of the world ichnological record was conducted. In this analysis we included 19 pes prints attributed to Sauropoda and 3 other marks attributed to Prosauropoda footprints. Generally sauropod pes prints are egg-shaped without diagnostic digit impressions. Well-preserved sauropod manus and pes prints are rare in the general fossil record. However, in some of the sauropod pes prints from the Upper Jurassic of Portugal were described 4/5 laterally oriented claw marks. These footprints present four sharp digit impressions and were analyzed together with other sauropod specimens from Middle Jurassic of Portugal, USA and Morocco, from Upper Jurassic of Spain and USA, from Lower Cretaceous of USA and England, as well as with prosauropods footprints from Upper Triassic of Lesotho. Ten landmarks and a variety of pseudo-landmarks were used in order to describe the footprint shape. Footprints were compared by superimposition (Generalized Procrustes Analysis) and deformation-based methods (Thin-Plate Spline). Quantification of the morphological differences in sauropod ichnites were obtained in order to a better characterization of the footprint morphologies that allow an improvement in the identification of the sauropod trackmakers. The quantitative results obtained with this geometric morphometric and multivariate analysis permit a better description of the sauropod ichnites than the traditional descriptive methods. The preliminary results allowed us to characterize and identify different morphological groups as well as identify portions of the footprint contour that present more changes in ichnites shape.

DINOSAUR TRACKS FROM THE LATE CAMPANIAN LAS AGUILAS LOCALITY SOUTHEASTERN COAHUILA, MEXICO

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During March of 2003, the Parras Basin Dinosaur Project conducted its second field season in the Late Campanian Cerro del Pueblo Formation, southeastern Coahuila, Mexico. Among the discoveries is a richly fossiliferous area named Las Aguilas. The area preserves remains of a diverse vertebrate fauna as well as some exceptional specimens, including several associated partial hadrosaur skeletons. In addition, Las Aguilas has yielded several new vertebrate track localities. One of these localities includes multiple trackways of theropods and hadrosaurs of varying sizes, representing the most extensive dinosaur tracksite known from Mexico. The theropod tracks at this location were made by at least two individuals of different size classes, with the trackway of the larger animal exhibiting an abrupt turn. The hadrosaur tracks, which bear well-defined, robust toes, also occur in at least two size classes and show both bipedal and quadrupedal gaits. Approximately 1 m above the main track-bearing layer is an additional track level containing natural track casts of hadrosaurs. Dinosaur skeletal remains are found in the immediate vicinity and one, a lambeosaurine skull and partial skeleton, appears to be in contact with the primary track layer.

An additional locality nearby preserves the trackway of what appears to be a large hadrosaur with an unusual gait. The animal was moving through deep mud using a quadrupedal gait. Interestingly, the alternating manus impressions are located far lateral to the pes impressions. One interpretation is that the animal was placing its hands distal to the midline in order to increase stability while traversing the muddy substrate. The Las Aguilas track localities are highly significant because of: 1) excellent preservation; 2) diversity in track size, gait, and apparent substrate; 3) potential correlations with some trackmaker taxa; and 4) paleoecological implications.

DINOSAURIAN LIFE HISTORY STRATEGIES, GROWTH RATES, AND CHARACTER EVOLUTION: NEW INSIGHTS GARNERED FROM BONE HISTOLOGY AND DEVELOPMENTAL MASS EXTRAPOLATION

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Comparisons of whole-body growth rates and life history strategies among extant vertebrates are typically achieved through the comparison of regressions of exponential stage growth standardized to body mass. In order to compare whole-body patterns between Dinosauria and extant taxa, similar quantified data are necessary. The recent merging of traditional bone histological analysis with scaling principles in a method termed Developmental Mass Extrapolation (DME) has provided the requisite tools and data to assess how dinosaurs really grew.

An analysis of dinosaurs spanning the phylogenetic and size diversity of the clade revealed that sigmoidal equations accurately describe the growth data for six diverse dinosaur taxa. The onset of somatic maturity occurred between the ages of three and 13 years, with values positively correlated with increased body size. The regression equation for Dinosauria indicates that while all dinosaurs grew at rates more rapid than those of extant reptiles, they exhibit rates below, equivalent to, or above the rates of extant mammals and did not attain the extremely rapid rates attained by modern altricial birds. Birds clearly attained a portion of their elevated growth rates from their dinosaurian precursors, but how and when they surpassed the rates of non-avian relatives has remained obscured. Our data indicate that small, non-avian maniraptoran dinosaurs were two to seven times slower growing than extant precocial birds, and that extremely rapid avian growth rates may have evolved only after the origin of Avialae.

DESCRIPTION AND INTERPRETATION OF THE PRILLWITZ MAMMOTH FROM SOUTHWESTERN MICHIGAN

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The Prillwitz Mammoth was collected in Berrien County in 1962 and is on display at Andrews University in Berrien County. Although the most complete mammoth yet recovered from Michigan, the specimen has not been adequately described or interpreted. The recovered skeleton included most of the skull (in several parts), a complete jaw, all four cheek teeth (with a vestigial alveolus on each maxilla), virtually all pre-caudal vertebrae, pectoral girdles and forelimbs proximal to the elbows, and most of the pelvis and hind limbs. Notably missing were the tusks.

One maxillary cheek tooth, fully exposed distally due to breakage, exhibited 23 enamel plates with 14 in wear. Other cheek teeth also exhibited 14 plates on the occlusal surface. Number of enamel plates falls in the range of overlap between M3 of *Mammuthus columbi* (~18-24) and *M. primigenius* (~20-29), whereas lamellar frequency (~7.5/10 cm) and enamel thickness (~2.4-2.6 mm) were within the range of *M. columbi* but not *M. primigenius*. The inferred tooth position (M3/m3) and degree of wear (about 60%) give an African Elephant Years (AEY) age of ~35-37 years.

Measurements of long bones were near or below the lower range of values obtained for *M. columbi* from Hot Springs, SD. The epiphyses of long bones were unfused or initiating fusion, with the exception of the fused distal humeri. These observations suggest a young adult (<~29 if male, <~20 if female) substantially younger than indicated by tooth wear (AEY scheme). A similar discrepancy has been noted for mastodons by others. The ratio of widths of ilium to horizontal pelvic aperture (2.48) was greater than typical for Hot Springs *M. columbi* (interpreted as males) but within the male range for *M. primigenius*. Based on these observations, we interpret the Prillwitz Mammoth as a relatively small young adult male. The taxonomic affinities of the Prillwitz specimen and other Great Lakes mammoths remain puzzling given uncertainty about the status of *M. jeffersoni* from the region. However, the Prillwitz Mammoth resembles *M. columbi* more than *M. primigenius*.

BEHAVIORAL IMPLICATIONS OF SAUROPOD STRESS FRACTURES

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The skeletal record provides evidence not only of structure, but also clues to activity. Insights, obtained from analysis of stress fracture patterns in Ceratopsia and Theropoda, allow new perspectives of sauropod behavior. Picturesque tripodal American Museum Natural History exhibition of *Barosaurus* stimulated testing the hypothesis that sauropods stood on their hind legs. Resuming normal posture from a tripodal stance would exert extreme forces on thoracic and lumber vertebrae and metacarpals or forefoot phalanges (as routinely noted in human ballet dancers), as evidenced by stress fractures.

Thoracic and lumbar vertebrae, phalanges and metapodials of sauropods were examined macroscopically for surface abnormalities. Stress fractures were recognized radiologically as oblique radiolucent knife-slice-like clefts with smudged (indistinct) periosteal overgrowth forming a surface bump.

Stress fractures were absent in forefeet (i.e., 221 metacarpals, 121 manual phalanges) and 1232 lumbar or thoracic vertebrae of examined sauropods (Chi square = 38.83, $p < 0.00001$). Pronounced anterior bulges, characteristic of stress fractures were recognized in 6% of sauropod metatarsals, with frequency indistinguishable among the genera: MT-I of *Apatosaurus*, *Camarasaurus*, MT-II of *Diplodocus*, MT-IV of *Apatosaurus* and *Brachiosaurus*, MT-V of *Apatosaurus*, and proximal pedal phalanges of *Apatosaurus* and *Nurosaurus*. While the articulatory joints of sauropods had sufficient range of motion to allow tripodal stance, absence of manual stress fractures documents that they did not actually assume such a stance. This contrasts with relatively frequent notation of pedal stress fractures. This suggests that the hindfoot provided much of the propulsive thrust of ambulation, perhaps with dry land habitat implications. Study of paleopathology permits us to discern not only what animals were anatomically capable of doing, but—in some cases—what they actually did.

REINTERPRETATION OF *REIGITHERIUM BUNODONTUM* AS A REIGITHERIIDAE DRYOLESTOID AND THE INTERRELATIONSHIPS OF THE SOUTH AMERICAN DRYOLESTOIDS

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Eighteen mammalian species have been named from isolated teeth and fragmentary jaws collected in the Late Cretaceous fauna of Los Alamitos Formation (Campanian-Maastrichtian), Patagonia, Argentina. Until recently most taxa from Los Alamitos have been interpreted as derived members of a dryolestoid radiation in South America and perhaps Gondwana. Based on a tooth-bearing jaw from the Upper Cretaceous La Colonia Formation, the original attribution of *Reigitherium* to dryolestoids was subsequently challenged and relo-

cated to Docodonta. If so, *Reigitherium* would be the only Cretaceous docodont worlwide and the sole record for the group in the Gondwanian continents.

New materials of Reigitheriidae from La Colonia Formation and of the Paleocene dryolestoid *Peligrotherium tropicalis* indicate that: 1) The original attribution of *Reigitherium* to Dryolestoidea was correct. The main lingual lower molar cusp is homologous with the protoconid and the buccal cusps result from the elaboration of the cingula, as those present in mesungulatids; contrary to known docodonts there are no postdentary bones in *Reigitherium*; 2) *Reigitherium* and *Peligrotherium* are more similar to each other than they are to mesungulatids and can be united under Reigitheriidae. Features uniting them are the presence of accessory buccal cusps in the upper and lower molariforms, development of the cingula, so as to approximate in height the main crown cusps; strong reduction of the buccal cusps in the upper molariforms with a dominant paracone, and a sloping buccal margin of P2-M1; 3) Both Mesungulatidae and Reigitheriidae have strongly developed cingula, anteroposteriorly compressed roots, and where tooth count is known, they have four molariforms that decrease markedly in size poosteriorly. Mesungulatidae and Reigitheriidae are likely sister-groups.

PALEONTOLOGY IN THE WRITINGS OF MARK TWAIN

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Mark Twain's life (1835-1910) paralleled the rapid development of paleontology in the late 19th and early 20th centuries. Twain's use of paleontology evolved along with the science. In the 1860s through the 1880s he was aggressively skeptical of the ability of archaeologists, geologists, and paleontologists to use artifacts and fossils to reconstruct the details of earth history, and he ridiculed the gullibility of journalists and the public in believing the scientists.

Twain's skeptical phase coincides with the development of the geological time scale and the appearance of Darwin's *The Origin of Species* (1859) and *The Descent of Man* (1871). Twain's skeptical essays thus may be viewed as a reflection of the struggle within American society to deal with the disturbing new paradigms of deep geologic time and the Darwinian revolution.

As early as 1870, Twain's private correspondence contained references to the insignificance of man in the context of geologic time and cosmic distances. In the 1880s his published writings became increasingly cynical and antagonistic toward Christianity, and after 1884 he abandoned his skeptical attitude toward paleontology and geology. Rather, he began to use emerging insights from these fields to communicate his growing disillusionment with religious orthodoxy. In essays written in 1903 (*Was the world made for man?)* and 1905 (*Adam's soliloquy*), Twain used paleontological discoveries to satirize biblical accounts of earth and human history. The evolution of Twain's use of fossils reflects, and probably helped to bring about, an increasing credibility and respectibility for the field of paleontology within American society, at the expense of biblical literalism.

RELEVANCE OF MODERN ECOSYSTEMS TO PLIO-PLEISTOCENE MAMMALIAN PALEOECOLOGY

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One traditional strength of Plio-Pleistocene mammalian paleoecology is the ability to reference modern biota. While it may be debated whether this has allowed progress or impeded innovation in the field due to over-reliance on extant faunas, conclusions presented here suggest that paleoecologic interpretations based on modern biota may be tenuous or even completely wrong.

Recent publications have shown the correlation of species level diversity in arvicoline and murine rodents with climatic variables. I have revised those correlations and have documented new ones with other mammalian groups (especially insectivorans, carnivorans, lagomorphs, sciurids, and heteromyids) based on the fauna from each North America ecoregion. Similarly, body mass distributions and ecological diversity histograms suggest re-occurring patterns between habitat types, climate, and the composite mammalian assemblage. These methods can provide more than gestalt interpretations; quantitative predictive equations may be generated from these data.

I used the sequence of Pliocene faunas from Hagerman Fossil Beds National Monument (south-central Idaho) to evaluate these models. The various predictive equations derived from modern ecosystems and applied to the Hagerman faunas yield widely conflicting results. Not only are results different from values and trends suggested by sedimentologic, isotopic and palynologic data, but they differ radically from each other. Use of modern ecosystems in paleoecological interpretations needs to be critically evaluated. Holocene deposits, in particular, may provide a valid testing ground and better link modern biotas with earlier time periods.

ANALYSIS OF WICHITA GROUP (REVISED) "SERIES A" *DIMETRODON* SPECIES USING BETA PROBABILITY PLOTS AND HOTELLING'S T^2 STATISTIC

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Dimetrodon species were identified based on morphological characters, stratigraphic horizon, overall size and the dimensions of various load-bearing bones. Specimens without morphological differences and from the same stratigraphic horizon were assigned to various species, and gender based on differences in the ratios of the lengths of bones vs. half the transverse widths of the dorsal vertebrae centra. Log-log bivariate plots were later used for graphical analysis. Species averages were used. Univariate statistics and normal probability plots of single dimensions of individual specimens were shown to be useful in identifying different groups within a population. Recently, Hotelling's T^2 multivariate statistic was shown to be useful in the analysis of bivariate dimensional measurements of dorsal vertebrae from individual *Dimetrodon* specimens.

Beta probability plots are used here for the analysis of Hotelling's T^2 bivariate data. The Wichita Group (revised) contains two morphologically similar "Series A" *Dimetrodon* species (*D. booneorum* and *D. limbatus*). One species (*D. limbatus*) was further subdivided by gender. The natural logarithms of the cervical and dorsal vertebrae length and half the transverse width of the dorsal vertebrae centra are analyzed. Cervical vertebrae are matched with dorsal vertebrae from the same specimen for analysis. Beta probability plots results indicate the presence of multiple groups. Cervical vertebrae indicate the presence of 2 groups. Dorsal vertebrae indicate the presence of 2-4 groups.

The conclusions are: 1) Beta probability plots of Hotelling's T^2 data of the natural logarithms of cervical and dorsal vertebrae length vs. half the transverse width of the dorsal vertebrae centra are useful in the analysis of *Dimetrodon* species; 2) beta probability plots indicate the presence of multiple groups; 3) further analysis is needed to determine the nature of these groups and identify which specimens belong to each group.

A SUPERTREE OF EARLY TETRAPODS

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Matrix representation using parsimony is used to construct a genus-level supertree for early tetrapods, based on 50 published source trees. Two analyses are discussed. Analysis I, deriving from a data set of 226 taxa coded for 958 matrix elements, includes the majority of published cladograms. The results place several Paleozoic groups (e.g. anthracosaurs and temnospondyls) in the tetrapod stem. Crown lissamphibians are rooted within lepospondyls, as sister group to a clade including microbrachid and hyloplesiontid microsaurs and lysorophids. Analysis II, based on 225 taxa and 710 matrix elements, excludes those source trees that are superseded by more comprehensive trees. It supports a deeper split between stem lissamphibian and stem amniote groups than the first analysis. Crown lissamphibians are rooted within dissorophoid temnospondyls. Both analyses support novel, often spurious groups that are not found in any of the source trees. However, instances of taxon incongruence are rare and involve few genera only, and do not imply drastic rearrangements within well-established clades. The ability of supertrees to summarize patterns from several independent topologies makes them a powerful analytical method in studies that include very diverse taxon exemplars. Nevertheless, we urge caution in their interpretation as phylogenetic hypotheses for the purpose of investigating macroevolutionary patterns.

NEW CENTROSAURINE CERATOPSIDS FROM THE LATE CAMPANIAN OF ALBERTA AND MONTANA AND A REVIEW OF CONTEMPORANEOUS AND REGIONAL PATTERNS OF CENTROSAURINE EVOLUTION

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New centrosaurine ceratopsids have been recovered from (1) the uppermost Oldman Formation of Alberta and (2) the lowermost Oldman Formation of Alberta and the coeval Judith River Formation of Montana. The former taxon is a new species of *Centrosaurus* distinguished from *C. apertus* by the possession of unique additional dermal ossifications as part of its parietal ornamentation, and a strong lateral inflection of its unmodified supraorbital horns. The latter taxon is the oldest known centrosaur and is the sister taxon of all other centrosaurines. It possesses a combination of characters unique for this subfamily, including large, robust chasmosaurine-like supraorbital horncores and a pair of large, pachyostotic hooks projecting from the caudolateral margins of the parietal.

Examination of the geographic and stratigraphic distributions of the Centrosaurinae from the late Cretaceous of the Western Interior Basin confirms that the Canadian and Montanan faunas have restricted ranges, with apparently little overlap. Within Alberta the best known taxa, *Centrosaurus apertus* and *Styracosaurus albertensis*, have known geographic ranges that are essentially congruent with the limits of outcroppings of the Dinosaur Park Formation. Their increasing abundance towards the northern limits of their ranges, and their pattern of stratigraphic overlap, suggests the temporal replacement of *Centrosaurus* by *Styracosaurus*, in association with the transgression of the inland sea during the late Campanian. Morphological and stratigraphic evidence fail to support a previously advanced hypothesis of anagenetic change within a lineage of Late Campanian-aged centrosaurs and instead reveals a hierarchical pattern of sister group relationships. Coeval stratigraphic replacement patterns of centrosaurs, chasmosaurs, and hadrosaurs in the Dinosaur Park Formation of Dinosaur Provincial Park suggest that a partial faunal turnover occurred within this region over a span of approximately 250,000 years.

FOSSIL CUT-WOOD FROM THE CANADIAN HIGH ARCTIC: NEW INSIGHTS INTO THE EVOLUTION OF WOOD-CUTTING IN CASTORIDS

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Although the modern beaver, *Castor* (Castoridae), is renowned for its tree-harvesting ability, it is not the only wood-cutting castorid. A locality in the Canadian High Arctic has yielded over 100 pieces of fossil wood with cut marks that match the incisors of the only castorid found at the locality, *Dipoides*. This is the first definitive evidence of wood-cutting by an extinct castorid.

I investigated the evolution of wood-cutting in castorids by conducting a cladistic analysis of Castoridae and mapping behavioral characters onto the resulting most parsimonious consensus trees. The data matrix comprised 33 castorid taxa, plus 3 outgoups, and 89 characters. Both cranial and postcranial characters were considered. All characters were treated as unordered. Five parsimony analyses were conducted that varied in character weighting and the inclusion of certain taxa.

The evolutionary history of wood-cutting was reconstructed using parsimony. Two

behaviors were considered: fossoriality and wood-cutting. These behaviors were treated as separate character states because, in their specialized forms, they correspond to mutually exclusive habitats and ecologies. Fossorial taxa are associated with open habitats whereas wood-cutting requires forested habitats. Fossoriality was inferred if the taxon had been found associated with fossil burrows and/or from morphological evidence. The morphological inferences were based on a comparative study of modern rodents.

The parsimony reconstructions recovered a single pattern of behavioral evolution. *Castor* and *Dipoides* along with several other taxa, including *Hystricops*, *Sinocastor*, *Eucastor* and *Castoroides*, may have acquired wood-cutting from a common ancestor that lived at least 20 million years ago. Members of this clade are known from both North America and Eurasia and presumably dispersed through high latitude, forested environments. The fossorial specialists are of North American provenance and were found to be basal to the inferred wood-cutting clade.

A NEW CROCODILIAN FROM THE LOWER CRETACEOUS CRATO FORMATION OF NORTH-EASTERN BRAZIL

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In 1991, a new mesosuchian crocodilian was found in the Lower Cretaceous (Aptian) Nova Olinda Member of the Crato Formation of the Araripe Basin, northeastern Brazil. Prior to its discovery crocodilian remains had not previously been reported in this formation. The specimen is represented by a partially articulated skeleton, comprising the skull and mandible, partial postcranial axial skeleton, forelimbs and portions of the osteodermal skeleton. Preservation of soft tissues includes the skin surrounding both forelimbs and the digits of the right hand. The state of preservation of the specimen suggests that it was incorporated into the basin as a desiccated carcass.

The Crato crocodilian is one of the oldest crocodilians with a eusuchian-type dorsal shield, comprising a tetraserial paravertebral shield and, either side of this, two sagittal rows of accessory osteoderms. It also possesses amphicoelous thoracic, lumbar and caudal vertebrae. This combination of postcranial features has never before been seen in a crocodilian and may warrant the erection of a new family within Mesosuchia. Taxonomically, the new specimen is similar to a number of Early Cretaceous mesosuchians previously considered to have given rise to eusuchians, most notably the Glen Rose crocodilian from the Glen Rose Formation of central Texas and the Cloverly Formation of Montana. It is also similar to recently discovered, but undescribed crocodilian material from Australia, from the Lower Cretaceous Winton and Middle Eumeralla Formations of western Queensland and southern Victoria respectively. Preliminary study of the Australian material, particularly that from Victoria, indicates it may belong to the same family as the Crato crocodilian, supporting hypotheses of high latitude interchange between the vertebrate faunas of South America and Australia during the Early Cretaceous.

ECOMORPHOLOGY OF THE TARSAL COMPLEX IN AFRO-MALAGASY TENRECOIDEA

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The 30± extant species of the Tenrecoidea live in a diverse range of microhabitats. They exhibit markedly different postural behaviors, including the four basic locomotor repertoires: terrestrial running and walking, climbing, digging, and swimming. Due to their insular ecological adaptive radiation in Madagascar, Malagasy tenrecoids are an ideal model for testing functional-adaptive hypotheses of skeletal form. Articular surfaces from the upper, middle, and lower ankle joints in ten Malagasy tenrecid, one potamogalinid, one solenodontid, and one macroscelidid species were compared, and results were tested against published data on other therian locomotor specialists. Descriptive examination supported by bivariate and multivariate analyses demonstrates significant differences in many aspects of tarsal morphology that are supportive of function-based hypotheses. The three closely related tenrecines *Hemicentetes*, *Setifer*, and *Echinops* show divergences in form that are consistent with their respective fossorial, terrestrial, and arboreal modes of locomotion. Convergences are apparent between subfamilies, such as those between *Hemicentetes* and *Oryzorictes*, and *Limnogale* and *Potamogale*, yet conserved shared features strongly support phylogenetic affinity between subfamily members. Differences in tarsal form between *Geogale* and the oryzorictines support recognition of the subfamily Geogalinae, and similarities between *Limnogale* and the other oryzorictines contest a *Limnogale-Potamogale* clade. Data from this project are valuable for functional-adaptive interpretation of fossil materials; they also have use for unraveling intra-tenrecoid relationships, as well as investigating afrotherian skeletal evolution.

NECK BIOMECHANICS OF THEROPOD DINOSAURS

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Theropod dinosaurs are bipedal, generally carnivorous, and of variable size. Most biomechanical assessments of theropod dinosaurs in the past have focused on the function of the limbs. The functional morphology of the necks of several types of theropod dinosaur is examined to determine the range of motion of the cervical vertebrae and the neck-skull interface. Neck biomechanics are difficult to study because of the fragility of small bones (e.g. from ornithomimids), and the unwieldy nature of larger vertebrae (e.g. from tyrannosaurids). This problem can be overcome by the use of 3D visualization software and accurate models of the neck vertebrae. Computer modelling constrained by comparative morphological data is a useful tool for assessing the range of motion of the joints of extinct taxa. The determination of the range of motion of the neck has potential implications for inferring the behaviour and ecology of these organisms.

The articular surfaces of the joints of several types of theropod dinosaur are being measured and modelled digitally as complex three-dimensional surfaces. Digital models created from and constrained by the results of the comparative examinations can be manipulated using the DinoMorph software package in order to determine the limits of movement of a given structure in the extinct dinosaur taxa. Differences and similarities between the taxa can shed light on their ecology and behaviour.

ECOLOGICAL AND EVOLUTIONARY IMPLICATIONS OF GIGANTISM IN THEROPOD DINOSAURS

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Numerous studies of extant and recently extinct vertebrates demonstrate that body size is correlated with a variety of ecological parameters, often with resultant evolutionary consequences. By far the largest terrestrial carnivores known occur within the dinosaur clade Theropoda. Recent phylogenetic analysis indicates that gigantism (femur length >1.2 m) evolved independently within theropods at least four times during the Mesozoic. Significantly, although debate has ensued over which of these taxa was the largest, all appear to have achieved biologically equivalent body size (approximately 5-7 metric tonnes). This similarity strongly suggests that the evolution of gigantism in theropods may have been subjected to ecological (as well as mechanical) constraints. Ecological correlates among extant terrestrial carnivores suggest that the largest theropods were ectothermic, with low mass-specific metabolic rates that nevertheless required extensive, continent-sized geographic ranges. In support of this hypothesis, known occurrences of gigantic theropods are correlated with continent-sized landmasses.

The best known of these predatory giants is *Tyrannosaurus rex*, represented by numerous specimens recovered across much of the Western Interior of North America. Recent discovery of a *T. rex* specimen from the North Horn Formation of Utah documents the co-occurrence of this taxon with the titanosaurid sauropod *Alamosaurus* in an upland, intermontane setting. Combined with earlier finds, this new evidence indicates that *T. rex* was an ecological generalist, spanning a broad geographic area that included diverse habitats and a range of prey species. Furthermore, although tyrannosaurids existed in isolation on both eastern and western North America for at least 25 million years prior to the appearance of *T. rex*, these earlier forms were significantly smaller bodied (femur length <1.1 m). The evolution of gigantism in *T. rex* is posited to be causally linked to the doubling of habitat area associated with retreat of the Western Interior Seaway.

MORPHOMETRIC ANALYSIS OF LOCOMOTOR HABITS IN EXTINCT BEAVERS (CASTORIDAE)

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Paleontologists commonly use modern taxa to infer the locomotor adaptations of their extinct counterparts. This sort of analysis frequently has been used for various extinct mammal taxa including some rodents, but there have been no detailed morphometric comparisons of locomotor adaptations in the Castoridae—a family that includes ca. 20 genera (50 species) distributed in four well-established subfamilies that display consistent differences in cranial and postcranial anatomy. These subfamilies show variation in limb morphology related to locomotor specializations, including semiaquatic and burrowing habits. Inferences concerning extinct castorid locomotion have been postulated for some species, although detailed quantitative comparisons of locomotor characteristics within and between subfamilies are lacking. Preliminary results of a survey of locomotor morphologies from 4 extinct North American beaver genera (*Castor, Dipoides, Procastoroides*, and *Castoroides*) were compared with 4 semiaquatic and 3 terrestrial extant rodent genera (*Castor, Ondatra, Myocastor, Hydrochoerus, Aplodontia, Marmota*, and *Neotoma*). Specimens were measured for 28 functional osteological characteristics (e.g. limb bone length, breadth, anterior-posterior diameter). Principal components analysis and discriminant function analysis were used to assess correlations between morphology and semiaquatic adaptation in extant genera and to infer locomotor behavior of extinct beavers. Extinct *Castor* was not significantly different from the extant Castor except with regard to size. The 3 genera of extinct beavers from the subfamily Castoroidinae display similar locomotor morphologies, but are less specialized for semiaquatic locomotion than *Castor*. All of the semiaquatic rodent taxa studied show some morphological convergence linked to this locomotor habit. Different locomotor specializations in extinct castorids may help to explain patterns of extinction and diversification of the group. Future analyses will include additional modern and fossil taxa and will help elucidate the origin(s) of semiaquatic adaptation in beavers.

MAGNETIC STRATIGRAPHY OF THE LOWER-MIDDLE MIOCENE OLCESE SAND AND ROUND MOUNTAIN SILT, KERN COUNTY, CALIFORNIA

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The Round Mountain Silt and the underlying Olcese Sand, northeast of Bakersfield California, are famous for their large collection of marine vertebrates from the Sharktooth Hill Bonebed and fossil mollusks from both units. Their ages are poorly constrained, although they are thought to be early to middle Miocene. Magnetic samples were taken from two sections spanning 180 feet of the Round Mountain Siltstone: one at Ernst Ranch and the other along Poso Creek; and from the 220-foot thick Nickel Cliff section of the Olcese Sand. The samples

were demagnetized with both alternating field and thermal demagnetization, and produced stable remanence that passed a reversal test. Most of the Round Mountain Siltstone is reversed in polarity except for the very base of the section, and a short normal magnetozone in the upper third. Based on a Sr isotope ages of 15.5-16.3 Ma for the base of section, the best correlation is with Chrons C5Bn1r to C5Cn1, or 15.0 to 16.2 Ma. The entire middle part of the section, including the Sharktooth Hill Bonebed, correlates with Chron C5Br (15.2-16.0 Ma). This confirms the middle Miocene (Barstovian) age of the unit, as has been suspected from the few terrestrial mammals recovered. The Olcese Sand is mostly normal in polarity, except for short reversed magnetozones at the top of the section. Based on Sr ages ranging from 16.8-17.6 Ma, we correlate the Olcese Sand with Chrons C5Cn2-C5Cn3 (16.2-16.5 Ma), or latest early Miocene.

SYSTEMATICS AND PALEOECOLOGY OF THE SPANISH ANCHITHERIINAE (PERISSODACTYLA; EQUIDAE).

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The Anchitheriinae Leidy, 1869 is a Miocene clade of three-toed horses which comprises the genera *Anchitherium*, *Sinohippus*, *Megahippus*, *Hypohippus* and *Kalobatippus*. The first fossils of *Anchitherium* were found in Europe in 1825 and were described by Cuvier under the name of *Paleotherium aurelianense*. In 1844 Meyer erected the genus *Anchitherium* to segregate these fossils from the Paleotheriidae. In Spain, *Anchitherium* is registered from the MN 3 zone (Middle Miocene) to MN 9 (Upper Miocene) and is an abundant and diversified element of Spanish fossil faunas during most of its chronological range. The adaptive radiation of the Spanish anchitheriinae led to the appearance of two lineages and at least eight species. The fossil record of the last Spanish anchitheres (MN 6-MN 9) is scarce, and the better-known species are the probable immigrants *Anchitherium hippoides* and *Sinohippus sampelayoi*. It is possible to infer the biome of a locality based in its macromammal fauna, and we can infer the presence in the Iberian Miocene of temperate evergreen forests, tropical decidous forests, and savannas. Paleoecological studies reveal that there is a relationship between the size of the dentition relative to body size in *Anchitherium* and the variations in temperature. Populations occupying more seasonal environments presented a relatively bigger dentition than the inhabitants of non-seasonal environments. The relative abundance of *Anchitherium* in the fossil local faunas seems to be mainly ruled by temperature, and it is more abundant in fossil assemblages from colder areas. The two Iberian lineages shown similar paleoecological behavior: more or less ubiquitous species, adapted to densely forested environments are replaced by more derived species adapted to ecosystems with a dry season which were predominant in the Iberian Peninsula during the middle Miocene. Another ubiquitous species, the immigrant *A. hippoides* enters the Iberian Peninsula in MN 6 zone, in a faunal reorganization probably related to the progressive increase in environmental humidity.

LONG AND GIRDLE BONE HISTOLOGY IN SAUROPOD DINOSAURS: METHODS OF STUDY AND IMPLICATIONS FOR GROWTH, LIFE HISTORY, TAXONOMY, AND EVOLUTION

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Sauropod long and girdle bones are the most common and best preserved remains of these largest of terrestrial animals. The histology of the bones provides unique information about the biology and evolution of the group. Histology is primarily studied in thin and polished sections. Destruction can be minimized, however, by controlled sampling with spezialized tools such as small core drills. Sauropod long and girdle bones are well suited to histologic study because of appositional growth of bone tissue due to the simple bone shape. Because bone is resorbed and remodelled from the inside out, growth series need to be sampled to account for the loss of ontogenetically earlier bone in older individuals. Research has focused on the sauropod faunas of the Upper Jurassic Morrison Formation and Tendaguru Beds but data are also available for the earliest sauropods and the Middle Jurassic *Lapparentosaurus*.

Due to size and shape differences, the bones of a single skeleton grow at different rates, resulting in different histologies. Thus, growth marks may be well expressed in the relatively slow-growing cortex of e.g. a scapula but may be absent from the femur. Conversely, the femur may preserve a longer growth record because of less remodelling. Limb as well as girdle bones should be sampled, with the humerus and femur almost always preserving a good growth record while girdle bones are less consistently useful.

Growth can be studied qualitatively, as changes in tissue type through ontogeny, and quantitatively, using growth marks and tissue apposition rates. From their first occurrence, sauropod dinosaurs had growth rates of large mammals. As opposed to mammals, sauropods apparently became sexually mature well before reaching maximum size. A single sample from the right location can determine the ontogenetic status of an individual. Applied to *Camarasaurus*, histology supports the notion of a small and a large species. Some sauropod genera show diagnostic histologic patterns. Very high growth rates are seen already in the earliest sauropods, indicating that the phylogenetic body size increase of sauropods was due acceleration.

A THREE-DIMENSIONAL RECONSTRUCTION OF THE ENDOCRANIUM OF *CERATOSAURUS* BASED ON CT-SCAN DATA

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Endocranial anatomy is now known for several derived tetanurine theropods, including *Allosaurus*, *Tyrannosaurus*, *Troodon*, and others, but has yet to be extensively described for more basal members of the clade. *Ceratosaurus* is now regarded as a basal tetanurine. A well-preserved braincase of *Ceratosaurus* from the Morrison Formation of western Colorado was recently CT-scanned to provide a more complete description of the endocranium, inner ear, and pneumatic system than that published by Marsh.

The *Ceratosaurus* specimen was coronally scanned using a slice thckness of 3mm with 1mm overlap. These images were subsequently processed on readily available (and inexpensive) software to produce 3D renderings of the endocranium, vestibulocochlear system, and pneumatic sinuses. We present this anatomy along with a description of the rendering technique, in the hopes of making this type of analysis more readily available to the growing number of researchers with CT data.

The endocranial anatomy of *Ceratosaurus* is very similar to that of *Allosaurus*. These results indicate that the initial evolution of the endocranial region in tetanurine theropods was slow.

THE RELATIONSHIP BETWEEN LUMBOSACRAL STRUCTURE, FUNCTION, AND POSITIONAL BEHAVIOR IN AUSTRALOPITHECINES (MAMMALIA, HOMINIDAE)

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This study examines the link between lumbosacral structure, function, and positional behavior in australopithecines. The combination of postcranial autapomorphies and human- and ape-like features in these early hominids has caused ongoing debate about their positional repertoires. This study was undertaken because most research on early hominid positional behavior has focused on the appendicular skeleton. Also, in mammals variation in axial postcranial morphology is strongly correlated with postural and locomotor differences. The numerous musculoskeletal adaptations of the lumbosacral spine for vertical columnar stability and for resisting stresses associated with habitual bipedality in humans identify this anatomical region as especially suitable for assessing the ability of early hominids to engage in sustained bipedal behaviors.

Comparative allometric and morphological analyses were performed on a large sample of lumbar vertebrae and sacra from modern catarrhine primates and Pliocene fossil hominids (*Australopithecus afarensis* and *A. africanus*), including a previously undescribed lumbosacral series from Sterkfontein, South Africa (Stw-431, *A. africanus*). The results demonstrate that australopithecines and humans uniquely share features of the neural arch and spinal curvature critical for frequent bipedal walking and standing. Conversely, their high incidence of centrum pathology and differences in size and proportions of centra between australopithecines and humans indicate dissimilarities in spinal mechanics. These differences show that evolutionary transformation to obligate bipedality occurred in a mosaic fashion, with intrinsic lumbar lordosis and stable balance of the trunk over the pelvis initially more important than vertical columnar weight bearing. Combined with other evidence, the results suggest that australopithecines were predominantly bipedal, but with more versatile positional repertoires than in humans. In this view, australopithecines appear to have been compromise rather than committed bipeds that benefited more from effectiveness in diverse ecological settings than from bipedal efficiency.

NEW THEROPOD AND BIRD TEETH FROM THE LATE CRETACEOUS (MAASTRICHTIAN) HELL CREEK AND LANCE FORMATIONS

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Theropod and bird diversity in northern North America can be documented for the final several million years of the Late Cretaceous, prior to the K/T extinctions, based on large collections of teeth recovered from microfossil sites. Detailed taxonomic analyses of Maastrichtian theropod and bird teeth include descriptions, photographs, measurements, and bivariate plots to quantify tooth morphotypes. Teeth were recovered by surface collecting and screening microfossil sites from the Lance and Hell Creek Formations of Montana, Wyoming, and North Dakota (n=530) by the University of California Museum of Paleontology and the Pioneer Trails Regional Museum.

Taxa (excluding tyrannosaurids) include: *Richardoestesia isosceles* (32%), *R. isosceles* Morphotype 1 (formerly *Paronychodon*) (20%), *Richardoestesia* sp. (3%), *Saurornitholestes* sp. and dromaeosaurid indet. (23%), *Troodon* sp. (13%), troodontid indet. (0.7%), and Aves (8%). In Maastrichtian theropod microsite assemblages, dromaeosaurids are less common than they are in the Campanian. Instead, Maastrichtian assemblages are dominated by *Richardoestesia isosceles*, which are often 50% of the assemblage. However, we know almost nothing about this unusual, small theropod except that it contained straight to slightly recurved teeth, may have been a fish-eater, and may have been convergent with spinosaurids from Africa, Europe, and South America. The diversity of theropod assemblages based on microsites was lower in the Maastrichtian compared to the Campanian because of fewer species of dromaeosaurids and the dominance of the enigmatic theropod, *R. isosceles*.

THE USE OF CT-SCAN IN TAPHONOMIC INTERPRETATIONS

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CT-scan technology, along with a volume-rendering software program, has largely been used by researches to obtain morphological and evolutionary data from the specimens analyzed. For instance, the braincase digital endocasts that have been created by the use of this technology have allowed paleontologists to study the pattern of brain changes over the course of some group's evolution.

In this project, this technology was used to get taphonomic data. Turtle fossil material collected in the "Tartaruguito" site, Municipality of Pirapozinho, São Paulo State, Brazil, was scanned with a Siemens-Somatom Plus 4/ Volume Zoom equipment. The 3D digital map of the specimen's structures and the resulting images processed, represented by different densi-

ties of bone and matrix, allowed us to interpret not only external but also internal features of the individuals. It was also possible to make a digital preparation from a plaster jacket containing more than one individual.

In the "Tartaruguito" site, famous for its abundance of fossil material, many specimens are disposed in different directions and some overlap others. It is almost impossible to avoid damage during collecting and preparation processes. By the use of the CT-scan technology we can avoid preparation damage, maintaining the original characteristics of the material, so important to taphonomic study. It also speeds up the research, as sometimes it takes weeks to properly prepare a specimen by mechanical methods.

DINOSAURS TRACKS FROM THE ALGARVE BASIN, PORTUGAL

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The presence of vertebrate fossils in the Mesozoic Algarve Basin was reported for the first time in 1975 and 1977 and consisted of fish and uncertain reptiles remains in Triassic deposits. In 1992 and 1995 at Praia de Porto de Mós and Praia da Salema (Lagos and Vila do Bispo, Portugal), respectively, the first dinosaur osteological and ichnological remains were found. Praia da Salema is an ichnosite with two track levels in Lower Cretaceous layers (Barremian). One reveals a bipedal narrow trackway with eight footprints, as wide as long, three of them tridactyl pedal imprints, with rounded distal ends. The best preserved footprint morphology is characteristic of iguanodontids. This trackway was the first evidence of iguanodontid tracks in Portugal. The hip height of this ornithopod was about 2.2 meters walking at a speed of about 1.7 km/h. In another level of this ichnosite, theropod footprints pertain to unknown theropods whose posterior limbs were about 70 cm to 1 m long walking at a speed of about 3.5 km/h. Another ichnosite was found at Praia Santa (Vila do Bispo, Portugal) with two Lower Cretaceous tracklevels (Barremian). In the lower level we identified dinoturbation, and in the upper level four bipedal trackways. These trackways are narrow sequences of tridactyl and mesaxonic footprints almost as wide as long, with an inner and an outer indentation in the heel mark, wide and short prints of digits II, III and IV, with parallel edges and U shaped end. These well preserved footprints in Praia Santa ichnosite reveal the characteristic iguanodontid morphology and their similarity with the prints attributed to *Iguanodontipus* ichnosp. allow their inclusion in this ichnogenus. The hip height range of the ornithopods was between 1.8 and 2.4 meters walking at a speed of about 3.1 to 4.4 km/h. This research allowed the recognition of the presence of iguanodontids and unknown theropods in the Lower Cretaceous of Algarve Basin (southwest Portugal).

EFFECT OF DATA SELECTION IN PHYLOGENETIC ANALYSIS OF THE ELASMOSAURIDAE (REPTILIA: SAUROPTERYGIA)

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This study investigated the effect of the choice of morphological characters and/or terminal units in a cladistic analysis of elasmosaurid plesiosaurs. The analysis is based on a data matrix of 215 characters on 34 terminal taxa/specimens, including recently described elasmosaurid and polycotylid plesiosaurs from Saskatchewan, Canada. Three subsets of taxa were analyzed for three subsets of characters, and comparison of the nine analyses showed the effect of choice of taxa and/or characters. It was demonstrated that choice of taxa and/or characters greatly influences the outcome of the analysis, such as the number of MPTs, measures of character fit, and tree topology. Deletion of quantitative characters resulted in an increased number of MPTs and loss of resolution in the consensus tree, indicating the importance of quantitative data, particularly among Cretaceous elasmosaurs. A taxon with a high percentage of missing data often, but not always, behaved as a wildcard taxon. Deletion of such taxa resulted in fewer MPTs and improved degree of character fit, but it also affects tree topology. Members of traditionally defined Elasmosauridae never formed a clade in any of the nine analyses. Preferred cladograms from this study supported a previous analysis in demonstrating the monophyly of most Cretaceous elasmosaurids, a close relationship of Jurassic elasmosaurs with non-elasmosaurids, and a close relationship of polycotylids and cryptoclidids. Application of recently proposed phylogenetic definition of the Elasmosauridae, however, resulted in a large clade that is taxonomically far more inclusive than the original, because one of the specifiers was constantly found near the base of the Plesiosauria.

THE MIXOSAURS (ICHTHYOSAURIA) FROM THE MIDDLE TRIASSIC OF NEVADA (USA): IMPLICATIONS FOR THE SYSTEMATICS OF THE GROUP

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The nearly cosmopolitan Middle Triassic Mixosauridae is of particular interest in addressing phylogenetical and paleobiological questions within the Ichthyopterygia. Among new material from the Middle Triassic Favret Formation of Nevada (USA), two taxa can be discerned: *Phalarodon nordenskioeldii* and *Phlarodon* sp. nov. Both species are also found in the Middle Triassic of Spitsbergen and British Columbia.

P. nordenskioeldii is represented by a new specimen consisting of the trunk region with one forelimb and both hindlimbs, which reveals clear mixosaurian synapomorphies. In addition, two characters diagnostic of the species can be recognized in this specimen: the number of primary digits in the forelimb is increased to six, and the metatarsal III gives rise to two digits.

Phalarodon sp. nov., best represented by a three-dimensionally preserved skull, cervical vertebrae, and one scapula, shows several mixosaurid synapomorphies as well. Autapomorphic features of *Phalarodon* sp. nov. seen in this specimen are the dorsal orientation of the external naris, the individual elements of the sclerotic ring being concave, and the distinct coronoid process. Within the postcranial skeleton, there are unique features, as well: very short and high cervical vertebral centra bearing a ventral keel, and the enlarged axis neural spine. Autapomorphies documented by other specimens are very short and high dorsal vertebral centra and the posterior margin of the ulna being distinctly notched.

A phylogenetic analysis including all currently recognized mixosaurs species (*Mixosaurus cornalianus*, *M. kuhnschnyderi*, *M. atavus*, *P. nordenskioeldii*, and *Phalarodon* sp. nov.) results in a fully resolved hypothesis of the in-group relationships of the Mixosauridae. *M. cornalianus*, *M. kuhnschnyderi*, and *M. atavus* form a clade, the sister-group of which is a clade consisting of *P. nordenskioeldii* and *Phalarodon* sp. nov. These results suggest the retention of the genus name *Phalarodon* for *P. nordenskioeldii* and *Phalarodon* sp. nov.

USING AN 'OPEN PREP LAB' IN EXHIBITION STORYLINE DEVELOPMENT

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'Open' preparation laboratories are a popular way to provide museum visitors with a view behind the scenes in a paleontological museum. Quite often, these 'open' preparation labs are either separated from the visitors by a thick glass wall, or are scaled down to an isolated 'special activity' in an exhibition hall, leaving the preparation work detached from the entire laboratory behind it.

The Natuurhistorisch Museum Maastricht has used a temporary 'open prep lab', not only to enable visitors to follow the preparation of a new mosasaur closely, but also to acquire feedback actively from the public, which was subsequently used in developing the exhibition on the new mosasaur.

In this temporary 'open lab', the entire laboratory was moved from the basement to an exhibition hall, enabling the public to get a real feeling of the preparatory work, and allowing them to ask all kinds of questions they might have.

Having the public around in a prep lab without glass walls involves various additional safety issues (dust, hazardous chemicals, etc) that were successfully addressed.

In the open prep-lab-setting, the intensive interaction with the public enabled the preparators to compile a detailed list of queries raised and of misconceptions among the public (Did mosasaurs swim in the Maas River? Did they eat Romans?). Other means of visitor survey would by far not have yielded similarly detailed information. The story-line of the subsequent exhibition of the specimen was largely based on this feedback.

NEW TRACKWAYS OF *MAGNOAVIPES*: FURTHER EVIDENCE OF GREGARIOUS BEHAVIOR IN SMALL CRETACEOUS THEROPOD DINOSAURS

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Numerous trackway assemblages provide evidence suggestive of gregarious behavior in dinosaurs, but the majority of these examples record large herbivorous species, such as sauropods and ornithopods. Very few dinosaur trackways provide support for gregarious behavior in small bipedal dinosaurs, and perhaps as few as five such sites are representative of small theropods.

Newly discovered dinosaur tracks on the Comanche National Grassland in southeastern Colorado are attributable to a small theropod dinosaur, *Magnoavipes* Lee, and preserve minimally four individual trackways. Nine prints are preserved as natural casts atop a widely exposed, iron-stained bedding surface at the top of the Mesa Rica Sandstone (Early Cenomanian), Dakota Group. Individual pes prints are tridactyl with slender digits, a sinuous middle digit, and well-defined claw impressions. "Heel" impressions are largely absent, and each print shows a wide divarication angle (up to 120°) between digits II and IV. The prints are all roughly the same size, ca. 15 centimeters in length and width, which borders on the smallest size reported for *Magnoavipes* tracks.

The individual trackways are parallel and are closely and regularly spaced, with each individual trackway separated by ca. 10 centimeters. Given the similar size of each trackmaker, similar trackway trends and stride lengths, and the intimate association of the assemblage as a whole, one plausible interpretation is that it records an episode of gregarious behavior for the *Magnoavipes* track-maker. This interpretation has only been offered for one other *Magnoavipes* track site, which interestingly occurs within the same drainage only a few kilometers distant. Other possible explanations for the similarly oriented, closely spaced trackways is some form of physical constraint in the environment, perhaps a trail free of obstruction in an area otherwise choked by vegetation. Another possibility is a combination of gregarious behavior and a physically controlled pathway.

SORICIDS FROM THE MEDICINE POLE HILLS LOCAL FAUNA (LATEST EOCENE) OF NORTH DAKOTA

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The Medicine Pole Hills Local Fauna is a highly diverse vertebrate assemblage from a stratigraphically restricted interval of the basal Chadron Formation. This study is a continuation of the analysis of the small mammal fauna. Two species of *Domnina* are present, differentiated primarily by size. *Domnina* sp. is the larger of the two and is more common, although both species are relatively rare in the fauna. *Domnina* sp. is nearly identical in morphology to *D. gradata*, but is approximately 20% larger. The Medicine Pole Hills specimens of *Domnina* sp. are most similar in size to *Domnina* sp. from the Uintan Swift Current Creek Local Fauna of Saskatchewan. However, the Medicine Pole Hills specimens lack a well developed lingual cingulum that blocks the paraconid-metaconid valley which is present in the Saskatchewan sample. Pending additional data, we consider the two samples as likely representing distinct species. The smaller of the two Medicine Pole Hills species fits the morphology and size range of *D. thompsoni*, which is smaller than *D. gradata*. Other than size, small morphologic differences occur between Medicine Pole Hills species. In the upper molar, the ectoloph of *Domnina* sp. is symmetric whereas the ectoloph of *D. thompsoni* is skewed posteriad,

although this difference may be related to tooth position. In the lower molars, *D. thompsoni* has better development of the cingulum on the M_1 than the M_2, in *Domnina* sp, the M_2 has a better developed cingulum than the M_1. *Domnina thompsoni* has been reported from the Pipestone Springs (Montana) and Raben Ranch (Nebraska) Local Faunas, both of which are considered middle Chadronian. The only other occurrence of a large species of *Domnina* is from the late Uintan Swift Current Creek Local Fauna. The *Domnina* material does not provide definitive information on the age of the fauna, but the previously interpreted age of early Chadronian is still considered likely. If so, the *Domnina* material represents the first known early Chadronian record of soricids.

MICROBIAL BIOMINERALIZATION AND EXCEPTIONAL PRESERVATION OF VERTEBRATE FOSSILS

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Exceptional preservation is generally accepted to mean the preservation of structures normally lost in the process of fossilization, including soft tissues and/or original organic components. Fossils that exhibit exceptional preservation contribute greatly to our understanding of extinct organisms. Such preservation implies virtually instantaneous mineralization, certainly before decay and degradation of these soft tissues is complete. Microbes have been known to cause or greatly increase mineral precipitation by multiple means, including chemical alterations of microenvironments to favor precipitation in the immediate environment.

We will present data, including immunochemical data, documenting the exceptional preservation of a series of fossil specimens, and propose microbial mechanisms that may have contributed to the rapid mineralization of soft tissues and other aspects of organisms that are not normally preserved in the fossil record.

NEW FOSSIL OF THE LARGEST KNOWN COELACANTH, FROM THE LATE CRETACEOUS OF SOUTHEASTERN USA

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The Late Cretaceous species *Megalocoelacanthus dobiei*, a very large, marine coelacanthid known from Santonian to Maastrichtian deposits in the eastern USA, was among the larger coelacanths in the fossil record. It is also the youngest known fossil coelacanth taxon. The original specific (and generic) description was based on well preserved holotype and paratype cranial and branchial material, from which we derived total length estimates of larger individuals of 3.5 to 4.0 m.

A new coronoid specimen, from a locality in the early Campanian Blufftown Formation in eastern Alabama, is significantly larger (~ x 0.28) than the coronoid in the type series. The same locality has previously yielded *M. dobiei* material, and the morphology shows that the coronoid is from the same species. By extrapolation, and assuming no significant allometry, the new coronoid came from a fish that was ~5.0 m in length, and thus was the largest known coelacanth, living or fossil. The abundance of specimens now known from *M. dobiei* shows that this recently described, huge fish was a major component of the Late Cretaceous near shore biota of the southeastern USA.

NEW MULTITUBERCULATES (MAMMALIA, ALLOTHERIA) FROM THE LATE PALEOCENE OF ALBERTA, CANADA, AND EVOLUTION OF MULTITUBERCULATES IN WESTERN CANADA

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With a geological range spanning some 165 million years, multituberculates were undoubtedly among the most successful groups of mammals, achieving great success both in terms of numbers and diversity in the Paleocene. Despite the relatively dense record in the Torrejonian (middle Paleocene) and Tiffanian (late Paleocene) of the Western Interior, the study of Tertiary multituberculates has been limited more often than not to isolated teeth or, more rarely, incomplete skull, gnathic, or post-cranial remains. The current study reports on new, exceptionally well preserved multituberculate specimens from the late Paleocene DW-2 locality of south central Alberta, Canada. The specimens are preserved in fine silts of the Paskapoo Formation, and consist of incomplete skulls, jaws, and post-crania, many of which are in articulation or association. Included among these specimens are the earliest records of the ptilodontid *Prochetodon*, three new species of the neoplagiaulacid *Neoplagiaulax*, and the most dentally complete Cenozoic neoplagiaulacid. Analysis of multituberculates from DW-2, as well as from the late Torrejonian Who Nose? locality, the earliest Tiffanian Cochrane 2 locality, and the late Tiffanian Gao Mine locality, suggests multituberculate diversity in western Canada is greater relative to paracontemporaneous localities from the Western Interior of the United States, contrary to hypotheses of lowered mammalian diversity in response to decreasing mean paleotemperature during the Tiffanian. Although ptilodontoids dominate the Torrejonian and early Tiffanian local faunas, the Gao Mine locality is unusual in the abundance of the microcosmodontid *Microcosmodon* to the near exclusion of ptilodontoids. Facies differences, sampling artifact, or some combination of both is offered as a partial explanation for the apparent incongruities.

ON THE VALIDITY OF *EQUUS LAURENTIUS* HAY, 1913

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The species *Equus laurentius* Hay, 1913 has been controversial since its inception. Authorities have differed over the interpretation of this taxon; some have considered it a legitimate Pleistocene horse species, while others have proposed that the name is invalid on the basis that the holotype specimen is a mineralized skull of a recent horse. As the taxon is still frequently employed in studies of Pleistocene equids, it is important to correctly assess its validity.

Our study presents the results of accelerator mass spectrometry ^{14}C dates obtained from the holotype skull and mandible. The radiocarbon measurements confirm that both the skull and the mandible are younger than 400 years in age. Protein chemistry and stable isotope analyses also support a recent age for the specimens. The size and morphology of the specimens fall within the range of like elements of modern *Equus caballus* Linnaeus, 1758. The species *Equus laurentius* Hay is a junior synonym of *Equus caballus* Linnaeus. Neither the taxon nor its holotype is taxonomically or phylogenetically pertinent to studies of North American Pleistocene *Equus*.

DIAGENESIS AND THE PALEOECOLOGICAL ANALYSIS OF A LATE PLEISTOCENE FOOTPRINT SITE IN THE BARINGO-BOGORIA BASIN, KENYA RIFT VALLEY

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There is a wealth of paleoecological and paleobiological information encoded not only in fossil footprints, but also in the sediments that preserve them. Knowledge of the taphonomy of fossil footprints can also contribute greatly to interpretations of depositional environments. We are presently conducting research to characterize the various factors that contribute to vertebrate footprint taphonomy and to establish a quantitative method of expressing these factors as measurable variables of footprint morphology. Presented here is an example that demonstrates the necessity for a sedimentological approach to studying footprint sites, and the utility of fossil footprints in the interpretation of sediments.

A large-bovid and hippo-trampled fossil footprint site has been identified in the Pleistocene Ilosowuani Fm. in the Baringo-Bogoria basin, just north of the equator in the Kenya Rift Valley. The footprinted bed is preserved by zeolites (locally up to 20% analcime) and calcite (calcrete) cementing lake margin silty and sandy clays, which also preserve root mats. Zeolites are most commonly formed in environments where there is evaporation of saline, alkaline ground water and within the lacustrine sediments of saline, alkaline lakes. These cements are thought to take thousands of years to form in stable arid/semi-arid conditions; in the Kenya Rift Valley, such a climatic period occurred approximately 20,000-12,000 years ago.

Prior to the discovery of the hippo footprints, the site had been interpreted as the margin of a small saline alkaline lake adjacent to a larger freshwater lake. Modern hippo ecology and footprint morphology and taphonomy suggest that the probable environment during the phase of hippo inhabitance was actually a freshwater (alkaline) lake margin marsh. This interpretation is also supported by the presence of fossil root mats within the same bed. Thus, it is imperative when interpreting aspects of paleobiology and paleoecology, and paleoenvironments of fossil vertebrates from fossil footprints, to consider their alteration by taphonomical factors and the alteration of the sediments by diagenetic factors.

LUMBOSACRAL DORSOSTABILITY IN GREAT APES: HOMOLOGY OR HOMOPLASY?

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African apes (*Pan*, *Gorilla*) and orang-utans (*Pongo*) have positional repertoires that include forelimb-dominated behaviors such as climbing, bridging, below-branch suspension, and brachiation. These behaviors benefit mechanically and kinematically from dorsostability of the lumbosacral region of the spine. However, due to inconsistencies between character complexes there is continuing debate about whether skeletal adaptations underlying dorsostability are synapomorphies of the great ape clade, or homoplasic. The late Miocene ape *Sivapithecus* is interpreted as the sister taxon to *Pongo* based on craniodental similarities, but differs postcranially in being adapted more for pronograde activities and in lacking features for forelimb-dominated behaviors. If *Sivapithecus* is the sister taxon to *Pongo*, it would suggest that postcranial features shared between African apes and orang-utans arose via parallel evolution. Conversely, some adaptations for dorsostability of the lower spine and suspensory behaviors were already found in fossil great apes (e.g. *Morotopithecus*) as early as the Lower Miocene.

Previous analyses dealing with this issue have concentrated on the appendicular skeleton. This study focuses on the axial postcranium, in particular the lumbosacral region, which in mammals is functionally correlated with positional capabilities. The results show that *Pongo* accomplishes dorsostability via a unique functional complex comprising an unusual combination of lumbosacral pedicle robustness, transverse process position, and prezygapophyseal angulation. Other vertebral traits also differentiate *Pongo* from African apes, such as regional numbers of vertebrae. Early Miocene apes lack the full complement of dorsostable features of extant apes. Together these findings indicate that dorsostability and associated behaviors independently arose multiple times in large-bodied apes.

CLIMATE-DRIVEN DIVERSITY CHANGE IN PALEOCENE MAMMALS OF THE NOTHERN ROCKY MOUNTAIN REGION

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Climate has long been considered an important driving factor in mammalian evolution, but the relationship is often hard to demonstrate. This study analyzed diversity change though 6.6 m.y. of the Paleocene, spanning 11 mammalian biozones, 7 with quarries and 6 with surface collections, in the Bighorn and Crazy Mountain basins. Taxonomic data were compiled from publications and from unpublished collections and represent 10,716 cataloged dental specimens. Marine $\delta^{18}O$ records from foraminifera were used as a proxy for continental temperatures. Correlation is based on age calibrations of marine cores and paleomagnetic chrons in the study area. Inequality of sample size was corrected with rarefaction, requiring an estimated number of individuals for each sample. Estimates were made using two counting methods due to taphonomic and collecting biases. Total Number of Specimens was used for claygall quarries and surface collections, and Minimum Number of Individuals for mudstone quarries.

Resulting diversity and temperature records both decrease from the late Torrejonian to the middle Tiffanian, and then increase to the end of the Clarkforkian. Least squares regression (LSR) and Spearman's rank correlation (SRC), a nonparametric technique, were used to measure linear association. Data were detrended by generalized differencing to eliminate serial correlation. Correlation between temperature and quarry diversity is highly significant, both for detrended data (LSR: $r = 0.93$, $p = 0.007$), and for data before detrending (LSR: $r = 0.93$, $p = 0.001$). Correlation in the combined dataset was significant using SRC ($p < 0.05$), but not LSR ($r = 0.44$, $p = 0.077$). Surface collection diversity did not pass either test, but was positively correlated with temperature. Surface samples in four zones were the smallest in the dataset, however, and surface collections are usually considered to be less representative of 'true' diversity than are quarry samples due to collecting biases. I conclude that quarry data are robust and demonstrate a strong correlation between temperature and diversity. The data corroborate hypotheses of climate-driven faunal change.

THE HARDERIAN-PINEAL-HYPOTHALAMIC AXIS IN EXTANT AND EXTINCT AMNIOTA, WITH SPECIAL ATTENTION TO ARCHOSAURIA

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The Amniote Head Research Program (AHRP) is devoted to the examination of various cephalic structures and systems. The objective of the AHRP is to clarify anatomical and physiological macroevolutionary differentiation and stasis within Amniota across major clades through a comparative study of extant and extinct basal taxa in the theoretical framework of phylogenetic systematic.

The extant sample includes cephalic material from adults, juveniles, and embryonic serial stages from alligators, tinamous, basal afrotherians, and various squamates. The extant specimens are studied at multiple levels, ranging from embryological development through to physiology. Numerous techniques are employed, including gross anatomical observation, serial histological sectioning, radioimmunoassays, clearing and staining, micro-CT, and immunohistochemistry.

The present focus of the AHRP is the Harderian-pineal-hypothalamic axis (HaH) and its relation to circadian rhythms (cyclical behavioral patterns regulated by indoles) in archosaurs and other amniotes. The precise structure of the components of the HaH axis, including their vascular and nervous supply, was examined to resolve several issues, including: (1) the presence of a functional pineal gland in crocodilians; (2) comparison of Harderian glands and the biological significance of the secretions in extant avesuchians; and (3) the osteological correlates of HaH axis structure in fossil archosaurs and their implications for extinct archosaur biology; e.g., diurnal, seasonal, and reproductive cycles including rhythmic anatomical, metabolic, and behavioral changes.

INTERRELATIONSHIPS OF LIVING AND EXTINCT AFROTHERIAN PLACENTALS

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Molecular sequence data have provided strong support for the monophyly of the placental superorder Afrotheria, but this hypothesis is still viewed with skepticism by various researchers, some of whom have argued that afrotherian monophyly is not supported by morphological data. This is not necessarily correct, because short internal branches within crown Afrotheria have left the interrelationships of non-paenungulate afrotherians (and thus ancestral character states within crown Afrotheria) unclear. If, for example, Macroscelidea is more closely related to the Afro-Malagasy zalambdodonts than to Paenungulata (as suggested by Murphy et al.'s (2001, *Science*, v. 294) analyses of a 16.4 kb molecular data set), then the unique morphological features shared by macroscelideans and paenungulates may be plesiomorphic within—but nevertheless provide morphological support for—Afrotheria, while the seemingly plesiomorphic, "insectivore"-like morphological features of tenrecs and golden moles may actually represent reversals from a more "condylarth"-like ancestor. Here I present a phylogenetic analysis of 60 living and extinct afrotherian species that combines 415 morphological characters with the molecular data set of Murphy et al. Parsimony analysis of the total data set supports afrotherian monophyly and the following interordinal relationships within that clade: ((Chrysochloridae, Tenrecidae), ((Macroscelidea, Tubulidentata), (Proboscidea, Hyracoidea, Sirenia))). Excluding molecular data and constraining analyses to recover afrotherian monophyly results in a ((Chrysochloridae, Tenrecidae), (Tubulidentata, (Macroscelidea, (Hyracoidea, (Proboscidea, Sirenia))))) topology. Neither of these results is consistent with the (Paenungulata, (Tubulidentata, (Macroscelidea, (Chrysochloridae, Tenrecidae)))) topology of Murphy et al., but their analyses employ more sophisticated models of evolution and also provide a more appealing solution to the problem of morphological support for afrotherian monophyly. Increased sampling of extinct afrotherians from the Cretaceous and Paleogene of Afro-Arabia will provide the most appropriate tests of these competing hypotheses.

THE EFFICACY OF LOW-MAGNIFICATION STEREOMICROSCOPY IN DIAGNOSING DIET ACROSS ORDERS OF MAMMALS

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The efficacy of a new and rapid method of scoring dental microscopic use wear which uses refractive light microscopy instead of scanning electron microscopy (SEM) is evaluated for consistency and reproducibility of measurements between independent observers, across repeated counts by the same observer, and across orders of mammals. Results show that use-wear features can be counted in a consistent manner by independent observers over independent trials and that the method has low intra- and inter-observer measurement error. There is also robusticity as to the selection of measurement site, in that the method works equally well when applied to upper or to lower molars. The method depends, as does SEM microwear analysis, on identification of features such as pits and scratches on enamel surfaces, but unlike SEM, it does not rely on detailed measurement. Rather, features are identified through an evaluation of their light refractive properties. Consequently, the new method succeeds in generating large amounts of data rapidly and with relative ease. The new technique, originally developed for and applied to extant and extinct Artiodactyla, Perissodactyla, and Proboscidea is now applied to Primates and Rodentia. Analysis of variance reveals a consistency of use-wear signals across mammalian orders. Graminivores, folivores and frugivores are effectively distinguished as are seed predators and hard-object feeders. Results are compared statistically and displayed graphically into a use-wear trophic triangle. Species sort according to dietary habit regardless of their systematic affinities.

LATE CRETACEOUS MARINE VERTEBRATES FROM THE BASAL GREENHORN LIMESTONE IN SOUTHEASTERN COLORADO

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The Comanche National Grassland located in southeastern Colorado is managed by the USDA Forest Service. It includes exposures of the Lincoln Limestone Member of the Greenhorn Limestone (Upper Cretaceous). The lowermost part of the Lincoln Limestone contains calcarenite beds rich in disarticulated remains of marine vertebrates. To provide a framework for the responsible management of this locality, we have examined the composition of the paleofauna through surface collecting and acid treatment of rocks. The paleofauna is taxonomically diverse, including chondrichthyans, osteichthyan fishes, and aquatic reptiles. The following chondrichthyans have been identified: *Ptychodus* cf. *P. anonymus*, *P. decurrens*, *P. occidentalis*, *Carcharias amonensis*, *C. saskatchewanensis*, *C. tenuiplicatus*, *Archaeolamna* sp., *Cretolamna appendiculata*, *C.* cf. *C. woodwardi*, *Cretodus semiplicatus*, *Cretoxyrhina mantelli*, *Squalicorax curvatus*, *S. falcatus*, *Rhinobatos incertus*, and *Cretomanta canadensis*. The identified osteichthyan fishes include Pycnodontidae, Albulidae, *Xiphactinus audax*, *Protosphyraena* sp., *Enchodus* cf. *E. gladiolus*, and *E.* cf. *E. shumardi*. The recovered aquatic reptiles include at least two types of plesiosaurs (cf. *Brachauchenius* sp. and cf. *Trinacromerum* sp.) and a dolichosaurid lizard, *Coniasaurus* cf. *C. crassidens*. Whereas the most common vertebrate fossils are *Enchodus* teeth followed by teeth of *Ptychodus*, *Cretoxyrhina*, and *Squalicorax*, the occurrence of more than 100 shed teeth of *Coniasaurus* from ca. 50 kg of rocks is notable. The composition of vertebrate fauna as well as some identified molluscan taxa (e.g., *Ostrea beloiti*, *Inoceramus* cf. *I. rutherfordi*, and *Eucalycoceras* sp.) suggest a middle/early late Cenomanian age (95.0-94.6 Ma).

TAXONOMIC DIVERSITY AND MICROVERTEBRATE FAUNAL ANALYSIS OF THE LATE CRETACEOUS MEETEETSE FORMATION, NORTHERN WYOMING

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Estes' classic work in the Lance Formation (late Maastrichtian) resulted in the recovery of more than thirty thousand microvertebrate specimens, representing over seventy-five different species, from the type localities. Estes' ecological analyses provided important paleoenvironmental information on the Lance Formation. The Meeteetse Formation (late Campanian–early Maastrichtian), which underlies the Lance Formation, has yielded relatively few vertebrate fossils until now, when the discovery of a new microvertebrate site at Elk Basin establishes the potential of the Meeteetse Formation. Preliminary finds include isolated dinosaur teeth and bone fragments (Ornithischia and Theropoda), portions of turtle carapaces, gar scales (*Lepisosteus*) and freshwater ray teeth (*Myledaphus*). The Meeteetse Formation stands to provide a new window on Late Cretaceous faunas in Wyoming. In addition, the Elk Basin locality appears highly fossiliferous, and the potential exists for the discovery of rare squamate and new mammalian taxa.

THE ASTRAGALUS-CALCANEUM COMPLEX OF *MYCTEROSAURUS* AND *VARANOPS* (SYNAPSIDA: VARANOPIDAE): MORPHOLOGY, LOCOMOTION, AND PHYLOGENY

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Well-preserved tarsal elements of *Mycterosaurus* and *Varanops* permit a detailed

description of the astragalus-calcaneum complex of these two forms. The astragalus is L-shaped and the calcaneum is circular in ventral view, as in most pelycosaurian-grade synapsids. The astragalus-calcaneum complex of *Varanops* is more robust than that of *Mycterosurus*. The most distinctive feature of the complex is the curved perforating foramen; the dorsal opening is formed equally by both the astragalus and calcaneum, a condition common to all synapsids, but the foramen is peculiarly curved medially so that the ventral opening is completely encased within the astragalus. This condition has never been reported for early synapsids. An ontogenetic series of *Mycterosaurus* calcanea indicates that the medial surface of the calcaneum contributes less to the foramen as the animal matures, hence suggesting that the groove for the perforating artery is initially formed between the complex. In *Varanops*, a medial triangular process of the calcaneum articulates with an emargination of the astragalus ventrally, indicating no rotation between these two elements. Reconstruction of the available hind limb elements of *Varanops* indicates that the tibial articulation with the astragalus is a highly movable joint, but movement between the fibula and proximal tarsus is restricted to a small degree of lateral rotation with no dorsoventral flexure. Furthermore, in *Mycterosaurus* and *Varanops*, the concave distal articular facet of the astragalus-calcaneum complex faces dorsodistally and articulates in part with the convex, dorsoproximally facing proximal articular surface of the enlarged fourth distal tarsal. This morphology indicates a highly mobile mesotarsal joint in *Varanops* and *Mycterosaurus*, refuting earlier claims that little movement was present between the tarsals of early synapsids. This observation, coupled with ichnological evidence, supports the presence of a semidigitigrade stance.

MOQUEGUA: THE FIRST DESEADAN SALMA (LATE OLIGOCENE) LOCAL FAUNA OF PERU

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We report the discovery of the first Deseadan South American land mammal "age" (SALMA: late Oligocene -?earliest Miocene) local fauna from Perú. This occurred as part of our paleontological reconnaissance of southern Perú in August 2002. The Deseadan SALMA fossils were found in the Moquegua Formation (a.k.a , "Upper Moquegua Fm."), at the summits of Cerro Pan de Azucar and nearby Cerro Mono. Despite the short time allowed to prospect the region, we recovered numerous remains of notohippid and mesotheriid (*Trachytherus*) notoungulates, as well as fragmentary remains of a macraucheniid litoptern, an indeterminate reptile, and a large avian "raptor."

The first fossil from the Moquegua Fm. was discovered by RQ during her study of the Sotillo Formation (= Lower Moquegua Fm.). She found the jaw of a new genus of notohippid while scaling Cerro Pan de Azucar with JA, AF, and co-discovers and coauthors Adan Pino and Nestor Jarica, and sent the specimen to the Museo de Historia Natural in Lima, thus prompting our collaboration and the field survey in Moquegua.

Cerro Pan de Azucar ("Sugarloaf Mountain") was the principal locality investigated. It is located 9 km WSW of the city of Moquegua, Perú, at 17°12'36" South and 71°00'36" West, within the Llanuras Costaneras, the costal plains between the Cordillera de la Costa and the Cordillera Occidental. Vertebrate fossils were also found at the summit of Cerro Mono ("Monkey Mountain"), 2 km SW of the summit of Pan de Azucar. The fossil bearing sediments are from the Moquegua Fm., inconveniently exposed at the tops of Pan de Azucar and Cerro Mono.

Tosdal and colleagues published K-Ar dates of 25.3 and 22.8 Ma from ashes of the Moquegua Fm., permitting the assignment of a late Oligocene to earliest Miocene age. This radiometric age is consistent with the vertebrate fossils we recovered.

LATE PERMIAN TETRAPODS FROM THE SAHARA

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Based on the presence of common genera in southern Africa, India, Europe, and Russia, the Late Permian has been interpreted as a time of broad cosmopolitanism among terrestrial vertebrates. In particular, the Beaufort Group of South Africa has shaped our understanding of late Paleozoic and early Mesozoic terrestrial ecosystems because of its thick sedimentary sequence and long history of paleontological study.

Recent fieldwork in the Upper Permian Moradi Formation of northern Niger suggests that this more equatorial region of Pangea hosted an endemic tetrapod fauna with a community structure remarkably different from that of the Beaufort Group. In contrast to the dicynodont-dominated faunas known elsewhere, the herbivores of the Moradi Formation are predominantly captorhinids, represented by *Moradisaurus*, and pareiasaurs, represented by a new genus possibly related to *Elginia*. The latter taxon is known from abundant cranial and postcranial material and is characterized by globular bosses over the external naris, orbit, and temporal region. Faunal dissimilarity also extends to the amphibians. Beaufort temnospondyls are rare and low in diversity, with *Rhinesuchus* and *Laccocephalus* representing the only Permian genera. The Moradi Formation has yielded the remains of at least three new taxa, including one possible rhinesuchid and two larger forms that represent families not known from the Permian of southern Africa. Most surprisingly, therapsids are only tentatively present in the Moradi Formation; several isolated maxillae and caniniform teeth possibly belong to a gorgonopsian or therocephalian predator.

Our research in the Moradi Formation suggests that West Africa may not conform to the model of faunal homogeneity previously considered for the Late Permian. The rarity (or potential lack) of dicynodont herbivores, coupled with a unique reptile and amphibian fauna, instead indicates a previously unsuspected area of biogeographic isolation and endemism in the center of Pangea.

RECONSTRUCTION OF EAR OSSICLES IN EXTANT AND EXTINCT MAMMALS USING ULTRA HIGH RESOLUTION X-RAY COMPUTED TOMOGRAPHY

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In mammals the ear ossicles play a crucial role in transmitting sound from the tympanic membrane to the inner ear. They amplify sound by mechanical and hydraulic processes in order to overcome the impedance mismatch between air and the fluids in the labyrinth. The relative proportions of the ear ossicles thus influence the range of sounds that an animal can hear, and so the size and shape of these bones is a guide to the habitually perceived sound frequencies. The morphology of the ear ossicles can also provide key phylogenetic information, particularly in terms of the form of the stapes. Fossil ear ossicles are rare, both because of their small size, and because of their tendency to fall out before fossilization. Even if ossicles remain in the middle ear cavity in fossil mammals, it may be impossible or impractical to remove them for study. Ultra high-resolution X-ray computed tomography (uhrCT) offers a method for non-invasive study of ear ossicles while they are still in place. Unlike conventional ("medical") X-ray computed tomography, slice thickness in uhrCT is thin enough to allow accurate reconstruction of the key features of ear ossicles that influence sound transmission. A method for extracting data from ear ossicles that are still in place in the skull is demonstrated using a large sample of extant mammals including primates, rodents, and marsupials. This method is also applied to a Late Paleocene (Clarkforkian) micromomyid primate. Micromomyids are among the smallest primates (30-40 grams) and the ear ossicles preserved are each about 1.2 mm long in the longest dimension. Preliminary analyses of these bones allows for new insights into the auditory anatomy of the most primitive primates.

THE SEMICIRCULAR CANAL DIMENSIONS OF BIRDS AND CROCODILIANS: IMPLICATIONS FOR THE ORIGIN OF FLIGHT

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The semicircular canals are vestibular organs which register changes in angular acceleration experienced by the head in motion. Numerous comparative studies have associated the size of the semicircular canals with locomotor behavior, observing that more agile species have canals with larger arc dimensions than less-agile species. Among birds, some studies have suggested that highly maneuverable species, such as pigeons and raptors, have larger semicircular canal dimensions relative to body size, whereas slower, more stable fliers, such as ducks and geese, have smaller relative dimensions. Others have noted that bird canal dimensions are larger than other tetrapods relative to body size.

Using computed tomography, we assessed the morphology, circumferential arc length (streamline length) and planar orientation of the bony semicircular canals in 31 bird species and 3 crocodilian species. This represents the first systematic CT survey of bird vestibular morphometrics ever conducted. Bird anterior semicircular canals are characterized by hyperelongation and deflection out of plane. The posterior and lateral canals also exhibit pronounced excursions out of their respective planes, and are sub-equal and absolutely smaller than the anterior canal in streamline length. By comparison, the crocodilian morphotype is characterized by a true planar conformity of canal streamlines, and elongation of the anterior canal is less pronounced. Our data corroborate early observations that agile birds, such as *Columba livia*, have larger canal radii of curvature relative to body size than stable fliers such as *Cygnus olor*. Furthermore, terrestrial birds such as *Struthio camelus* have canal dimensions more in common with crocodilians and mammals.

We hypothesize that the relatively large semicircular canals and unique morphology of bird inner ears relate to the development of active flight in this lineage. In the future, we plan the addition of primitive avialian and non-avian theropod specimens to this study to assess the shift from terrestrial bipedal locomotion to modern avian flight function, and the timing of this event.

APATITE COMPOSITION: A SENTINEL MINERAL FOR VERTEBRATES

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Studies from the medical perspective on bone and tooth mineral have begun to define the chemical ranges for modern bioapatites. This information offers a way to evaluate fossil materials from a wide range of geographic/geological sites and inversely may be of use medically.

Beyond morphology of the organ and tissue textures, the chemical composition of the mineral fraction can be used to discriminate between original, i.e. 'normal', bioapatite vs diagenetic, or altered, mineral phase. Beyond the optical techniques used to identify and prevent inclusion of any 'extra' mineral phases, or other confounding materials, scanning electron microscopy with energy dispersive analyses (SEM/EDAX) on thin sections establishes elemental distribution. This high-resolution method pinpoints extraneous phases, illuminates textural relationships, and provides detailed chemical characteristics of the bioapatite.

The levels and range of elements normally encountered in fossil bone or tooth samples, relatively easily and rapidly obtained, can be used to test the Ca/P ratio of the bioapatite and Na, for example. The presence of other and extraneous elements, perhaps from the surrounding matrix, or soil associated with the fossil burial, can be detected whether adsorbed or incorporated into the original mineralized tissues over time.

Although these sensitive techniques have been available for quite some time, exploration of the wide range of naturally occurring trace elements in the mineral matter of modern bones and teeth have not been adequately investigated. We know that living skeletons act as a filter, integrating what is ingested, but the permissible upper limit before an element becomes hazardous, copper and arsenic, for example, are not known. Studies on fluorine have shown one mechanism tied to the mineral crystallography. Paleoskeletal chemistries may represent extreme uptake for some elements but the results from such studies may help us to define the boundaries and mechanisms for other elements. Chemical data on fossil mineralized materials could enable us to predict potential pathological environmental exposures.

A TALE FROM THE CRYPT: STRUVITE MINERALIZATION IN A ROTTING RHINOCEROS

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In 1983 the headless carcass of a white rhinoceros (*Ceratotherium simum*) was buried on the University of Wisconsin, Madison campus. The carcass was buried in sandy, oxygenated and well drained but perpetually moist soil at a depth of 2m. The temperature presumably was fairly constant at Madison's mean annual temperature of 7.3C. Burial conditions were selected to maximize the rate of decay, while minimizing damage from freeze-thaw and plant roots.

In the spring of 2002 the carcass was exhumed. The hind limbs and the distal forelimbs were largely flesh-free, although fragments of toe pads were recovered from the front feet. The bulk of the carcass was surrounded by a thick layer of adipocere. The chest and abdominal cavities were hollow and contained remains of internal organs and gut contents. The muscles of the forelimbs and shoulder were moist, pliable, and bright red. Very little skin was preserved.

Given the presence of oxygen around the carcass (attested by the presence of insects), and the fact that the carcass had been exhumed and reburied in the early 1990's, the observed soft tissue preservation was remarkable. Microbiological and geochemical examination of tissue samples may shed light on the early diagenesis and possible mechanisms for long-term preservation of soft tissues.

Of particular interest are crystals of struvite (ammonium calcium phosphate hydrate) growing in voids between bones. Struvite occurs only in association with the decomposition of nitrogen-rich organic material, such as guano. As such, struvite may be a marker for preserved soft tissue. Moreover, the calcium and the phosphate components of struvite have three potential sources: bone, soft tissue and groundwater. Each source has a distinct calcium and oxygen isotope composition. If groundwater is not the sole source of calcium and phosphate in struvite, struvite should indicate the presence of soft tissue by its Ca and O isotope compositions. Over time struvite may alter into other minerals, such as apatite, by the loss of NH_4, but this alteration should not erase the original soft tissue isotopic signal.

EARLY PERMIAN TETRAPOD ICHNOFAUNA FROM THE MAROON FORMATION, COLORADO: AGE, PALEOECOLOGICAL, AND BIOSTRATIGRAPHIC SIGNIFICANCE

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The Maroon Formation of central Colorado is a massive nonmarine red bed unit (4,600 m thick) deposited in a subsiding cratonic basin. Conglomerates, coarse-grained sandstones and a few thin limestones dominate the lower half of the Maroon Formation. Siltstones and fine-grained sandstone units dominate the upper half of the Maroon Formation. The Maroon Formation is tentatively dated as Pennsylvanian/Permian, with no good age constraint at the top of the formation. There are non-vertebrate traces and a few plants of little chronostratigraphic value present. Conspicuously absent from the Maroon are vertebrate body fossils and vertebrate tracks, except for one reported but undescribed lacertoid trackway.

Hundreds of tracks were recently discovered from a high altitude (3,600 m) site in the Maroon Bells Wilderness Area, White River National Forest, administered by the United States Forest Service. The tracks (including trackways) come from one horizon in the upper half of the formation. The tracks occur in associated large blocks that are not in situ. The verticality of the strata prevents precise stratigraphic placement. The three ichnotaxa in the Maroon Bells assemblage are: *Ichniotherium cottae* (Diadectidae) (the most common track); *Varanopus* sp. (Captorhinomorpha); and *Dimetropus* sp. (Eupelycosauria). The conifer *Walchia* dominates the plant remains associated with the prints.

The Maroon Bells tetrapod ichnotaxa assemblage is important in that: 1) it provides the best record of *Ichniotherium* outside of Europe; 2) the assemblage strongly resembles the Tambach Formation assemblage of Germany, with the Maroon Bells taxa representing three of the four Tambach ichnotaxa, strengthening the faunal ties recently established between the Tambach Formation and some Early Permian redbeds in North America; 3) the Tambach Formation is considered Wolfcampian in age, suggesting the same age for the previously undated upper Maroon Formation; and 4) the Tambach Formation is interpreted as a rare Early Permian herbivore-dominated upland paleoecosystem, suggesting the same for the Maroon Bells track site.

NEW SPECIES OF *ISCHNACANTHUS* (ACANTHODII: ISCHNACANTHIFORMES) FROM CANADA: SIMILARITIES TO EXTANT SPECIES FLOCKS

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The ischnacanthiform genus *Ischnacanthus* is known from several species in two main geographic areas. The two largest collections of *Ischnacanthus*, *I. gracilis* from the Early Devonian Old Red Sandstone (ORS) of Scotland, and a collection of specimens previously described as *I. gracilis* from the Early Devonian Man On The Hill (MOTH) fish beds, Mackenzie Mountains, NWT, Canada, are preserved as both body fossils and isolated jaw elements.

Several new species have been identified from the MOTH collection based on dental morphology. In addition, all MOTH ischnacanthiforms possess a small cusp at the base of the medial surface of each main tooth, a feature not described for *I. gracilis*, suggesting a monophyletic origin for the MOTH species. The jaws of the new species differ markedly from ORS *I. gracilis* in dental morphology, although body fossils are remarkably similar to each other and to ORS specimens. Body fossils differ from *I. gracilis* in only a few features: MOTH specimens are deeper-bodied and possess enlarged scales at the bases of the fin spines.

Morphological similarity of the bodies of the fishes in the two most abundant ischnacanthiform assemblages raises the question of the degree of conservation of the body morphology of ischnacanthiform acanthodians during the Early Devonian. Perhaps body morphology changed little, while new patterns of dentition arose through selection for exploitation of different food sources. A modern analog can be found in Lake Victoria, Africa, which contains a diverse species flock of cichlid fishes. Body morphology of Lake Victoria cichlids is conservative whereas dental characteristics differ significantly, each species' dentition suited to different dietary specializations. The similarity in postcranial anatomy of species from MOTH and the ORS, and the fact that the new species from MOTH are only distinguishable using dental features, may have resulted from similar selective pressures to those experienced by Lake Victoria cichlids where significant evolutionary change occurred only in dental characteristics.

CRANIAL VARIATION WITHIN *ALLOSAURUS FRAGILIS*

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A considerable amount of non-size-related variation exists within some of the bones making up the crania of *Allosaurus fragilis*. Specimens from Dry Mesa, Cleveland-Lloyd, Dinosaur National Monument, Como Bluff, and an isolated site in eastern Utah were compared to document this variation. Some of the differences include changes in the orientation of paroccipital processes and the arrangement of the bones making up the basisphenoidal recess. Allometric variation in the pneumatic recesses in the wall of the basisphenoid was noted previously. Differences also exist in the supraoccipital and parietal bones making up the nuchal and parietal crests. The prootic, laterosphenoid, and opisthotic are fairly conservative. There also appears to be little non-size related endocranial variation, but these results are based on limited information. The available specimens include a bisected specimen and prepared endocranium, both from Cleveland-Lloyd, and ct-scan results of a larger specimen from Dry Mesa. As in other elements, braincases from Cleveland-Lloyd tend to be smaller than those from other sites.

The observed variation is not a function of the geographic location, stratigraphic position, or size of the animal. These results have functional and systematic implications. A posterior deflection of the paroccipital processes would limit lateral skull movement, while apparently permitting dorso-ventral movement at the occipital condyle. At this point, all of the material is regarded as being derived from a single variable species, *Allosaurus fragilis*.

FOSSIL VERTEBRATES FROM THE KAIPAROWITS FM, GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT: AN IMPORTANT WINDOW INTO THE LATE CRETACEOUS OF UTAH

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Recent paleontological work conducted by the Utah Museum of Natural History has yielded abundant new evidence of fossil vertebrates in the Upper Cretaceous Kaiparowits Formation in the Grand Staircase-Escalante National Monument. Dinosaur and other vertebrate remains have been previously recovered from the Kaiparowits, but few have been diagnosed to species level because of lack of identifiable remains. This project, financially supported by GSENM, seeks to identify new specimens from the Late Cretaceous of southern Utah and understand their temporal, ecologic, and phylogenetic implications.

As a result of three years of intense prospecting and excavation, a diverse fossil vertebrate assemblage has been recovered including fish, amphibians, and lizards. The largest and most conspicuous components of the fauna are the numerous dinosaurian taxa. One of the major discoveries is that of a partial skull from a new chasmosaurine ceratopsid as well as representative elements from the postcranium. Evidence of other ornithischian taxa includes ankylosaurs, lambeosaurine and hadrosaurine hadrosaurs, a pachycephalosaur, and a basal ornithopod. Theropod remains include the partial skeleton of a large tyrannosaur, a small caenagnathid, and less diagnostic material from other maniraptorans and ornithomimids.

Previous researchers have suggested the Late Cretaceous Western Interior contains two latitudinally distributed biozones (ie. a distinct northern fauna and a distinct southern fauna). Utah has been hypothesized to occur at the boundary between the biozones and may represent a zone of faunal interchange. Ultimately, descriptions of these new taxa from the Kaiparowits Formation sediments of GSENM will enable comparisons with coeval faunas both north and south, allowing paleontologists to test an array of ecological and evolutionary hypotheses.

ON THE OCCURRENCE OF *MAJUNGATHOLUS ATOPUS* IN INDIA: IMPLICATIONS FOR ABELISAUROID PALEOBIOGEOGRAPHY

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Given their pattern of distribution and the poor Gondwanan Cretaceous tetrapod record as a whole, abelisauroid occurrences are paleobiogeographically important. Whereas abelisauroids are well known from South America and Madagascar, they have long been rep-

resented in India and Africa by only fragmentary specimens. Five shed crowns (GSI 19991-19995) from the Maastrichtian Lameta Group in Gujarat, India that were referred to ?*Megalosaurus* B, C, and D by Mathur and Srivastava possess morphologies very similar to the teeth of the abelisaurid *Majungatholus atopus* from Madagascar. GSI 19991 and 19992 in particular possess the distinctive morphology of *M. atopus* premaxillary teeth of triangular crown shapes with round labial faces, slightly convex lingual faces, and denticulated carinae located lingually on the crowns. The teeth possess basally curving interdenticular sulci that cause the denticles to appear to fan toward the apices. The crowns show a slight distal recurvature but the recurvature profiles curve smoothly toward the apices. A stepwise discriminant function analysis (DFA) using squared Mahalanobis distances was run to test the hypothesis that GSI 19991 and 19992 are referable to *M. atopus* (GSI 19993-19995 were also analyzed). The DFA compared the teeth against a dataset of in situ theropod dentitions of known taxonomic affinity (including *Majungatholus* and *Masiakasaurus*), using variables referring to crown length, base length and width, squatness, curve shape, denticle size, and apex location with respect to crown base. For all five Lameta teeth, the analyses produced statistically significant results of <10 Mahalanobis distance units (MDU) between the mean score for the tooth in question and the group centroid of a standard of in situ *M. atopus* data. The next nearest centroid to the Lameta teeth was that of *Lilienstern*us at a mean of 131 MDU, which is not significant (nor was the *Masiakasaurus* centroid). The morphological congruence of the Lameta teeth with *M. atopus* and the statistically robust DFA suggests this taxon existed in both Madagascar and India.

FURNISHING A NEW PALEONTOLOGICAL CURATION AND RESEARCH FACILITY AT JOHN DAY FOSSIL BEDS NATIONAL MONUMENT, OREGON
SMITH, Matthew, FREMD, Theodore J., FOSS, Scott E., John Day Fossil Beds National Monument, Kimberly, OR.

The Thomas Condon Paleontology Center (TCPC), recently constructed at the Sheep Rock Unit of the John Day Fossil Beds National Monument (JODA), is a research and curation facility with an interface for public education and appreciation. The architectural concept was designed to surround the public with both a functioning paleontological research collection and exhibits that are designed to be flexible, in order to reflect current scientific inquiry. Visitors will be able to view the adjoining preparation laboratory, accession storage, and dedicated collections storage. The facility also houses a research library, education offices, and multi-purpose spaces.

Most of the equipment we have procured to outfit the new laboratory is targeted toward the development of bone preserved in zeolitized tuffaceous claystone, which encases the majority of specimens that are prepared. Flexibility is maintained to efficiently handle the wide range of matrices and taxa collected over a 10,000 square mile area, throughout a variety of geological microhabitats. Casting and molding will be essential functions as well, reflecting the effort we are making to house casts of diagnostic specimens collected prior to 1975, which are permanently stored outside of the John Day Basin. Fabrication of exhibits and the move of collections will take place from fall until the spring of 2004. The TCPC is scheduled to begin to recieve visitors and support active research during the summer of 2004.

IMPLICATIONS OF A PENTADACTYL GROUND STATE FOR THE AVIAN HAND ON THE HOMOLOGY OF THE THEROPOD MANUS: SHOULD THE FRAME-SHIFT HYPOTHESIS BE SHIFTED?
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A homeotic shift in digit identity during the evolution of the Theropoda (Frame Shift hypothesis) provides the best reconciliation of seemingly contradictory paleontological and embryological data. This theory holds that in the theropod lineage, after secondary reduction of digits DV, and then DIV, a deletion of condensation CI occurred to eliminate redundancy in digital condensations. This forced a homeotic shift in digit identity such that condensation CII develops into digit DI, CIII develops into DII, CIV develops into DIII, and CV does not differentiate. Recent embryological data have revealed a pentadactyl arrangement of prechondrogenic digital anlagen in the avian manus, suggesting a highly conserved pentadactyl ground state for the avian hand. Given this new embryological data, it seems unlikely that redundancy in condensations was the impetus behind digital reduction. It may be more parsimonious to hypothesize frame shift occurred earlier in the Theropod lineage, and through a different evolutionary scenario, than originally proposed.

This alternate scenario hypothesizes loss of the digital developmental pathway of condensation CI prior to Neotheropoda, coincident with a homeotic shift in the developmental identity of the initial digital condensations such that condensation CII develops into digit DI, CIII develops into DII, CIV develops into DIII, and CV develops into DIV. A homeotic shift in digit identity occurring prior to Neotheropoda, as opposed to Tetanurae, is more parsimonious considering the numbers of elements that would have to be lost or re-evolved under either scenario. This hypothesis would also reconcile the pattern of digital reduction in the theropod manus with an apparently highly conserved pattern of digital reduction among amniotes, and may explain why advanced development of CV relative to CI is observed in chick embryos. Rearrangement of wrist elements in neotheropods may also be related to initial loss of the digital developmental pathway of CI. Despite the parsimonious appeal offered by this hypothesis, the putative presence of digit DV in some *Coelophysis* specimens could refute this scenario.

A THEORETICAL MODEL OF NECK MUSCULOSKELETAL FUNCTION IN THE TYRANNOSAURIDAE
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Neck functional morphology is central to amniote feeding. A reconstruction of major cervical and craniocervical muscles in *Tyrannosaurus rex* indicates a combination of traits respectively closer to the avian and crocodilian conditions. This inferred morphology forms the basis for a theoretical model of neck function, incorporating musculoskeletal geometry and aspects of muscle force generating capacity. The model predicts aspects of craniocervical feeding function in terms of a summation of muscle torques, and facilitates testing of several hypotheses.

For example, strong upward beveling of tyrannosaurid posterior cervicals indicates a favorable moment arm for neck dorsiflexion by *M. longus colli dorsalis*. A proportionally greater horizontal component of the muscle pull in smaller tyrannosaurids may have compensated for shorter dorsiflexive moment arms. Bilateral contraction of *M. longissimus capitis* is hypothesized to have effected powerful head retraction for excising flesh.

This modeling approach suggests constraints on the feeding capabilities of tyrannosaurids. However, it is less adequate for addressing issues of behavioral plasticity, such as whether tyrannosaurids paralleled extant archosaurs in modulation of inertial feeding.

NEW *ALLIGATOR* REMAINS FROM THE MIOCENE OF FLORIDA, AND NOTES ON *ALLIGATOR* PHYLOGENY
SNYDER, Daniel, Univ.of Iowa, Iowa City, IA.

Fossil specimens pertaining to two Miocene Florida *Alligator* taxa are described. The specimens include extensive, sometimes articulated, postcranial material, greatly expanding our knowledge of the clade's morphology. One species is easily referable to *Alligator olseni*, coming from the same Hemingfordian Thomas Farm locality that produced the type. Another species, from the Hemphillian Moss Acres locality, may be referable to the Clarendonian taxon *Alligator mefferdi*. The new fossils necessitate a phylogenetic reexamination, which shows a more complicated history than has been previously suposed. The issues of taxon sampling in tree reconstruction and the dispersal of *Alligator* are examined in light of the new phylogenetic hypothesis.

ISOLATED OCCURRENCES OF TWO NEW THELODONTS FROM THE SILURIAN OF THE MACKENZIE MOUNTAINS, NORTHWEST TERRITORIES, CANADA
SOEHN, Kenneth, WILSON, Mark V. H., University of Alberta, Edmonton, AB, Canada

New Thelodontomorphi from the Wenlock (Silurian) of the Avalanche Lake sections, Mackenzie Mountains, N.W.T., Canada, constitute two new genera and species. They are based on isolated scales from single horizons of earliest Sheinwoodian or latest Homerian age. Though no histological investigation is currently possible, their external architecture suggests that one is of apalolepid and the other of thelodontid type. This occurrence of an apalolepid is significantly early for this type of scale. Some researchers (Karatajute-Talimaa; Turner) consider apalolepids to be derived thelodontids. This record would indicate that their origins are much closer chronostratigraphically than previously believed.

Though no biostratigraphic range can presently be established for either species, as each is known only from a single site in the Selwyn Basin, the specimens of apalolepid type appear within the *centrifugus-insectus* Generalized Graptolite Zone, the *procerus* conodont Superzone, the *belli* regional trilobite Zone, the *septentrionalis-avalanchensis* regional brachiopod zone, and the *turbinata* regional vertebrate Zone. The specimens of thelodontid type are found within the *ludensis* Generalized Graptolite Zone, the *B. bohemica* Generalized Conodont Zone, the *harrisoni* regional trilobite Zone, and the *martinssoni* Generalized Vertebrate Zone.

PALEODIETARY TRENDS AMONG THE MERYCOIDODONTIDAE (OREODONTS) FROM THE LATE EOCENE TO LATE MIOCENE USING THE ABRASION-ATTRITION WEAR GRADIENT METHOD
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We used a recently developed macroscopic method for characterizing selenodont ungulate molar wear facet development, mesowear, to examine paleodietary trends within the family Merycoidodontidae from the Chadronian (late Eocene) to Clarendonian (late Miocene) North American Land Mammal Ages. A total of 2458 observations were made on 32 taxon-specific samples. The apex of the M2 paracone was classified as pointed, rounded, or blunt, and the valleys between the cusps were classified as either high or low. Among modern selenodont ungulates these variables correctly classify species into the classic dietary categories, browser, mixed-feeder, and grazer. In general, the data on oreodonts portray a gradual transition from attrition-dominated wear with predominantly high and sharp cusp apices to an increasingly more abrasion-dominated wear pattern with predominantly rounded cusp apices. In terms of modern-day ungulate diets, this shift represents a transition from browsing in the late Eocene to mixed feeding by the late early Miocene. During the Oligocene-Eocene transition there is actually a minor reversal in this trend among *Merycoidodon* and *Miniochoerus*. By Whitneyan time, these taxa begin to show an increased amount of abrasion dominated facet development. *Leptauchenia*, a more hypsodont form, shows a similar degree of facet development. There is little apparent change in facet development among Arikareean samples of *Leptauchenia*, *Eporeodon*, *Merychochoerus*, *Merychyus* and others. By Hemingfordian time, there was a conspicuous increase in dietary abrasion within samples of *Merychocheorus*, *Merychyus*, *Brachycrus*, and *Ticholeptus*. Mesowear trends appear to have been more or less stable through the Barstovian and Clarendonian. The Oligocene-Miocene trend toward increasing dietary abrasiveness appears to have been gradual, and was not necessarily punctuated by the appearance of more hyposont taxa, although later oreodont assemblages did contain an increasing relative number of more hypsodont taxa. None of the taxa sampled appear to have adopted a hyper-coarse grazing diet.

PALEOECOLOGY OF THE GIANT SHORT-FACED BEARS *AGRIOTHERIUM* AND *ARCTODUS*

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The hypothesis that giant short-faced bears of the genera *Agriotherium* and *Arctodus* were primarily carnivorous and preyed on large terrestrial herbivores is examined. It is argued that the shape and wear pattern of the cheek teeth, the position of the mandibular condyle, and the presence of the premasseteric fossa in these two ursids suggest a primarily herbivorous diet, while their broad rostra with short canines, small or laterally directed orbits, and long limbs with short and massive distal segments suggest they were ill-suited for predation on large terrestrial mammals. The skeletal and dental morphologies of *Agriotherium* and *Arctodus* are then compared to those of *Hemicyon*, an extinct ursid that is widely accepted to have been a predaceous carnivore. The comparison confirms this reconstruction of the paleoecology of *Hemicyon*, but also suggests that its diet included a significant amount of plant material. In contrast, the comparison provides further support for the hypothesis that *Agriotherium* and *Arctodus* were primarily herbivorous and seldom, if ever, preyed on large terrestrial mammals. However, it is argued that the diet of the two giant short-faced bears probably included a significant amount of animal material, which was obtained by scavenging.

JURASSIC DINOSAURS FROM NORTHEASTERN WYOMING: WYOMING'S QUIET CORNER

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The State of Wyoming is world-renowned for its wealth of Jurassic dinosaur skeletons, with the majority of quarries located in the southeastern part of the state. Less well known are the Morrison Formation sites in Wyoming's northeastern corner, found on the edges of the Powder River Basin. In 1902 the Carnegie Museum of Natural History had 3 separate collecting parties in Wyoming seeking display quality dinosaur specimens. W.H. Utterback was prospecting the Jurassic outcrops on the east slope of the Big Horn Mtns. after an unsatisfactory search in Cretaceous beds. Over the course of 4 years he primarily found sauropod dinosaur bones (*Apatosaurus, Camarasaurus, Diplodocus*, and ?*Haplocanthosaurus*). Most notable of these was *D. hayi*, a new species which was eventually traded to Houston where it is on exhibit. Partial remains of *Stegosaurus, Allosaurus* and *Dryosaurus* were also collected. This area of Wyoming remained untouched until 1977, when B.R. Erickson of the Science Museum of Minnesota removed tons of sauropod material including *Apatosaurus, Brachiosaurus, Camarasaurus*, a nearly complete *Diplodocus* and the northernmost specimen of *Haplocanthosaurus. Stegosaurus, Allosaurus, ?Elaphrosaurus, Camptosaurus* and significant juvenile material of several taxa were also discovered. M.J. Flynn of Sheridan College took over the quarry in 1990 and has continued work in the area for the past 12 years. He found the familiar Jurassic dinosaur fauna, as well as new dinosaur footprints and trackways. On the opposite side of the basin, fragmentary Jurassic dinosaur bone was found by F.B. Loomis during his 1902 stratigraphic study. In 1978 crews from the SDSM&T Museum of Geology began paleontological exploration on the west slope of the Black Hills. Remains of *Apatosaurus, Camarasaurus, Diplodocus, Barosaurus, Allosaurus, Stegosaurus, Dryosaurus, Camptosaurus, Othnielia* and various juvenile specimens were found, as well as small, tridactyl dinosaur footprints. Although less studied than other areas, northeastern Wyoming contains proven fertile ground for important new Jurassic fossils.

BIOGEOGRAPHIC AND GENETIC ORIGINS OF THE GREATER YELLOWSTONE ECOSYSTEM MAMMALIAN FAUNA

SPAETH, Paula, Palo Alto, CA; CONROY, Chris J., UC Berkeley, Berkeley, CA; CHAN, Yvonne, HADLY, Elizabeth A.,Stanford University, Stanford, CA, 94305.

Yellowstone National Park is a home to a diverse, high-elevation north temperate community. This modern assemblage is the result of the recent migration of animals onto the Yellowstone Plateau that was glaciated until 12,000 ybp. A survey of the biogeographic origins of mammalian taxa that have colonized Yellowstone National Park in the Holocene has been conducted to estimate the major direction of colonization of this unique community. In addition, a genetic analysis of the phylochronology of a highly opportunistic species, the long-tailed vole (*Microtus longicaudus*), based on time-series genetic data obtained from late-Holocene fossils from Yellowstone National Park, was performed to detect the source population and locate potential geographic corridors into this ecosystem. We present evidence that taxonomic identity, life history, and habitat association have influenced migration routes. This study provides a unique perspective on ecosystem assembly by examining patterns of species movements on taxonomic and genetic levels.

ECOLOGICAL IMPLICATIONS OF MICROSCALE $\delta^{13}C$ ISOTOPIC ANALYSIS OF AN ONTOGENETIC SERIES OF THE HADROSAURIAN DINOSAUR *EDMONTOSAURUS*

STANTON THOMAS, Kathryn J., CARLSON, Sandra J.,University of California, Davis.

Stable isotope analysis of vertebrate biominerals, primarily in mammals, has been used to address questions of paleodiet, paleoclimate, trophic level, migration, foraging zone, and thermophysiology, with varying degrees of success. Isotopes are less commonly used to study ecology in dinosaurs, generally because 1) non-avian dinosaurs lack the close modern relatives that are used as analogs in isotopic studies of, for example, mammals, and 2) difficulty in serially sampling very thin tooth enamel, which is the biomineral most likely to preserve an original isotopic signal rather than a diagenetic one. By utilizing a relatively new technique in microsampling, this study addresses the following questions: Do microscale analyses of carbon isotopes from mineralized tissues of hadrosaurian dinosaurs record temporal variation? If so, is the cause of the variation physiological, ecological, or environmental?

Isotope values from the carbonate component of enamel ($\delta^{13}C$) were obtained by microsampling multiple teeth in a temporal series from the dental batteries of a juvenile, subadult, and adult *Edmontosaurus* from the Maastrichtian Hell Creek Formation of South Dakota. To establish isotope variability in an extant archosaur, consecutive teeth in a temporal series from an *Alligator mississippiensis* specimen were microsampled for isotopic analysis and compared to those of *Edmontosaurus*. Heavier than predicted $\delta^{13}C$ values in *Edmontosaurus* are hypothesized to result from 1) enrichment of $\delta^{13}C$ in ingested plant material due to higher atmospheric $\delta^{13}C$ values in the Late Cretaceous; 2) taxon-specific $\delta^{13}C$ effects of ingested plants (primarily gymnosperms); 3) enriched $\delta^{13}C$ of ingested plant material due to osmotic stress from proximity to the Western Cretaceous Interior Seaway, 4) taxon-specific $\delta^{13}C_{\text{diet}} - \delta^{13}C_{\text{enamel}}$ fractionation factors for *Edmontosaurus* that vary from those observed in modern mammals, and/or 5) diagenesis. Microsampling provides a detailed perspective on the ecological (dietary) mechanisms of carbon isotope incorporation in dinosaur biominerals that is not obtainable through bulk sampling alone.

FUNCTIONAL AND MORPHOLOGICAL EVOLUTION OF THE LIZARD SKULL

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The evolution of the lizard skull was investigated from a morphological and functional perspective. More than 550 extant and fossil lizard skulls were photographed in lateral view, and thirteen functionally relevant landmarks were digitized on these photographs. Morphometric analysis using relative warps was used to summarize shape variation among all species. A phylogeny of relationships among the lizard families was plotted on these relative warps, to describe directions and patterns of lizard skull evolution. An analysis of extant species only revealed a morphological split between Iguania and Scleroglossa, with Iguanians having shorter snouts, higher skulls, and larger areas for adductor muscle attachment than their sister group. This morphological difference implies slower, but more powerful jaws within the Iguania. Evolution among families within the Iguania has also been primarily divergent, with little overlap in morphospace between families, whereas evolution in the Scleroglossa is characterized by much morphological convergence. Fossils indicate that this basal dichotomy is a true morphological divergence that was in place as early as the Paleocene. Fossil taxa always occur within the area of morphospace occupied by the extant members of their families, and species from extinct families occur within the area delimited by all extant lizards. This pattern suggests that morphological evolution of the lizard skull is characterized by early, rapid divergence, followed by smaller scale evolution within families.

CARBON ISOTOPE EVIDENCE FOR ECOLOGICAL NICHE PARTITIONING AMONG HERBIVOROUS DINOSAURS OF THE JUDITH RIVER FORMATION, MONTANA

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Carbon isotope studies have been successful in identifying plant photosynthetic pathways and dietary preferences of both modern and Cenozoic herbivorous mammals. These methods, however, have not been applied as extensively to the study of dinosaurs. Here we present preliminary results of a detailed carbon isotope investigation of two herbivorous groups of dinosaurs. Twenty-three tooth fragments from Ankylosauria and Hadrosauria were collected from two microsites in the Late Cretaceous (Campanian) Judith River Formation in Montana. In addition, 16 samples of organic material were collected from sediments associated with the microsites. Carbon isotope ratios were determined for both tooth enamel and organic material.

Carbon isotope ratios (in per mil) of the hadrosaur tooth enamel ranges from -3.5 to 4.0 with an average value of 0.5. Carbon isotope ratios of ankylosaur tooth enamel ranges from 1.3 to 5.1, with an average of 3.3. Carbon isotope ratios of organic matter ranges from -24.0 to -15.0. Thus, ankylosaurs have higher carbon isotope ratios than the hadrosaurs, and the isotopic offset between the dinosaur tooth enamel and organic matter is ~20.0.

Differences in carbon isotope ratios between taxa suggest that these dinosaurs had different diets and provide the first isotopic evidence for partitioning of ecological resources by these vertebrates. The nature of these different resources can be investigated by looking at absolute isotope ratios of enamel and organic matter, both of which are high for a time period and region assumed to have had only C3 plants. C3 plants can have carbon isotope ratios as high as ~-20.0 in salt-stressed environments, and these plants might account for the lower carbon isotope ratio of the organic matter range between -24.0 to -20.0. In contrast, higher values found in organic matter suggest the existence of aquatic C3 plants or even C4 plants in the area. Lower carbon isotope ratios of hadrosaur teeth suggest that they ingested salt-stressed C3 plants; higher ratios of ankylosaur teeth suggest their diet was made up almost exclusively of aquatic C3 plants and/or terrestrial C4 plants.

PALEOECOLOGY OF SMALL MAMMALS FROM WATERFALL LOCALITY, YELLOWSTONE NATIONAL PARK, WYOMING

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Waterfall Locality (WL) is a late Holocene paleontological site located at 2330 m elevation in Yellowstone National Park, Wyoming, USA. The deposits derive from raptor pellets and carnivore scats collected by wood rats (*Neotoma cinerea*). The site contains 19 stratified layers alternating between organic and alluvial material spanning the last 3300 years. Over 20 mammalian species were represented by 3000 specimens, and the species abundances reflect

the spruce-fir forest environment that currently surrounds the site. We compared WL to Lamar Cave (LC), another late Holocene wood rat midden located 24 km SW of WL. LC is located 500 m lower in elevation in sagebrush grassland. The taxonomic composition of the sites was similar, indicating that the assemblages reflect the same ecosystem, but details of the communities were different. The taxa faithfully reconstruct the vegetation communities immediately surrounding the sites today. WL contained significantly more leporids than LC, but LC contained more pocket gophers (*Thomomys talpoides*) and deer mice (*Peromyscus maniculatus*), which characterize open and dry environments. Both sites contained equal abundances of voles, but species identifications using tooth morphology and ancient DNA indicate that the voles in WL were mainly red-backed voles (*Clethrionomys gapperi*), heather voles (*Phenacomys intermedius*), and long-tailed voles (*Microtus longicaudus*) while LC contained mostly montane voles (*Microtus montanus*). *Clethrionomys* is found in cold, rocky forests and woodlands, and *Phenacomys* prefers open coniferous forest. *M. longicadus* likes grassy areas within forests, while *M. montanus* prefers open grasslands. Sciuridae shows a similar pattern. WL contained flying squirrels (*Glaucomys sabrinus*) and golden-mantled ground squirrels (*Spermophilus lateralis*), neither of which was found in LC. Our fossil data were compared with trapping data from the modern communities outside both sites in order to ascertain the response of different communities to similar environmental changes.

QUANTIFIABLE CHANGE IN THE *ISURUS HASTALIS* POPULATIONS IN MIDDLE AND UPPER MIOCENE ROCKS OF CALIFORNIA

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Large samples of *Isurus hastalis* teeth from restricted horizons in Miocene rocks of southern and central California were studied to test for morphologic stasis. All specimens used in this study are from the collections of the Natural History Museum of Los Angeles County. The two populations central to this study are from the Sharktooth Hill Bonebed, Kern County, and a horizon near the top of the Monterey Formation in Orange County. Only teeth from the first position in the upper jaw were utilized. Crown height and crown basal width were measured for each tooth.

The Sharktooth Hill Bonebed is a well documented middle Miocene feature in the Round Mountain Silt. Terrestrial components of the fauna belong to the Barstovian North American Land Mammal Age. The Monterey Formation in Orange County spans parts of the middle and late Miocene. The horizon that produced the late Miocene population is from near the top of the formation in Laguna Niguel. Terrestrial components of the fauna from this part of the Monterey Formation are assignable to the Clarendonian NALMA. Graphic comparison of the crown height vs. basal crown width shows that the two populations overlap, but that the later sample has somewhat broader teeth for a given crown height than does the earlier sample. That is to say, the teeth of the later sample are more blade-like. Some authors refer to this later morph as *Isurus xiphodon*. A limited sample of teeth from the middle Miocene portion of the Monterey Formation in Orange County agrees with the Round Mountain Silt population. A limited sample from near the base of the Capistrano Formation, which overlies the Monterey Formation, conforms to the late Miocene Monterey Formation population. A rudimentarily serrated morph associated with a Hemphillian fauna is even broader, and the modern serrated morph (*Carcharodon carcharias*) is broader still. This temporal-morphologic cline seems to be applicable throughout California and Baja California.

A NEW SPECIES OF *CYMBOSPONDYLUS* (REPTILIA, ICHTHYOSAURIA) FROM THE MIDDLE TRIASSIC OF NEVADA AND ITS IMPLICATIONS FOR THE SKULL OSTEOLOGY OF THIS GENUS

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The representatives of the genus *Cymbospondylus* are medium to large-sized ichthyosaurs with a cosmopolitan distribution in the Middle Triassic. The genus was first described by Leidy (1868), and a number of species have been assigned to it since then. However, only two species are well known from almost complete skeletons rather than from fragmentary material: *C. petrinus* (Leidy, 1868) from the Humboldt Range, Nevada, USA, and *C. buchseri* (Sander, 1989) from the Grenzbitumenzone Beds of Monte San Giorgio, Switzerland.

A new species of *Cymbospondylus* was found in the Fossil Hill Member of the Favret Formation in the Augusta Mountains, Nevada. This indicates the presence of two species of the genus in the Middle Triassic of this area. The new species is based on one specimen, of which large parts of the skull as well as postcranial material are preserved in three dimensions.

The assignment of the new specimen to the genus *Cymbospondylus* is supported by a number of distinctive characters, but the new species differs from the other two in unique characters, especially in the anatomy of the skull. The postorbital has a rectangular shape and is dorsoventrally elongated, contributing to the lateral border of the upper temporal opening. It overlaps the anterior portion of the long and slender supratemporal. Moreover, the quadratojugal does not make contact with the quadrate and is restricted to the lateral side of the skull. The new species has between eight and ten cervical vertebrae and is therefore intermediate between *C. buchseri* with six cervicals and *C. petrinus* with 12.

The new find helps to clarify the controversial osteology of the skull of *Cymbospondylus*. Remarkably, there is an additional skull bone posterior to the parietal in all members of the genus. The position of the bone suggests it to be the postparietal. The loss of the postparietal has been viewed as a synapomorphy of the Ichthyosauria. However, the presence of a postparietal would have extensive consequences for the phylogeny and the origin of this group.

ICE AGE BIOSTRATIGRAPHY IN EASTERN BERINGIA

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Recent and ongoing studies of mammalian faunas have led to the beginnings of a biostratigraphic framework for the Ice Age (>2.6 Ma–10 ka) of Eastern Beringia, the largely unglaciated area of Yukon and Alaska.

At Thistle Creek in the southernmost part of the Klondike Goldfields, Yukon Territory, three pre-Wisconsinan units preserve mammalian faunas. The Old Crow tephra (~140 ka) underlies units Organic 2 and Organic 3, and these beds represent the last interglacial in the area (~125 ka). An older interglacial unit at Thistle Cheek, Organic 1, contains near its base Gold Run tephra, recently dated at 708 ± 68 ka. Each faunal assemblage from Thistle Creek includes at least eight species.

At Fort Selkirk YT, along the Yukon River, a fauna has been collected from loessal sediments beneath a tephra more than 1.48 Ma old and above a lava flow 1.83 Ma old. One of the most primitive *Microtus* species, *M. deceitensis*, is well represented in this 12-taxon fauna. Comparison of Fort Selkirk *M. deceitensis* teeth with the type sample from Cape Deceit, Seward Peninsula of western Alaska, has shown that the Cape Deceit population is evolutionarily less advanced and presumably the older of the two. The Cape Deceit fauna, from normally magnetized sediments, is assigned to the Olduvai subchron, probably about 1.8 Ma old and latest Pliocene.

Concentrate has been screen-washed at locality CRH-94, on the Old Crow River in northern Yukon. These beds, dated by the Little Timber tephra at 2.29 Ma, will produce a fauna from a Pliocene interglacial near the beginning of the Ice Age.

NEW MAMMALIAN FOSSILS FROM THE EARLIEST EOCENE (WA-0), BIGHORN BASIN, WYOMING

S*TRAIT, Suzanne G., Marshall University, Department of Biological Sciences, Huntington, WV.*

The beginning of the Eocene is marked by abrupt global warming and faunal turnover. The first evidence of this faunal turnover in North America comes from earliest Wasatchian (Wa-0) localities. Surface prospecting and intensive screen-washing at a Wa-0 site in the southeastern Bighorn Basin (Castle Gardens) has resulted in the identification of over 800 mammalian specimens. Lipotyphlans comprise the majority of the sample (33%). Castle Gardens is dominated by *Macrocranion junnei*, but other rarer insectivores have been recovered as well (e.g., cf. *Pontifactor*, *Plagioctenodon*, *Wyonycteris*, cf. *Parapternodus*). The second most abundant group are the condylarthrans. The majority of these are the phenocodontids *Ectocion parvus* and *Copecion davisi*, but *Phenacodus*, *Dissacus*, *Chriacus*, *Princetonia*, *Thryptacodon*, and *Hyopsodus* have been recovered as well. Three marsupial species (*Mimoperadectes labrus*, *Peradectes protinnominatus*, and *Peratherium innominatum*) are common and make up 14% of the fauna. Rodents are also quite abundant at Castle Gardens (accounting for 10% of the total sample); the majority are *Acritoparamys atwateri*, but *Paramys taurus*, *P. copei*, and the rare *Reithroparamys ctenodactylops* have also been recognized. Multituberculates are also fairly well sampled (9%), with both *Ectypodus tardus* and *Parectypodus lunatus* being represented. Primates are less adundant (5%), with *Niptomomys favorum* being the dominant form. Perissodactyls, carnivorans, creodonts, tillodonts, taeniodonts, pantodonts, artiodactyls, and apatotheres all comprise less than 3% of the collected specimens.

In addition to the main site of Castle Gardens, surface collecting around adjacent areas has proven productive. One particular bed appears to represent the "Wa-0? Interval" of Gingerich. Thus far, fragmentary remains of *Meniscotherium*, Rodentia, and a large ceratomorph have been recovered. The presence of this perissodactyl confirms a Wasatchian age for this fauna. Additionally, this new first appearance datum for ceratomorphs in North America raises interesting biogeographic issues concerning the origin and radiation of this group.

DISCOVERY AND SIGNIFICANCE OF GOBIID OTOLITHS FROM THE MIDDLE EOCENE (EARLY LUTETIAN) CANE RIVER FORMATION OF LOUISIANA

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Gobiids (Family Gobiidae, Class Actinopterygii) were tentatively identified on the basis of otoliths in a previous study of the Cane River Formation (middle Eocene, early Lutetian) of Louisiana. Additional sampling of the site and subsequent analysis has verified the presence of this family of bony fishes. The Family Gobiidae contains the largest number of species (approximately 1,875) of any modern family of marine fish in the Class Actinopterygii. The family is also one of the most highly diversified groups of all modern vertebrates, yet its early evolutionary history is poorly known.

The appearance of otolith-based gobiids in the earliest Lutetian is highly significant. First, it extends the range of gobiids in North America from the Bartonian (approximately 39 million years old) to the earliest Lutetian (approximately 46.5 to 48 million years old). This is a substantial increase of at least 7 million years. Secondly, the 26 gobiid otoliths from the additional sampling of the Cane River Formation represented over 10% of the total otolith-based fish assemblage. This indicated that gobiids were not only present, but also fairly abundant and well established by the early Lutetian. The abundance of the gobiids may attests to an even earlier origin of the family and suggests the potential for older occurrences in the Gulf Coast Tertiary. The Cane River Formation gobiids appear to be older than the single gobiid otolith reported from the Harudi Formation (Lutetian) in western India. Thus, the Cane River

Formation gobiids from Louisiana would represent the earliest, well-documented occurrence of otolith-based gobiids in the world. Furthermore, the gobiid otoliths from the Cane River Formation may be as old as any skeletal-based record of this highly diversified family of actinopterygians.

LIFE AND DEATH IN THE LATE TRIASSIC: AN EXTRAORDINARY TETRAPOD ASSEMBLAGE FROM THE NEWARK SUPERGROUP OF NORTH CAROLINA

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An extraordinary tetrapod assemblage has been recovered from Upper Triassic red fluvial mudstones of "Lithofacies Association II" of the Deep River Basin of the Newark Supergroup near Raleigh, NC. It provides a unique snapshot of trophic interactions between Triassic tetrapods. A well-preserved partial skeleton of a rauisuchian (*Postosuchus* sp.) has gut contents comprising a partial skeleton of a small aetosaur (*Stegomus* sp.), a snout and limb-bones of a juvenile traversodont cynodont, a partial dicynodont digit, and a dermal bone of an indeterminate temnospondyl. Beneath the torso of the rauisuchian, a nearly complete skeleton of a new taxon of sphenosuchian crocodylomorph was preserved. The latter specimen shows bite marks to the head and neck, which match the teeth of the rauisuchian in size. This association supports the interpretation of rauisuchians as top predators in Late Triassic continental ecosystems. Associated teeth attest to scavenging of the rauisuchian by phytosaurs, and *Scoyenia* burrows near and through some bones indicate additional scavenging by arthropods.

Preliminary paleomagnetic data support an early Norian age for the new tetrapod assemblage. The composition of this assemblage is consistent with other data indicating that terrestrial faunal change at the Carnian-Norian boundary was not as marked as previously claimed.

A FUNCTIONAL ASSESSMENT OF HIND FOOT POSTURE IN THE PROSAUROPOD DINOSAUR *PLATEOSAURUS*

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The prosauropod dinosaur *Plateosaurus* is among the best known of Triassic dinosaurs. With few exceptions, whole body reconstructions in the literature as well as specimens mounted in museums depict the hind feet of *Plateosaurus* in a digitigrade stance, with an angle between crus and metatarsus approaching 180° and substantial extension at the metatarsophalangeal joints. Our assessment of pedal posture and function in *Plateosaurus* is based on a nearly complete skeleton (estimated length, 5.5 m) from the Fleming Fjord Formation of East Greenland in which the tarsal elements are well preserved. The configuration of the metatarsophalangeal joints permitted very slight extension of the proximal phalanges, but by no means the high degree of angulation commonly illustrated in *Plateosaurus* reconstructions with digitigrade feet. During weight bearing, the plane of the metatarsus formed an angle of 30-40° with the substrate. The convex distal articular surface of the astragalus faces anteroventrally (rather than ventrally as is depicted in digitigrade reconstructions). This orientation, together with the wedge-shaped third and fourth distal tarsals, accommodates the angulation required between the distal foot in contact with the substrate and the upright crus. In contrast to the well ossified and delineated facets of the crurotarsal, proximal and distal metatarsal, and interphalangeal joints, the mesotarsal joint appears to have been extensively cartilaginous. The type of pedal plantigrady observed in *Plateosaurus*, which contrasts to the digitigrady that is widespread among dinosaurs, is possibly a synapomorphy of sauropods and at least some prosauropods, or alternatively may represent a convergence relating to large body mass.

VERTEBRATE FAUNAL SUCCESSION IN THE UPPER CRETACEOUS, SAN JUAN BASIN, NEW MEXICO, WITH IMPLICATIONS FOR CORRELATIONS WITHIN THE NORTH AMERICAN WESTERN INTERIOR

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The vertebrate faunas from the Upper Cretaceous Kirtland and Fruitland formations, San Juan Basin, New Mexico, contain many endemic taxa, and past attempts to correlate them to other faunas have not been entirely satisfactory. A recent resurgence in collecting fossil vertebrates, primarily in the Kirtland Formation, has resulted in an increased understanding of the faunal composition of these units. New taxa, as well as additional specimens of previously known taxa, and a more precise stratigraphic organization of fossil vertebrate localities have also produced a more robust biostratigraphy for the San Juan Basin Upper Cretaceous. Recent dating of ashes in the San Juan Basin has provided a chronostratigraphic anchor whereby the faunas can be accurately positioned in time. The Fruitland/Kirtland vertebrate faunas do not represent an endemic paleobiogeographic assemblage, as advocated by some, rather they represent a single, temporally distinct vertebrate assemblage. While these vertebrate faunas have been correlated to the Judithian and/or "Edmontonian" NALMA (or more appropriately, NALVA), neither "age" characterization is accurate. New data suggest that the vertebrate faunas of the Fruitland and Kirtland formations represent a segment of Late Cretaceous time between the classic Judithian and "Edmontonian." This interval spans ~ 2.5 million years, is equivalent to "Bear Paw time" and merits recognition as a new NALVA between the Judithian and Edmontonian. This NALVA is defined as the time between the first appearance of *Pentaceratops sternbergii* and the first appearance of *Pachyrhinosaurus canadensis*. The characteristic assemblages are the Hunter Wash and Willow Wash local faunas, which include the taxa: *Pentaceratops sternbergii, Melvius chaudiodous, Prenocephale goodwini, Nodocephalosaurus kirtlandensis, Denazinosuchus kirtlandicus, Kritosaurus navajovius, Anasazisaurus horneri, Naashoibitosaurus ostromi, Parasaurolophus cyrtocristatus, P. tubicen, Saurornitholestes langstoni, Ornithomimus antiquus*, and an unnamed tyrannosaurid.

***PARADJIDAUMO*: FIRST DESCRIPTION OF POSTCRANIAL ANATOMY, FOSSORIAL BEHAVIOR AND PALEOECOLOGICAL IMPLICATIONS**

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This is the first description of the postcranial skeleton of a North American eomyid. Eomyids are thought to be the sister group of the geomyids, a group of fossorial rodents endemic to North America. The European genus *Eomys* has recently been shown to be an arboreal (gliding) form. One articulated skeleton and two associated specimens of the genus *Paradjidaumo* occur in a fossil burrow from the Orella member of the White River Formation near Douglas, WY. This new material provides an opportunity to describe the postcranial anatomy of a terrestrial eomyid. The burrow structure and taphonomic context elucidates behavioral and paleoecological aspects. Osteology and taphonomic occurrence support a fossorial lifestyle for this rodent. The presence of three closely associated individuals give evidence of sociality among *Paradjidaumo*. A cooler, drier, shrubbier, less forested earliest Oligocene may have contributed to the shift of North American eomyids from an arboreal to a fossorial lifestyle. This is consistent with changes resulting from the Eocene (Chadronian) Oligocene (Orellan) transition in the interior of North America.

EVALUATION OF BONE-TENDON MORPHOLOGY OF FOSSIL SKELETONS BASED ON RECENT CROCODILIAN ANCHORING FIBERS: A PRELIMINARY REPORT

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The reconstruction of muscles is a main themes in vertebrate paleontology. However, direct evidence of muscle morphology and insertion is very limited. In contrast, the internal bone structure is often well preserved. We investigated the internal bone structure at the tendon/muscle insertion area of recent crocodiles and other reptiles using cross-sections of decalcified (histological) and ground specimens. In addition, we observed ground sections of Triassic ichthyosaur ribs to test fossil specimens.

It is known that crocodiles have three types of bone-tendon interface as shown by observation of decalcified histological thin sections, i.e. unmediated bony insertion, calcified fibrocartilage insertion, and hyaline cartilage insertion. Observation under polarized light microscope (PLM) of the first two types demonstrates that the tendon fibers insert deeply into bone/fibrocartilage matrix, and these fibers in bone are termed anchoring fibers, which indicates some of the morphology of bone-tendon interface, such as tendon insertion angle. In observations of ground thin section under PLM, the anchoring fibers were observed as microstriation in thin section. In addition, the following characters are confirmed in tendons inserted partly in ground section: 1) the dark striations, which are parallel to tendon fiber orientation, are prominent. 2) bony lacunae, which are distributed tubercle of tendon insertion, are also arranged parallel to the tendon fiber in bone. These characters, although obscure, are also found in ichthyosaur ribs and traceable in the tendon/muscle insertion type and its angle.

The bone-tendon interface is variable in reptiles but the all their tendon insertion that have the anchoring fibers could be preserved in fossils. Traditional muscle reconstruction of fossil specimen is fundamental to refer to the close recent living analogues. Although the reference to recent animals is still needed, this new technique is enable to detect the insertion angle of muscle/tendon direction bone itself. Moreover, the insertion angles will suggest the kinematics of fossil reptiles if the complete fossil were examined.

THE POSTCRANIAL MORPHOLOGY OF THE ARCHAIC TURTLE *MONGOLOCHELYS EFREMOVI* (TESTUDINES, CRYPTODIRA)

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The uppermost Upper Cretaceous Nemegt Formation of Mongolia yields the archaic large turtle *Mongolochelys efremovi*. Although its skull and shell morphology has been described as primitive, a figure and detailed description of other postcranial elements have not yet been presented. The Hayashibara Museum of Natural Sciences–Mongolian Paleontological Center Joint Expedition Team collected several specimens of *Mongolochelys* from the Nemegt formation in the localities of the western Gobi desert, including Bugin Tsav, Gurlin Tsav, Nemegt, Altan Ula, Tsagan Khushuu and Khermeen Tsav. This new material consist of the skull, lower jaws and postcranial elements including well-preserved vertebral series, providing new information for more detailed taxonomic work. Study of the new specimens shows that *Mongolochelys* has many primitive features in the skull and shell, including: parietal and squamosal widely in contact; the lack of temporal emarginations; canalis caroticus internus formed only by basisphenoid; the presence of dorsal processes on the epiplastra; the presence of mesoplastra; nine pairs of costals, and nine neurals. On the contrary, this form also has derived features in the vertebrae as follows: central articulations in the cervical vertebrae are concave-convex; central articulation of the eighth cervical is biconvex; first thoracic rib does not extend halfway to the first costal; and central articulations of the anterior caudals are procoelous. The cranial and postcranial bones of this animal show coexistence of primitive and derived character states, in contrast to previous work. The phylogenetic relationships of the animal should be reconsidered on the basis of these newly observed character states.

LATE CRETACEOUS THERIAN POSTCRANIALS FROM THE KYZYLKUM DESERT, UZBEKISTAN: A PRELIMINARY ASSESSMENT OF TAXONOMIC PROPERTIES

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Over 140 identifiable postcranial elements referable to metatherians and eutherians have been recovered from the Upper Cretaceous Bissekty Fm., Kyzylkum Desert (ca. 90 Ma). They have been described and analyzed from a functional-adaptive perspective in order to obtain taxonomic properties. Many of the elements (e.g., vertebrae, metapodials, fragments of ilia) are as yet of little use taxonomically, but others were sorted into clusters based on an increasing size scale and matched (approximately) with formally named taxa based on teeth. Hence, the various samples of homologous elements were tentatively allocated to the dental taxa. Some of the phena (e.g., humeri, femora, etc.) may, in the future, be associated with one another, and perhaps more securely allocated to dental taxa. In light of the postcranial attributes, we re-examined a variety of hypotheses of eutherian phylogeny. A previous analysis of cranial evidence supported a Zalambdalestidae + Glires clade, as well as a Zhelestidae + Ungulata clade, so these Late Cretaceous eutherians were included in the crown group Placentalia. Our analysis of the postcranial evidence, however, is equivocal, at best, regarding the zhelestid-"condylarth" grouping, and cannot be used to support the association of zalambdalestids with Glires. Nevertheless, the zhelestid humeri are adaptively very similar to those of *Protungulatum*. The few postcranials of the presumed deltatherioid from Kyzylkum are more primitive than those of any other known fossil metatherians for which postcranials have been recovered.

PHOSPHATE-MEDIATED TAPHONOMY: A CONCENTRATED BONE AND BIO-ERODED COPROLITE BED FROM THE MAASTRICHTIAN OF MALI

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A laterally continuous bed (~1 sq. km) in northeast Mali preserves abundant bones, phosphatized coprolites and intraformational cobbles. The bed was deposited as a transgressional lag on a shallow marine shelf. This deposit is part of a relatively thin package of limestones, shales, phosphates and sandstones deposited in the Gao-Ansongo Trough during a major transgressive episode following rifting of the West African craton and development of the Trans-Saharan Seaway. Phosphate minerals, often preserved as fine matrix among the carbonate-dominated sediments, are common in this Maastrichtian-Ypressian sequence in northeast Mali.

Bone specimens concentrated in the bed provide a census of local marine vertebrates, including teeth and dental plates from eagle rays, sharks, lungfish, pycnodonts and dyrosaurs. Preservation of the unassociated bones is excellent. Coprolites (~5 cm long) are abundant in the bed, showing a variety of morphologies. Internal fabric of the coprolites is composed of mottled phosphatic mud and minor fish bone fragments. Vertebrates represented by the bone assemblage are likely producers of the coprolites. The coprolites and intraformational cobbles of the bed are often penetrated by flask-shaped *Gastrochaenolites* borings produced by bivalves. These are the first described bored coprolites. Margins of the borings are sharp and some are infilled with surrounding sediments verifying that the coprolites and cobbles were lithified and exposed to the water column for an extended period prior to ultimate burial. Phosphate-enriched waters encouraged the early cementation of the cobbles and coprolites, and enhanced preservation of bone material.

The regional extent of phosphatic sediments in northeast Mali suggests great potential for future vertebrate findings in this and other areas of northwest Africa. Taphonomic data suggest that phosphate-mediated depositional environments favor the preservation of vertebrate fossils (e.g., bones and coprolites). Therefore, identification and stratigraphic correlation of ancient phosphatic settings may be useful as a pragmatic and predictive tool for locating vertebrate-rich macrosites.

CENOGRAM ANALYSIS OF THE MAMMALIAN FAUNAS FROM THE WHITE RIVER GROUP WITHIN BADLANDS NATIONAL PARK, SOUTH DAKOTA

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Cenograms are a graphical representation of taxon-free analyses of mammalian body mass distribution within faunas. In theory, the shape (slopes, mean slope offsets, mean slope differences) of the cenogram indicates vegetational and climatic characteristics of the environment. In recent years, cenogram analyses of fossil mammal communities have been used to interpret paleoenvironmental conditions for a number of fossil bearing localities around the globe. However, the significance of a cenogram seems to be predicated on the ability to apply temporal and spatial constraints in the analysis. In the present study, fossil mammal faunas of the Chadronian, Orellan, and Whitneyan North American Land Mammal Ages from within Badlands National Park, South Dakota, are compared. These fossil faunas are known to bracket the Eocene-Oligocene transition, a well-documented period of significant climatic change for the continental interior of the US. Comparisons of the three cenograms indicate changes in the distribution of mammalian body mass suggesting progressive vegetational and climatic changes from an equitable humid forest during the late Eocene to a less equitable semiarid savanna in the early Oligocene. These conclusions agree with independently derived interpretations of the paleoenvironmental conditions for this region and suggest that cenograms provide significant information when temporal and spatial constraints are applied.

CHANGING PERSPECTIVES ON THE PHYSICAL PROPERTIES OF TEETH

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Dental enamel has traditionally been viewed as a rather homogeneous material. However, enamel is still a complex composite, made up of crystals and prisms spun together in a complicated fashion. As a result, one might expect summary-type measurements of properties such as hardness to be of limited value in functional interpretations. The purpose of this study was to use nanoindentation-testing to begin to compare the properties of molar enamel in two species of modern primates: *Homo sapiens* and *Alouatta palliata*.

Three isolated upper molars from each taxon were embedded in epoxy and then sectioned across the mesial cusps using a diamond saw. The exposed surfaces were finely polished, and microscopic indentations were made in the enamel ("Nanoindenter," MTS Systems Corp.) at regular intervals between the occlusal surface and the dentin-enamel junction.

Results indicate that (1) the enamel of the monkey teeth is generally softer and more elastic than that of the human teeth, and (2) the enamel of the monkey teeth exhibits a more limited range of hardness and stiffness values than does that of the human teeth, as the human teeth show significant decreases in enamel hardness and stiffness as one moves from the occlusal surface to the dentin-enamel junction. Since the enamel on the monkey molars is significantly thinner than that on the human molars, and since the monkeys have a more abrasive diet than do modern humans, these results raise interesting questions about the evolution of dental function in these primates.

BIOMECHANICAL MODELS OF THEROPOD MANDIBLES AND IMPLICATIONS FOR FEEDING BEHAVIOR

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A biomechanical approach is used to study feeding behavior in theropods. Mandibles can be modeled as beams undergoing a bending load during food ingestion. Assuming solid models, the bite force applied at any given point along the mandible should be proportional to the external dimensions of the mandible at that point. Thus, patterns of variation in these dimensions reflect the adaptation of the jaw to specific loads, related to the method of killing prey. To gain insight into the feeding behavior of theropods, beam models were compared to those constructed for two extant varanid species with distinct feeding behaviors: *Varanus komodoensis* (ambush predator with a slashing bite), and *Varanus niloticus* (molluscivorous). Theropods exhibit an extremely high diversity of feeding behaviors and only a few taxa exhibit similarities with *V. komodoensis*. Fortunately, some feeding categories can be identified: 1) *Antrodemus valens*, *Majungatholus atopus*, and *Carnotaurus sastrei* share the mandibular properties of *V. komodoensis*, suggesting that they delivered slashing bites; 2) dromaeosaurids have mandibular properties reminiscent of *V. komodoensis* for slashing bites but differences between dromaeosaurines and velociraptorines indicate that the former had a stronger bite than the latter and probably relied on it to capture and kill prey; 3) *Suchomimus tenerensis* and *Dilophosaurus wetherilli* both exhibit mandibular adaptations related to the capture of prey relatively smaller than themselves, the former probably practicing a bite-and-hold strategy while the latter probably finished its prey with slashing bites; 4) *Ceratosaurus nasicornis, Allosaurus fragilis, Acrocanthosaurus atokensis*, and *Giganotosaurus carolinii* demonstrate adaptations of the anterior extremity of the mandible for prey capture and delivering powerful bites in order to bring down prey or deliver the final blow; and 5) tyrannosaurids, unlike any other theropod, exhibit mandibular adaptations to resist high torsional stresses at the anterior extremity of the mandible, related to prey capture and bone crushing capabilities.

LATE CENOZOIC CAMELIDS (MAMMALIA: ARTIODACTYLA) FROM GRAHAM COUNTY, SOUTHEASTERN ARIZONA

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Graham County in southeastern Arizona is part of the Basin and Range province where the north-south orienting valleys have been filled with Late Cenozoic and Quaternary terrestrial sediments. All of the basins contain vertebrate fossil remains within the fill deposits, temporally ranging from Hemphillian to Rancholabrean. The presence of vertebrate fossils has been reported in the Safford Basin since 1936. Several of these fossils have been collected by the American Museum of Natural History (Frick Collection) and the University of Arizona. Recent work in the Safford Basin has yielded more material, particularly from the 111 Ranch fauna. Camelids are represented in this fauna by 5 genera, including 3 camels and 2 llamas.

WAS THERE A PROBOSCIDEAN GUILD IN THE AFRICAN CENOZOIC?

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The order Proboscidea represents one of the most derived groups of mammals, and while there are only two living species, the order has a very diverse evolutionary history. Changes in skull and dental morphology have been interpreted as a series of adaptive shifts in response to changing environments. New analysis of the fossil record of proboscideans in Africa reveals interesting peaks in diversity that are not directly correlated with climatic events, lending support to an alternative hypothesis for the mechanism driving evolutionary change. This mechanism is biotic in nature, suggesting that species interaction is important in maintaining diversity in proboscideans.

Eight families, 25 genera and 45 species from 174 African localities were examined. First (FAD) and last appearances (LAD) of each taxon were calculated based on the age ranges for the fossil localities, counted in 1 m.y. intervals, and plotted on a line chart extend-

ing from 63 Ma to the present. Three peaks in diversity are apparent, and these include several ecomorphic categories that are consistently filled throughout the Cenozoic, albeit by different species. Maintenance of these categories is similar to resource partioning in other mammalian guilds, and thus is interpreted as a proboscidean guild.

The ecomorphic categories include Category 1, vertical shearing browsers such as *Moeritherium*, barytheres, and deinotheres; Category 2, horizontal grinding browsers, such as the mammutids and gomphotheres; and Category 3, horizontal shearing browsers and grazers, such as *Loxodonta* and *Elephas*, the true elephantids. Categories 1 and 2 represent the ancestral morphologies and are filled from the Paleocene to the end of the Pleistocene. Biotic competition from these two categories, combined with abiotic changes such as increasingly patchy environments, is responsible for the appearance of Category 3 in the late Miocene. This is an alternative proposal to the traditional interpretation of climate as the driving force behind the evolution of the true elephantids, and represents a new method for examining evolutionary trends in morphology and diversity through time.

PRELIMINARY REPORT OF A OCCURRENCE OF THE LATE PLEISTOCENE MAMMALS FROM THE CUEVA ENCANTADA NEAR OF CHIMALACATLÁN MORELOS STATE, MÉXICO

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The fossils include numerous cranial and postcranial bone fragments between *Mastodon americanum* (smooth variety) (Proboscidea, Mammutidae) (based on 6 aisled molars corresponding to a young individual) and *Eremotherium mirabile* Leidy (Edentata, Megatheridae) (portion of skull which diagnostic characteristics include the shape of the occipital condyle hole and, the frontal-parietal region) which have been positively identified. Comparatively, both species were described origially from the alluvial context of the late Pleistocene local fauna at Apaxtla Guerrero State and, they represent a mixture of inhabitants forms of forest (*M.americanum*) and savannah with thorny shrubs (*E. mirabile*).

The Cueva Encantada was emplaced in volcanic terrains of the Oligocene-Miocene Complex at Cerro Frío (southwest part of Morelos State). It has a restricted entrance which lead to other cavities of major dimensions non yet explored. The deposits which contains the paleontological part consist of conglomeratic gravels mixed with volcanic sands and fine-grained deposits of approximately 4 meters of thickness, which cover the cavity floor on north-south slope of the groundwater downwards to the phreatic layer. The megaherbivore fossil remains have been scattered and, disjointed and accumulation probably occurred starting from the entrance of the cave which was utilized like refuge.

The discovery has been during the construction of a water-pipe trench inside the spring of the cave. Until the excavations have been completed, the stratigraphic and palynological analysis in preparation will help in the paleoecological interpretation and in the determination of the numerica age of the site.

LATE QUATERNARY ICHTHYOFAUNA FROM THE KIBISH FORMATION, LOWER OMO VALLEY, SOUTHWESTERN ETHIOPIA

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The late Quaternary Kibish Formation of the Omo Valley (southwestern Ethiopia) preserves environments reflecting a history of fluctuations in the level of nearby Lake Turkana, subaerial exposure and erosion, and downcutting by channels. The Kibish Formation has yielded a diverse mammalian fauna (as well as birds and crocodiles), stone artifacts, and hominid remains, including possibly the oldest anatomically-modern *Homo sapiens*. Fish are the most common vertebrate fossils in this unit, but have not previously been studied. I collected fish fossils from the three fossiliferous members of the Kibish Formation. Catfish (especially *Clarias* and two species of *Synodontis*) as well as Nile perch (*Lates niloticus*) predominate, but the gymnarchid *Gymnarchus niloticus*, cyprinids (*Barbus* and *Labeo*), tigerfish (*Hydrocynus*), and other catfish (*Bagrus*, *Schilbe*) are also present. In total, eleven genera are represented in this fauna, making it relatively diverse for a Cenozoic African freshwater fish fauna. The Kibish fauna represents a subset of the modern Omo-Turkana ichthyofauna (37 genera) and contains a strong Nilotic component. However, several taxa common in the modern fauna, including *Alestes* and members of the family Cichlidae, are not present in the Kibish Formation. Most specimens are preserved as disarticulated or broken skeletal elements, but some preservation of articulated elements (e.g., sets of vertebrae, crania with lower jaws or cleithra) also occurs. Many of the catfish and perch specimens are larger than the largest reported from the modern river or lake. Faunas of Kibish Members I and III closely resemble one another; the fauna from Member IV contains only the three most common taxa (*Clarias*, *Synodontis*, *Lates*), but this may result from insufficient sampling. In addition, bone harpoons have been collected from the upper part of the formation, indicating a long association between the human inhabitants and the fish fauna of the Lower Omo Valley.

OSTEOLOGICAL DESCRIPTION OF *CAIMAN CROCODYLUS* AND IMPLICATIONS FOR ITS SYSTEMATIC PLACEMENT

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Caiman crocodylus, or the spectacled caiman, is the most common of extant caimans and has been studied by a number of renowned anatomists. Its internal cranial morphology, however, has neither been described in great detail nor examined for phylogenetic purposes. For example, the complexity of the species' pneumatic and eustachian passages as well as the ontogeny of these structures may provide much systematic data. This study completes such an investigation of these areas in an effort to discover new systematic characters for *C. crocodylus*.

Computed Tomography data was used to describe the osteology and the complex system of pneumatic passages of *Caiman*. Each element of the skull was also isolated digitally, allowing study of various internal structures that otherwise would not be possible. Digital endocasts were made of the pneumatic passages of the skull, allowing future comparison of bony endocasts with soft tissue features. Finally, this study allows a re-evaluation of the systematic placement of Caiman in light of new osteological characters. These include characters taken from internal cranial morphology and from ontogenetic data, which has not previously been examined for *C. crocodylus*.

BIOMINERALIZATION, FOSSILIZATION, AND BIOCHEMISTRY: HOW THE ORIGINAL PHYSICAL AND CHEMICAL PROPERTIES OF BONE DICTATE ITS PRESERVATION.

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The chemistry of biominerals in fossil bone provides valuable information regarding the biology of the organism that cannot be obtained by any other means. Novel techniques are being developed to analyze minute quantities of ancient biomolecules, raising the possibility of retrieving genetic information even where survival of intact DNA is impossible. However, fossils are the remains of potentially complex materials and seldom survive into deep time without significant chemical and physical alteration. The nature and rate of alteration in any specific environment is dictated by the chemical and physical properties of the original biomaterial, and investigation of fossil bone chemistry requires a thorough understanding of the nature and rates of diagenesis. Bone is a complex composite material composed of a protein matrix intimately associated with crystals of carbonate hydroxyl-apatite. The protein matrix of bone is often consumed by microbes such as fungi and bacteria, dramatically reducing the preservation potential of the bone. Bone crystals are among the smallest biologically synthesized crystals known, less than 5 nanometers (a few oxygen atoms) in their smallest dimension. Such small sizes inevitably lead to instability in the crystal lattice and increase the potential for rapid alteration in crystal chemistry during diagenesis. In this talk we discuss microbial and abiological degradation of bone protein, show how bone crystal morphology and chemistry can be altered within years of death, and finally present new evidence to suggest that fossilization of bone is frequently complete within 1 to 10 thousand years post-mortem. The original characteristics of bone as a biomaterial influences all these processes, exerts a first order control on the fossil record of vertebrates, and governs the information that may be retrieved from fossil bones.

RADIOMETRIC EVIDENCE FOR DIACHRONY OF MAMMALIAN FAUNAS FROM THE MORRISON FORMATION AND PURBECK GROUP AND IMPLICATIONS FOR CORRELATION IN THE MIDDLE MESOZOIC

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For many years the ages the Morrison Formation of the Western Interior, U. S. A. and the Purbeck Group of southern England have been thought to be correlative. This assessment was based on similarities of land vertebrate faunas between these widely separated areas. With a few exceptions, the reptilian and mammalian faunas from the Purbeck Group have been interpreted to be taxonomically similar to those of the Morrison Formation, and several genera are common between the two areas. The largest sample of mammalian fossils from the Morrison Formation, from Quarry Nine at Como Bluff in southeastern Wyoming, has been compared most closely to the mammalian fossils from the Purbeck Group.

Biostratigraphic and magnetostratigraphic studies over the past several years have demonstrated that the Purbeck Group is most likely entirely Early Cretaceous in age. My own radiometric age data from the Como Bluff region, from very close to the stratigraphic level of Quarry Nine, places this quarry as definitely Jurassic in age and at least 8 m.y. older than the mammal-bearing beds of the Purbeck Group.

My new age data from the Morrison Formation raises several questions: Because the two faunas can now be said to be asynchronous, what is the source for the similarity of fossils? Were the fossils simply mis-identified? Are the similarities a taxonomic artifact that further work will clarify? Or, is it possible that mammalian evolution proceeded at extremely slow rates at this time compared to later in mammalian history? If the latter was the case, the faunas, while not contemporaneous, might still be considered closely related.

If the mammalian faunas from these two areas were as similar as previously thought and thus remained unchanged for many millions of years, this would support a conclusion that the use of mammalian fossils for correlation for at least the Late Jurassic and Early Cretaceous is risky and is not recommended.

REEVALUATION OF THE ANTHRACOTHERIIDAE (MAMMALIA; ARTIODACTYLA) FROM THE EOCENE PONDAUNG FORMATION, MYANMAR

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We reevaluate the classifications of the anthracotheres (Mammalia; Artiodactyla) from the uppermost middle Eocene Pondaung Formation, central Myanmar. The three anthracotheriid genera previously known from the Pondaung Formation, *Anthracothema*, *Anthracokeryx*, and *Anthracohyus*, are synonymized into *Anthracotherium*. As many as 13 species had been recognized in the Pondaung anthracotheres, but they are summarized into four species (*Anthracotherium pangan*, *Anthracotherium crassum*, *Anthracotherium birmanicum*, and *Anthracotherium tenuis*), based on the difference of the size of lower first molars (~ difference of body size). Dental morphology in each species indicates high variation, and the four species are not separable based on their dental morphology. The dental morphology

of the Pondaung *Anthracotherium* species are distinct from that of other species and are the most primitive. In addition, the Pondaung *Anthracotherium* species are the oldest in age among the genus and they are dominant in collection size among the Pondaung mammals. The genus *Anthracotherium* might have originated and rapidly radiated around the Pondaung area during the latest middle Eocene. On the other hand, *Siamotherium pondaungensis* described from the Pondaung Formation as the Anthracotheriidae is a junior synonym of *Pakkokuhyus lahirii* (Artiodactyla: Helohyidae).

EVOLUTIONARY CHANGES IN ATTACHMENTS OF THE AXIAL MUSCULATURE IN THE OCCIPITAL REGION IN MARGINOCEPHALIA (DINOSAURIA)
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The axial musculature attaching to the marginocephalian occiput has been reconstructed in several studies with a view to its functional implications. Most such reconstructions, however, have relied on the anatomy of just one clade of reptiles, most frequently that of Squamata, and lack phylogenetic justification. I tested these reconstructions by dissecting various extant diapsids and comparing osteological correlates of their muscles with those in marginocephalians. Conditions unique to Lepidosauria/Squamata within Diapsida are found in some muscles. For example, the subvertebral muscle inserts on the basal tubera in Lepidosauria; however, innervation patterns indicate that it is divided into two parts in Archosauria, inserting on both the basal tubera and the distal end of the paroccipital process. Proximal to the insertion of this muscle on the basal tubera in Archosauria is that of m. transversalis cervicis. This relationship is reversed in Squamata. *Sphenodon* has a condition similar to Archosauria, in that the subvertebral muscle partially surrounds m. transversalis cervicis at their insertions, indicating that the squamate condition is unique to this clade within Diapsida. Thus, the past reconstructions that simply superimpose the squamate condition onto the marginocephalian occiput are not justified phylogenetically.

Evolutionary changes in suboccipital muscles within Marginocephalia can be inferred by tracing changes in their osteological correlates. For example, Ceratopsidae has a longitudinally elongated neural spine/neural arch of the atlas-axis and two pairs of large depressions in the exoccipital. These are the putative origin and insertion, respectively, of m. rectus capitis posterior, suggesting the massive development of the muscle. The pachycephalosaur *Stygimoloch* also has a deep depression as the putative insertion of this muscle, suggesting its convergent hypertrophy in derived pachycephalosaurs and ceratopsians to support a heavy skull. The attachments of other axial muscles are also enlarged in these dinosaurs and are correlated with an expansion of the parietosquamosal shelf in derived marginocephalians.

AN ARTICULATED SKELETON OF *VARANOPS* (SYNAPSIDA; VARANOPIDAE) WITH EVIDENCE OF SCAVENGING
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A new articulated skeleton of *Varanops* has been found in Lower Permian strata south of Abilene, Texas. Prior to this find, all known skeletal remains of this genus were restricted to the famous *Cacops* bonebed at Indian Creek, Baylor County, Texas. In contrast to the association of the *Cacops* bonebed *Varanops* with the dissorophid *Cacops* and the caseid *Casea*, the new skeleton was found in association with trimerorhachid, diadectid, and *Diplocaulus* remains. The femur of this specimen of *Varanops* is about 10 percent larger than the largest known femur from the *Cacops* bonebed, suggesting that this individual was an adult at the time of its death. This is supported by the preservation of the posterior coracoid in articulation with the left scapula, a bone that usually shows delayed ossification in members of this family, and has not been preserved in any *Cacops* bonebed *Varanops* skeleton. The skeletal remains show a remarkably high quality of preservation, much better than the skeletons in the *Cacops* bonebed, and prior to its unexpected and tumultuous unearthing by a large bulldozer, it was probably fully articulated.

Parts of the skeleton show evidence of scavenging. The large number and position of tooth marks primarily on the limb bones leads to the conclusion that a tetrapod fed on this individual, and their size indicates that the perpetrator was larger than this *Varanops*. It is not possible to determine what caused the death of this synapsid. However, this skeleton provides the oldest known direct osteological evidence for terrestrial scavenging or feeding by vertebrates. Surface cracks on the skeletal elements also indicate that the animal lay exposed for a long period of time before being covered, but despite this exposure, the specimen remained articulated.

CARNIVORES AND MICROTINE-LIKE RODENTS FROM A NEW LATE MIOCENE (HEMPHILLIAN) LOCALITY IN NORTH-CENTRAL NEBRASKA
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The biostratigraphic record of the central Niobrara River Valley is well represented by strata younger than 4.5 million and older than 9 million years. The new Rick Irwin Site (RIS) and Bear Tooth Slide are the only Hemphillian fossil localities filling the gap in this portion of the valley. The RIS was discovered during highway construction in Keya Paha County, Nebraska in an unconsolidated sand and gravel channel fill that disconformably overlies the Merritt Dam Member, Ash Hollow Formation (Clarendonian) and underlies the Long Pine Formation (Blancan). The nearly 15,000 identifiable macro- and microfossil specimens recovered during four field seasons of intensive dry screening constitute the Wyman Creek l.f.

The microtine-like rodents and carnivores from this fauna are particularly useful biochronologic indicators. The occurrence of the arvicolid *Prosomys mimus* restricts the age of the site to the late Hemphillian. A second microtine-like taxon, *Goniodontomys disjunctus*, an aberrant cricetid, had not previously been found in deposits younger than the late early Hemphillian. The Wyman Creek l.f. documents the first North American co-occurrence of these two genera and extends the range of *G. disjunctus* into the late Hemphillian.

The carnivore component appears to be the most taxonomically diverse of any late Hemphillian fauna in North America and includes five canids, two felids, one procyonid, and at least seven mustelids. This fauna contains widespread late Hemphillian taxa such as *Eucyon davisi*, *Vulpes stenognathus*, *Machairodus* sp., and *Pliotaxidea nevadensis* and documents rare Great Plains occurrences of *Martinogale alveodens*, *Pliogale furlongi*, and *Carpocyon limosus*. A new species of *Mustela* extends the generic range back into the late Hemphillian and a new "*Meles*"-like taxon is present. So far, ursids are not represented in the fauna.

EVALUATION OF TEXTURAL AGING AS A METHOD FOR DETERMINING RELATIVE ONTOGENETIC AGE IN MODERN AND FOSSIL ARCHOSAURS
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Use of bone surface texture as an ontogenetic indicator theoretically may be broadly applicable among tetrapods, but this has yet to be rigorously tested in either fossil or modern animals. Detailed study of textural changes in extant taxa is critical, in order to determine biological causes of different textural types and the effect of growth regime on patterns of textural change, as well as to evaluate whether any universal patterns may exist. This study begins such testing in extant and extinct archosaurs, by examining members of Aves (*Branta Canadensis*), Crocodylia (*Alligator mississippiensis*), and Dinosauria (*Centrosaurus apertus*).

Femur, tibia, and humerus were studied for all three taxa, as well as parietal and squamosal in *Centrosaurus*. Grossly visible textural types were defined without reference to size or skeletal maturity estimates, and were ordered based on decreasing porosity. Only after establishment of this sequence was the relationship between texture type and skeletal maturity addressed. Selected elements were thin-sectioned to evaluate growth regime and histological features underlying textural types.

A regular pattern of decreasing surface porosity occurs during ontogeny in *Branta*, with juvenile, subadult, and adult age classes distinguishable by long bone textures. No consistent pattern of textural change is apparent in long bones of *Alligator*; both porous and smooth textures occur throughout the size/age spectrum. Adult *Centrosaurus* are distinguished from juveniles and subadults by both postcranial and cranial textures; cranial textures may distinguish juveniles from subadults if a sufficient portion of the element is preserved. Results suggest textural aging may be applied with varying success to taxa with determinate growth regimes, but is not useful for taxa with indeterminate and/or interrupted growth. Application to fossil taxa without prior understanding of growth regime is thus risky at best. Surface textures observed in the three taxa were not directly comparable, suggesting that establishment of universal textural aging criteria may not be possible.

CROCODYLIFORM BIOGEOGRAPHY DURING THE MID-LATE CRETACEOUS AND THE TIMING AND ORDER OF GONDWANA CONTINENTAL DIVISION
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Questions remain regarding the timing and order of Gondwana division during the Cretaceous. Tectonic models provide temporal constraints to paleogeographic reconstructions but only provide a maximum date for separation between landmasses. Constructing well-resolved paleogeographic scenarios based on tectonic models therefore depends upon interpretation of sedimentological and phylogenetic patterns. The result has been increased interest in phylogenetic and historical biogeographic patterns of Cretaceous Gondwanan vertebrates. Traditional paleogeographic reconstructions suggest that South America and Africa share a more recent geographic history. If this is the case, they should share a more recent faunal history as well. Global distributions of archosaurs, crocodyliforms and dinosaurs in particular, have traditionally been cited supporting this link. However, a recent alternate model for global biogeography, and fossils uncovered from fieldwork in Africa, South America, Madagascar, and India call this association into question. Evidence from abelisauroids, titanosaurids, basal mesoeucrocodylians, and gondwanathere mammals indicate that South America may share a more recent faunal history with Indo-Madagascar.

This study tests for a vicariant pattern among mesoeucrocodylians in the late Cretaceous. Tree reconciliation analysis was applied to a broad sample of basal mesoeucrocodylians from Africa, South America and Madagascar. A time-slicing methodology was adopted and a refinement introduced to account for divergence times. The analysis revealed a biogeographical pattern inconsistent with traditional paleogeographic reconstructions and provides the first statistically robust evidence for a Late Cretaceous vicariant relationship between South America and Madagascar to the exclusion of Africa. This has important implications for choosing between models of Cretaceous continental break-up and the effects this tectonic activity had on the diversification of life.

BIOGEOGRAPHIC DISTRIBUTION OF DORUDONTINE ARCHAEOCETES IN NORTH AMERICA
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Dorudontines are fully aquatic archaeocete cetaceans that lack the vertebral specializations seen in basilosaurines. Dorudontines are important to studies of cetacean evolution because they are thought to be the earliest fully aquatic cetaceans, and are thought to be ancestral to modern Odontoceti and Mysticeti. In North America, dorudontines are only known from the Gulf Coast and southeastern Atlantic Coastal Plain sediments of late Eocene age. The four named species of North American dorudontines (*Chrysocetus healyorum*, *Dorudon serratus*, *Pontogeneus brachyspondylus*, and *Zygorhiza kochii*) are together known from Arkansas, Louisiana, Mississippi, Alabama, Georgia, Florida, South Carolina, and North Carolina. *Zygorhiza* and *Dorudon* appear to have disjunct, non-overlapping distributions with *Zygorhiza* restricted to the Gulf Coast, and *Dorudon* restricted to the southeastern Atlantic Coast. This distribution correlates with a significant change in lithology from the Gulf Coast to the Atlantic Coast (as well as with onshore to offshore), located in central Georgia. On the

Gulf Coast side, where *Zygorhiza* is found, there is considerably more clay in the deposits where dorudontines are collected. On the Atlantic Coast side, where *Dorudon* is found, there is much less clay, and dorudontines are usually found in carbonates or phosphate-rich deposits. This disjunct distribution may represent a habitat preference by these closely related whales or it may represent separate dispersal events to North America from other parts of the world. It is interesting to note that *Zygorhiza* has only been reliably identified outside of North America in New Zealand, and *Dorudon* in north (and perhaps west) Africa.

REINTERPRETATION OF THE AUDITORY STRUCTURE IN *DESMOSTYLUS HESPERUS* (MAMMALIA: DESMOSTYLIA): NEW EVIDENCE FROM THE MIDDLE MIOCENE TACHIKARAUSHINAI FORMATION, HOKKAIDO, JAPAN

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A new specimen of *Desmostylus hesperus* Marsh, 1888, from the upper Middle Miocene Tachikaraushinai Formation, Utanobori, Hokkaido, northern Japan provides important data related to desmostylian auditory structure. The specimen consists of a nearly complete skull and mandible, but the posterior halves of the left side are broken away. It was a juvenile individual that retained a heavily-worn fourth deciduous molar (dm^4) in the right upper jaw.

There have been two different interpretations regarding the position of the external acoustic meatus of *Desmostylus*. The interior of the cranium of the new specimen reveals unequivocally that the position of the meatus should be identified as being the foramen immediately posterior to the zygomatic root of the squamosal. The position and structure of the external acoustic meatus suggests a peculiar (possibly aquatic) adaptation for hearing and is apparently comparable to that of early proboscideans but sirenians, among the Tethytheria. However, it will remain unclear whether the condition of the auditory structure in desmostylians and proboscideans is homologous or analogous until the skull of a neonate desmostylians can be obtained.

EXPLOITING THE COMPLEX INTERFACE BETWEEN PALAEOICHNOLOGY AND PALAEOBIOLOGY: THE CASE OF *PTERAICHNUS* AND PTEROSAURS

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Fossil tracks have had a critical impact on our understanding of the palaeobiology of several vertebrate groups, with pterosaurs among the most prominent of current examples. Integration of data from the rapidly expanding pterosaur track record (now more than 30 sites on four continents) with recent studies of body fossils, including several important new specimens, has expanded our understanding of the stance and gait of pterosaurs on the ground and allowed us to gain fresh insights into the palaeobiology of these animals, ranging from foot anatomy, through behaviour and ecology, to large scale evolutionary patterns. Exceptionally well preserved footprints exactly match new body fossils with evidence of soft tissues that show webbing between the digits and a scaly skin texture on the heel. Prints equivalent in size to feet of some of the smallest known, and temporally coeval, specimens of pterosaurs (individuals of *Pterodactylus kochi* from the Upper Jurassic Solnhofen Limestone), support other evidence for hyper-precociality in this species. Several distinct track-types (*Pteraichnus*, *Haenamichnus*, *Purbeckopus*), probably produced by different groups of pterosaurs, have recently been recognised, although only *Haenamichnus* has been linked (albeit tentatively) with a particular clade (Azhdarchidae). All tracks share a common set of features, however, including manus-pes pairs and elongate pes impressions, showing that their makers were exclusively quadrupedal and plantigrade. Apparently undirected 'shuffling' tracks found at many sites, associated with 'beak' marks, probably indicate feeding behaviour. Apart from a few prints tentatively assigned to basal pterosaurs ('rhamphorhynchoids'), the track record (Upper Jurassic to end Cretaceous) appears to have been almost exclusively produced by pterodactyloids and closely matches the known stratigraphic range of this clade. This is consistent with functional studies that suggest that the terrestrial ability of pterodactyloids was substantially more effective than that of basal forms ('rhamphorhynchoids).

ITERATIVE EVOLUTION OF LARGE SIZE AND HYPERCARNIVORY IN CARNIVORES AND THE MACROEVOLUTIONARY RATCHET

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Carnivorous mammals of large size appear to be limited by constraints on intake rate and foraging time. As predator body mass increases, it becomes increasingly difficult to subsist solely on small prey items. A survey of extant feeders of vertebrate and/or invertebrate prey revealed a 21.5-kg mass threshold, beyond which most (92%) carnivorans utilize prey that are 45% as large as themselves or larger, often exceeding the mass of the predator. Thus it appears that as carnivores evolve larger size, they are forced to become hypercarnivores that rely on relatively large prey. The fossil record of carnivorous mammals reveals many instances of increasing body size over time, following the pattern known as Cope's Rule. Here I address the question of whether the evolution of larger size is accompanied by the evolution of hypercarnivory and the ability to kill and consume relatively large prey. Can we recognize the 21.5 kg threshold among fossil predators? The chosen test group is the dog family Canidae, which has a superb North American fossil record and published phylogenies for two of the three subfamilies, Hesperocyoninae and Borophaginae. Body masses for all known extinct taxa were estimated from lower first molar and skull length. Diet and relative prey size were estimated from dental features and jaw depth, respectively. Previous work has established a strong correlation between jaw depth and prey size in living canids. Results support the 21.5-kg threshold for hypercarnivory and the taking of large prey. In both subfamilies, there is a tendency for mean body mass to increase with time and this is correlated with the appearance of hunters of large prey. Moreover, there appears to be an additional secular trend toward shorter species durations that is associated with the increased morphological and ecological specialization. It is argued that the evolution of large size in canids and other carnivores acts as a macroevolutionary ratchet, driving them to shorter species durations, reduced diversity, and ultimately clade extinction.

THE GEOLOGICALLY YOUNGEST ALBANERPETONTID AMPHIBIAN

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The Albanerpetontidae are salamander-like, Middle Jurassic–Tertiary lissamphibians known from Laurasia and Africa. Extensive series of albanerpetontid bones recently identified in collections from the Csarnota 2 locality, Hungary, extend the range of the clade forward some seven million years from the middle Miocene to the early Pliocene. The Hungarian material is diagnostic for the type genus *Albanerpeton*, and pertains to a new species that differs from the seven previously reported congeners (six species from the latest Albian/earliest Cenomanian—middle Paleocene, North America; one species from the early—middle Miocene, Western Europe) in a novel combination of primitive and derived character states of the jaws and frontals, including a unique ventromedian keel on the fused frontals. Some of the new specimens clarify details of the snout and cheek region in albanerpetontids. The nasals are small, paired, vaguely oval-shaped bones that contact one another medially, articulate anteriorly along the dorsal and, in some cases, laterodorsal edges of the premaxillary pars dorsalis, and separate the premaxillae from the fused frontals. The elongate jugal anteriorly overlaps the maxilla to articulate with the latter bone, the lacrimal, and at least one palatal bone in a complex arrangement. Cladistic analysis nests the new Hungarian species within the robust-snouted clade, as the sister taxon of two species: an unnamed Paleocene species (Alberta, Canada) + *A. inexpectatum* (early—middle Miocene, Austria, France, and Germany). This phylogeny and recent reports of diagnostic *Albanerpeton* material from the Maastrichtian of France and Romania suggest the evolutionary history of *Albanerpeton* was more complex than previously realized, with Europe having played a larger role.

REVISION OF THE LIZARDS FROM THE UPPER CRETACEOUS OF THE KAIPAROWITS PLATEAU

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A series of terrestrial sediments exposed within the Kaiparowits Plateau of southern Utah represent a nearly uninterrupted sequence from the Cenomanian through the Campanian. For nearly two decades this region has been the focus of ongoing studies on the terrestrial microvertebrate fauna, particularly the mammals. The results of this research have added extraordinarily to the body of knowledge concerning Late Cretaceous mammalian evolution and paleobiogeography. Although not as well known, an impressive array of lower vertebrate specimens, including several lizards, was collected along with the mammal specimens. This component of the fauna has been briefly accounted for in preliminary taxonomic lists, but has not yet received broader systematic treatment or been examined in light of its potential paleobiogeographical importance. We have reviewed the lizard specimens from Kaiparowits Plateau (in the collections of the Oklahoma Museum of Natural History) and have made several taxonomic revisions. Among these is recognition of a new teiid species with sharp, tricuspid teeth, and lingual and labial striae on the crowns (work by GEV). Also, two new polyglyphanodontine lizards are identified, and, several previously unnamed specimens are assigned to existing genera or species.

In addition to this revised taxonomy there also exist several distinct morphotypes (too incomplete for taxonomic assignment) that indicate that the potential diversity of the lizards from the Kaiparowits Plateau is even greater. This can only be shown only through the collection of additional specimens, a project currently underway.

THREE GENERAL TYPES OF SCHMELZMUSTER IN RODENT MOLARS.

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The morphological diversity of rodent molars is immense, nevertheless the enamel microstructures show only a very limited variation. A survey of low-crowned molars in about 250 genera representing the entire range of rodents indicates that only two general but derived schmelzmuster types are present.

The first schmelzmuster, the P-type, is characterized by radial enamel and represents the underived status. It occurs in some Sciuromorpha and Sciuravida. The second type of schmelzmuster, the S-type, shows thick Hunter-Schreger-bands (HSB). This schmelzmuster is found in most Sciuromorpha, Sciuravida, Hystricognathi and Caviida. The shared schmelzmuster does not indicate a monophyly since the thick HSB occur in many placental dentitions. In contrast, the third schmelzmuster, the C-type, forms a very unusual structure, a basal ring of lamellar enamel (BRLE) together with radial enamel. It occurs exclusively in Dipodidae, Muridae, Gliridae, Eomyidae and Geomyoidea, often united as Myomorpha. The possible monophyly of this group sharing the C-type schmelzmuster this highly derived schmelzmuster needs to be discussed, since there are a few exceptions within these groups. The S-type and C-type derived independently from the P-type schmelzmuster. There are not transitions between the thick HSB and the BRLE-schmelzmuster.

Biomechanically the thick HSB generally are a protection against cracking. The C-schmelzmuster is more sophisticated. The BRLE can be compared with a hoop surrounding a wooden barrel compensating transverse tension forces. The radial enamel in the upper part reduces abrasion.

In the course of further evolution hypsodont and euhypsodont molars were developed. That changed the basic biomechanic pattern and induced a secondary modification of the

schmelzmuster. Therefore the schmelzmuster of these molars only can evaluated when low-crowned teeth of related taxa are available.

ANAGENESIS VS. CLADOGENESIS IN THE ORIGIN OF *EQUUS* FROM *DINOHIPPUS*: NEW PERSPECTIVES FROM THE RECORD OF PLIOCENE HORSES IN NEBRASKA

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According to the classic interpretation of horse evolution propounded by W. D. Matthew, *Equus* arose gradually (anagenetically) from advanced *Pliohippus* (now *Dinohippus*) during the time interval separating the Coffee Ranch (Hemphillian) and Mt. Blanco (Blancan) local faunas. Most current literature, in contrast, advocates a more abrupt, cladogenetic, origin for *Equus*. Rare finds of *Dinohippus* specimens in Blancan-age strata in California and Mexico have been cited in support of the cladogenetic hypothesis.

My study of a large (>500 MNI) sample of mid-Blancan *Equus simplicidens* from the Broadwater locality in western Nebraska shows that about 2% of the dentitions, if found separately, would be assigned to *Dinohippus* on the basis of size, hypsodonty, curvature, or shape of the metaconid/metastylid column. Importantly, the *Dinohippus*-like specimens do not form a separate mode within the sample but rather grade imperceptibly into primitive *Equus*-like morphologies. At the other end of the variability spectrum in the Broadwater sample are dentitions which, taken out of context, are readily identifiable as *Equus idahoensis*, a larger, more derived species than *E. simplicidens*. *E. idahoensis* numerically dominates Nebraska late Blancan mammal assemblages, succeeding *E. simplicidens* in the Great Plains just as it does in Idaho.

The variability noted in the Broadwater equid collection cannot be attributed to mixing of heterochronic elements. All fossils were excavated from a thin (<30 cm) fine-grained stratum with no evidence of reworking or fluvial transport. The presence of sharply defined age groups and high proportion of breeding-age adults in the sample indicate that the Broadwater bonebed originated from a nonselective mass death event lasting no more than a month or two. Thus the coexistence of 'ancestral' (*Dinohippus*) and 'descendant' (*E. idahoensis*) morphologies within an interbreeding herd of *E. simplicidens* is the interpretation of the data I now favor.

A LATE PLEISTOCENE (RANCHOLABREAN) VERTEBRATE FAUNA FROM THE WANIS VIEW ESTATES HOUSING PROJECT, OCEANSIDE, NORTHWESTERN SAN DIEGO COUNTY, CALIFORNIA

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A late Pleistocene vertebrate fauna was recovered during grading for the Wanis View Estates housing development along the San Luis Rey River, east of the city of Oceanside, northwest San Diego County, CA. Both macro-and microvertebrate fossils were recovered from rocks representing a transgressional sequence of lake muds and floodplain deposits that accumulated in response to rising sea level. These deposits range in elevation from 14 to 41 meters (45-135 feet) and are here tentatively correlated with the oxygen isotope stage 7 Stuart Mesa marine terrace, dated at 225 ka. The underlying unit, previously mapped as the middle Eocene Santiago Formation, is here assigned to the Sespe/Vaquerous Formation based on lithology and the presence of micromammals of Arikareean (late Oligocene/early Miocene) age. A diverse assemblage of late Pleistocene fish, amphibians, reptiles, birds, and mammals were collected during excavation activities. The freshwater fish assemblage contains *Eucycogbius*, *Cottus*, *Mugil*, *Gasterosteus*, and *Gila* (or *Rhinichthys*) and is the most diverse for all southern California sites. Other lower vertebrates including the anurans *Bufo* and *Hyla*, and the pond turtle *Clemmys*, corroborate the sedimentological evidence for a lacustrine depositional environment. The mammalian fauna is represented by *Sylvilagus*, *Spermophilus*, *Thomomys*, *Perognathus*, *Reithrodontomys fluvescens*, *Neotoma mexicana*, *Microtus*, cf. *Urocyon*, *Equus*, *Tapirus californicus*, *Bison*, *Mammut americanum*, and *Mammuthus columbi*, and is typical of other Rancholabrean faunas from Western North America.

***DEINOSUCHUS* MATERIAL FROM THE MESAVERDE FORMATION OF WYOMING: FILLING IN A GAP**

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A large crocodylian osteoderm was found in the vertebrate paleontology collections at the University of Wyoming in Laramie. The specimen (U.W.16040) is a cervical or dorsal osteoderm collected from the Mesaverde Formation of Washakie County, Wyoming. This represents the first described *Deinosuchus* material from the state of Wyoming. The material is significant as it provides more information on the presence of the large crocodylian predator on the Western margin of the Interior Seaway during the mid-Campanian (74-80 Ma).

The specimen is 13 cm by 7 cm and is partially eroded on the surface with the vague presence of a keel. Wide pits intersect below the surface and several of these are 1cm in depth. Crocodylian osteoderms are highly diagnostic with regard to thickness and size, shape and pitting. Tentative reports of *Deinosuchus* material in the form of teeth and osteoderms have been suggested in the past but little formal information has been confirmed. Although no lithofacies information was recorded at the time of collection, it is probable that the osteoderm came from the partial marine Parkman Sandstone Member of the Mesaverde Formation, which is associative to the marine Bearpaw Member lithofacies of the Judith River Formation where the holotype material of *Deinosuchus hacheri* may have been originally found. *Deinosuchus* material has also been found in the associative Aguja Formation of southern Texas.

The Mesaverde Formation in Wyoming represents a marine marshy-terrestrial regression. The large amount of turtle and dinosaur material found in this environment suggests it could easily support a large predator. Remains of *Deinosuchus* are being regularly found in marine sediments in the southeast along the ancient shorelines of the Gulf Coastal Plains. Specimen U.W 16040 is an interesting occurrence in one of the main depositional environments of the Western Interior Seaway.

THE SEMICIRCULAR CANALS OF PLESIADAPIFORM PRIMATES AND THEIR FUNCTIONAL SIGNIFICANCE

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The semicircular canals of vertebrates are integrating angular accelerometers and receptors for extrinsic eye muscle and neck muscle reflexes. The radii of curvature of semicircular canals of extant primates have been shown to be correlated with locomotion. Large radii are found in species that have fast and frequent changes in angular motion. Small radii are found in those that are slow climbing or less jerky in their locomotion. It follows that semicircular canal morphology can be used to retrodict the locomotion of extinct species. Together with biomechanical analysis of the postcranial skeleton, this gives us a second, independent, means of discovering the locomotor habits of extinct animals.

Crania of four plesiadapiform species were scanned using ultra-high resolution X-ray computed tomography. These are the plesiadapid *Plesiadapis cooke*, the paromomyid *Ignacius graybullianus*, the carpolestid *Carpolestes simpsoni*, and an unnamed micromomyid. The resulting high-resolution slices were then re-sliced digitally to image the semicircular canals. The canals were measured and then studied with estimated body masses in a regression analysis with results from extant primates and other mammals whose locomotion is known.

The average radius of curvature of the four plesidapiforms falls at the small extreme of those seen in modern non-cetacean mammals. This might be because all early Tertiary mammals had relatively small canals and that they have subsequently enlarged, as has relative brain size. However, it is the lateral canal that gives the greatest locomotor discrimination in living primates and *I. graybullianus* and *C. simpsoni* have lateral canals that fall in the range of small, quadrupedal, arboreal lemurs. This matches the interpretation of the postcranial skeleton. The micromomyid and the much larger *P. cookei* lie with modern slow-climbing lorises.

NEW MUSTELID FROM THE GRAY FOSSIL SITE (MIOCENE), WASHINGTON CO., TENNESSEE: A NEW SPECIES AMONG MANY?

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The Miocene Gray Fossil Site, Washington Co., Tennessee, has produced numerous vertebrate taxa including fish, amphibians, reptiles, birds and mammals. In addition, the site is rich in pollen, plant macrofossils, and invertebrates such as gastropods and ostracodes.

In the fall of 2002, the partial upper dentition (RI1, LI1-3, RC1, LP2?, LP3?, LP4, LM1) of a medium-sized carnivore was recovered within a thin gravel lens. The P4 (greatest length = 1.17 cm) exhibits a shallow carnassial notch, a prominent paracone, and a reduced metacone. The protocone is nearly absent; however, there is a distinctive hypoconal crest leading to the hypocone. The M1 (greatest length = 1.88 cm) exhibits a large paracone that is linked to the metacone via a centrocrista. The protocone is positioned along the anterolingual edge of the tooth and is connected to the hypocone via a centrocrista-like crest. The hypocone is somewhat expanded and is complemented by several small accessory cusps (including the metaconule?). A prominent talon-like basin extends posterior and is approximately 1/3 the size of the remainder of the tooth. A cingulum, which is crenulated and exhibits many small accessory cusps, is present anteriorly, labially, and posteriorly, but is reduced to absent along the lingual edge of the tooth. The C1 also exhibits heavy crenulations. The P4 is clearly mustelid; however, the size and unusual cusp pattern of the M1 suggest that this material likely represents a new species. Moreover, the above characters suggest an affiliation to perhaps otters or badgers.

Small terrestrial vertebrates often have very restricted ranges and the paucity of similar-aged sites in east-central North America increases the likelihood of "first occurrences" at the Gray Site. In addition, unlike many Miocene localities, the Gray Site records a closed, woodland environment with virtually no grassland taxa (Equidae are conspicuously absent). Therefore, the richness and, more importantly, location of the Gray Fossil Site suggest that many "new" species will be recovered.

A PRIMITIVE LEPTARCTINE (CARNIVORA: MUSTELIDAE) FROM THE EARLY MIOCENE OF WESTERN GANSU, CHINA AND ZOOGEOGRAPHY OF EARLY MUSTELIDS

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The subfamily Leptarctinae belongs to a unique group of mustelid carnivorans that possesses some of the most specialized morphologies with a massive skull and considerably bunodont dentition related to a dietary specialization of omnivory. Members of the subfamily are mostly found in the Miocene of North America, with the exception of a single species in Asia and a few fragmentary remains in Europe. A very primitive member of this peculiar group (likely a new genus) was recently discovered in the early Miocene of Danghe (Taben-Buluk) area in the northern front of the Tibetan Plateau. This new form not only fills in a large gap of fossil record of this group but also shed much needed light in the zoogeography of early mustelids in the Holarctic.

Derived characters in the new Danghe form that indicate membership in the Leptarctinae include: skull with double temporal crests and roughened surface on the temporal area; short muzzle; small orbit; deep zygomatic arch; anterolaterally expanded ectotympanic to fuse with postglenoid process; and a lateral opening of the postglenoid foramen. On the other hand, it lacks some highly derived features in advanced leptarctines, such as a ventrally projecting bulla, a hypocone or internal cingulum on P4, and a quadrate form on M1, suggesting that the Danghe form occupies a basal position within the leptarctines.

Generally considered to be near the basal part of the mustelid phylogeny, leptarctines has some close relatives from the European early Miocene, such as *Paragale* and *Plesiogale*, although the European forms are quite different morphologically. The sudden appearance of the leptarctines in North America is regarded as an immigration event in the Hemingfordian. As is often the case, exotic forms in Europe or North America are assumed to have their origins somewhere in Asia. It is thus especially gratifying to discover a new form from the Tabenbuluk area that is linked to the highly derived cranial morphology of North American leptarctines and the very primitive dental patterns in European basal mustelids.

THE FIRST DISCOVERY OF DIVERSE JURASSIC DINOSAUR FAUNAS IN MONGOLIA

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Diverse dinosaurian faunas were found in western and central regions of Mongolia by the Hayashibara Museum of Natural Sciences and Mongolian Paleontological Center Joint Paleontological Expedition. The Jurassic vertebrate fossil localities, Shar Teg and Dariv in the Gobi-Altai Aimag, and Bakhar in the Bayankhongol Aimag, were surveyed. From the Upper Jurassic Ulan Malgait Beds (red beds) in Shar Teg, sauropod and crocodylian fossils were found. The sauropod specimen consists of dorsal vertebrae, ribs, and pelvic elements. The crocodylian remains are referable to protosuchians. From the middle to upper Jurassic Dariv Formation, sauropod and theropod fossils were discovered. Although postcranial elements of sauropods were abundant in this locality, only one theropod specimen represented by fragmentary upper and lower jaws with teeth was found. A sauropod specimen consisting of associated elements (ilium, ischium femur, scapula, forelimbs, ribs, and caudal vertebrae) was also collected from this locality. Bakhar is a middle to late Jurassic locality where no dinosaur remains had been previously reported. The only archosaurian specimen that had been discovered before was one specimen of a pterosaur from the Ortsag beds, the lowermost beds exposed in this region. For the first time, we found a dinosaur specimen from the red layer overlying the Ortsag beds. This specimen consists of several associated bones (both cranial and postcranial elements) of a primitive ornithischian, probably a psittacosaurid. The Jurassic age of these beds yielding dinosaur fossils has been determined by Russian researchers largely based on the biostratigraphy of the associated invertebrate (insects) and plant fossils, and still needs to be reconfirmed with other methods such as magnetostratigraphy. Assuming this dating is correct, however, this is the first report of abundant Jurassic dinosaur remains in Mongolia. Thus, our discovery contributes greatly to the knowledge of the biogeography of dinosaurs in Mongolia, where previously only the Cretaceous dinosaurs have been extensively studied.

A NEW FOSSIL CHARADRIIFORM BIRD FROM THE LOWER EOCENE GREEN RIVER FORMATION OF WYOMING

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A new fossil shorebird (Aves, Charadriiformes) from the Lower Eocene Green River Formation of Wyoming is presented. This new specimen is exceptionally well-preserved and represents a new genus and species that can be assigned to Charadriiformes because of the presence of several osteological features postulated as derived within the order (six costal processes of the sternum; absence of sulcus medialis on sternum; processus acrocoracoideus not cranially directed), as well as on the basis of comparisons with other fossil and extant shorebirds. This new specimen represents one of very few substantial fossil records for these birds from the basalmost Tertiary.

Cladistic analysis including this new genus, other Tertiary records for Charadriiformes, and a large number of extant genera of these birds illuminate the basal divergences within shorebirds. Osteological information gained from fossils prove important to our understanding of the radiation of this large extant clade; our analyses resolve the relationships of several fossil shorebird taxa and allow us to estimate divergence times for clades within Charadriiformes and their immediate sister-groups.

DINOSAUR SKIN FOSSILS FROM THIS SIDE OF HELL, WYOMING: PALEOENVIRONMENTAL IMPLICATIONS OF AN UPPER CRETACEOUS KONSERVAT-LAGERSTÄTTE IN THE LANCE FORMATION

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Dinosaur skin and possible muscle tissue occurs in an Upper Cretaceous (upper Maastrichtian) Konservat-Lagerstätte in the Lance Formation of Park County, Wyoming. Soft tissue, preserved by authigenic pyrolusite (?-MnO2), surrounds or is associated with lambeosaurine dinosaur skeletal remains in the This Side of Hell Quarry. Pyrolusite apparently replaced soft tissue by forming a coating in bentonitic sandstone while it was sediment encasing the dinosaur carcass. This coating results in finely detailed preservation of small (1-2 mm) to large (5-30 mm) diameter pentagonal and hexagonal non-overlapping scales. Grooves between the scales range from 1-4 mm in depth. Thus far, skin has been collected only from the quarry region containing the scapula, ribs and upper humerus of the lambeosaur skeleton. Analyses were performed using a scanning electron microscopy (SEM) combined with energy dispersive x-ray analysis (EDXA) at The Ohio State University. Quantitative chemical microanalysis had detection limits of 0.1%. Similar control EDX analyses of rock matrix were also performed. Dinosaurs preserving soft tissue in the This Side of Hell Quarry are from an inferred marginal-marine setting including distal stream to shallow intertidal environments. The presence of pyrolusite in this context is likely related to burial of dinosaur remains in sediment saturated with saline pore water. Salinity of the pore waters may have inhibited scavenging and some bacterial breakdown of soft tissues.

DETAILED CRANIAL ANATOMY AND PHYLOGENETIC AFFINITIES OF THE MULTITUBERCULATE *MENISCOESSUS*

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CT-scanning of NSM-PV 20436, a near-complete skull of the North American multituberculate mammal *Meniscoessus robustus*, has revealed a wealth of anatomical information. Perhaps the most striking feature is extraordinary pneumatization of the skull. Paranasal sinuses have been described previously in Mongolian multituberculates, and cavities in the basisphenoid of *Nemegtbaatar* were illustrated but not discussed by Hurum (1994, 1998). In the larger *Meniscoessus*, the extent of pneumatization throughout the entire skull is greater; the braincase is floored with bone laminae separated by relatively enormous air cavities. Adaptive significance of these cavities is uncertain. Their presence in diverse lineages may indicate that cranial pneumatization is an autapomorphy of Cimolodonta, if not of Multituberculata. They may also explain the rarity of multituberculate cranial fossils relative to the comparative abundance of teeth in North American sediments; the bone is tissue-thin and fragile, even in relatively large species.

Direct comparison of NSM-PV 20436 with crania of the Asian *Lambdopsalis bulla* and phylogenetic analyses including these and other taxa suggest that *Meniscoessus* and *Lambdopsalis* are closely related. This relationship is indicated on the basis of molar morphology as well as cranial morphology, although enamel restriction on the incisors and reduction in number of premolars have previously been used to place *Lambdopsalis* in the Taeniolabididae. It is likely that *Lambdopsalis* like *Meniscoessus* belongs to the cimolomyid lineage. The origin of taeniolabidids is unclear; they are most derived at their first appearance, and it is uncertain whether similarities between cimolomyids and taeniolabidids indicate convergence or shared ancestry. Cimolomyids are not known from North America after the end-Cretaceous extinction, nor have they been recognized previously in Asia. It is possible that *Lambdopsalis* represents an offshoot of the lineage that migrated to Asia in the Maastrichtian or Paleocene.

A NEW SPECIMEN OF *POPOSAURUS* (ARCHOSAURIA: CRUROTARSI) FROM THE LATE TRIASSIC TECOVAS FORMATION OF TEXAS

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An associated partial skeleton of *Poposaurus gracilis* from the McCarty Ranch (MOTTU site 650) south of Crosbyton, Texas, sheds new light on the osteology of this rare crurotarsan archosaur. Identified elements include a partial cervical centrum, a cervical rib, five posterior dorsals, parts of all sacral vertebrae with sacral ribs, a partial anterior caudal, both ilia, the proximal parts of the ischia and pubes, the proximal and distal ends of the right femur, and a pair of dorsal paramedian osteoderms from the pelvic region.

The cervical centrum possesses an accessory dorsal parapophyseal rib facet. The right ilium is the first of *Poposaurus* to show the complete preacetabular blade, which is long and blade-like rather than paddle-shaped as previously thought. The paired osteoderms are pentagonal, twice as wide as long, and show distinct anterolateral projections. This specimen also confirms that isolated elements that were previously referred to *Poposaurus*, but are not present in the holotype (fused sacral vertebrae, the pubes and the ischia) indeed belong to that taxon.

The morphology of the cervical centrum and the preacetabular blade of the ilium is identical to the much larger type of '*Lythrosuchus*' *langstoni*, suggesting that '*Lythrosuchus*' is a junior synonym of *Poposaurus*. However, we tentatively retain the species as *Poposaurus langstoni* on the basis of larger size, absence of a distinct ridge on the lateral surface of the ilium, and the lack of a pit on the proximal end of the ischium. A recently found complete isolated cervical from the Tecovas Formation suggests that *Poposaurus*, or a closely related poposaurid, attained a giant size close to or larger than 10 meters. Poposauridae are characterized by an incipient perforated acetabulum, a massive supraacetabular crest, and an elongate preacetabular process of the ilium. These features clearly indicate a fully erect posture and possible bipedalism.

THE MORPHOLOGICAL DIVERSIFICATION OF CARNIVORES IN NORTH AMERICA

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Morphological disparity, in conjunction with taxonomic diversity, provides a powerful tool to interpret the evolutionary processes underlying the patterns of biodiversity. It has been proposed that the diversification of carnivoramorphans was suppressed by the incumbent creodonts early in their history (Carnivoramorpha is operationally defined as Carnivora and the fossil taxa within "Miacoidea"). The taxonomic decline of Creodonta at the end of the Eocene

coincided with the beginning of the radiation of Carnivora, which rapidly generated most modern families. It is not known if creodonts were actively displaced by competitive interaction with carnivoramorphans or if the pattern of increasing carnivoramorphan taxonomic diversity was the result of passive replacement.

I test the hypothesis that morphological diversification was limited, relative to taxonomic diversification, early in the evolutionary history of the clade Carnivoramorpha. The morphological and taxonomic diversification of the clade Carnivoramorpha and a more inclusive ecological group of terrestrial eutherian meat-eaters are quantified using the North American fossil record. I apply a new, comprehensive method developed for this study to quantify the morphological disparity of dentition. Because teeth are directly involved in the consumption of food, their morphology provides good indicators of diet and ecology. Morphological disparity is calculated as average pairwise dissimilarity among the quantified dental forms in two-million-year intervals, and patterns of taxonomic diversity and morphological disparity are compared.

The results do not support the hypothesis that carnivoramorphans were morphologically suppressed early in the clade's history. The increase in carnivoramorphan disparity at the end of the Eocene was the result of expansion into the only area of morphospace still occupied by creodonts. The decline of the creodonts in North America does not significantly affect carnivoramorphan disparity levels. While it is not known if carnivoramorphans were taxonomically suppressed, it does not appear that they were morphologically limited by the presence of creodonts.

RHYNCHOSAURS, TEETH, AND TIME: NEW AND REVISED CHARACTER STATES FROM COMPARATIVE MORPHOLOGY

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Restricted wholly to the Triassic, rhynchosaurs are extensively used to correlate continental faunas worldwide. Their sturdy toothplates, characterized by multiple rows of teeth on the maxilla, are typically the most common element preserved. Gross aspects of dental morphology including the number of toothrows and grooves on the maxilla and dentary have been widely used to distinguish taxa and for biochronologic purposes (e.g. two maxillary grooves have historically denoted Middle Triassic rhynchosaurs, a single groove Late Triassic rhynchosaurs). Detailed description of the Middle or Late Triassic rhynchosaur from Madagascar, *Isalorhynchus genovefae* and firsthand comparisons with most other rhynchosaur taxa known worldwide support the inclusion of new and revised diagnostic character states for incorporation in phylogenetic studies of the Rhynchosauria. For example, cervical epipophyses (previously considered unique to *Mesosuchus*) and second sacral rib caudal spines (reported in *Mesosuchus, Howesia,* and *Stenaulorhynchus*) are present in *Isalorhynchus,* and occur in varying states in most members of the group. Distinctive features of *Isalorhynchus* include caudal rib dorsal processes, heretofore unrecognized in rhynchosaurs, and a low number of toothrows in combination with dimorphic maxillary teeth. Characters diagnosing members of the Late Triassic genus *Hyperodapedon,* especially tarsal features, have proven difficult to score in *Isalorhynchus* because they are intermediate between those seen in other rhynchosaurs. *Isalorhynchus* clearly bears features prevalent in *Hyperodapedon,* including an *anguli oris* crest on the jugal and a single maxillary groove. Interestingly, a well-developed single maxillary groove has recently been reported in a new taxon from the early Middle Triassic Moenkopi Formation (Arizona), calling the polarity of this character state into question. Dental character states associated with the number of maxillary grooves present a degree of complexity not previously appreciated and as such should be viewed with caution when making biochronologic inferences.

PLIOCENE *ODOCOILEUS* FROM HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO, AND COMMENTS ON THE TAXONOMIC STATUS OF *ODOCOILEUS BRACHYODONTUS*

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Hagerman Fossil Beds National Monument (HAFO) is an extremely fossiliferous middle Pliocene site located in south-central Idaho. Although *Odocoileus* was previously recorded from HAFO, fossils were not given a more specific taxonomic identification. The only *Odocoileus* described from ages comparable to the middle Pliocene Glenns Ferry Formation of HAFO is *O. brachyodontus*. Due to the lack of other cervid species described from similar time intervals in North America, our attempts to identify cervid material from HAFO began by making detailed comparisons to *Odocoileus brachyodontus*. A recently recovered upper third molar from Hagerman (HAFO 5151) permitted this comparison because the holotype of *O. brachyodontus* includes an upper third molar. Measurements of HAFO 5151 (height 5.7 mm, length 15.3 mm, and width 14.8 mm) were compared with measurements of the holotype of *O. brachyodontus* (height 12.0 mm, length 17.0 mm, and width 19.0 mm) as well as measurements of 61 modern central Texas *Odocoileus* (height 4.24 to 14.95 mm, length 12.07 to 18.90 mm, and width 11.90 to 18.27 mm). Additionally, occlusal patterns observed on HAFO 5151 and previously described and depicted for the *O. brachyodontus* holotype were compared with the wear patterns of modern *O. hemionus* and *O. virginianus*. Neither the morphometric ratios nor occlusal pattern was sufficient to distinguish HAFO 5151 or the *O. brachyodontus* holotype from the variation seen in modern *Odocoileus* specimens measured. Based upon the observed variation in the dental characters we consider known cervid dentition insufficient to diagnose a species of *Odocoileus*. Previous studies surmised that *Bretzia* cannot be distinguished from *Odocoileus* by the use of dentition. Therefore, we consider *Odocoileus brachyodontus* a nomen dubium and discourage the use of dentition to diagnose taxa within Odocoileini.

FOSSIL EVIDENCE OF SOCIAL BEHAVIOR AT RANCHO LA BREA BY *PANTHERA ATROX* BETWEEN 14 AND 11 KYR BP

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Inferences for or against social behavior in fossil felids have been drawn from an assortment of evidence, but a compelling case remains elusive. This is not surprising because the understanding of why living cats form prides is still developing. Packer and colleagues have been instrumental in replacing pride myth with field biology fact. Packer accepts the "lion panel" at Chavet Cave depiction of "mane-less, pride-dwelling lions" *(Panthera spelaea)* as the work of "keen observers of wildlife." For Rancho La Brea (RLB), the largest sample of extinct *P. atrox*, the challenge is to find an objective, testable parameter for sociality that is preserved in the tar seeps. Sexual dimorphism is evident, but only proves gender. Low sexual dimorphism bodes poorly for sociality, but substantial sexual dimorphism and a 2:1 or greater female bias is found in pride lions, nomad or non-pride lions, and the least social of other living *Panthera*. It neither proves not refutes sociality. For all living *Panthera*, whether or not social, the male mortality rate is higher at all ages. For both sexes, the subadult mortality at the time large wild cats become independent is extremely high. However, the fossil collection from RLB does not record a living population. It is an entrapment assemblage, where gender and ontogenetic age can be determined, and proides a mortality rate by age. We estimate the overall mortality rate for male *P. atrox* to have been 3 times that for females, with the living population estimated at 2 females per male. The entrapment rate for subadults from RLB pits 3 and 61/67 is up to 9 males per female. Dates from these deposits range between 11 and 14 kyr BP (C^{14}). This bias exists only in this time window indicating, that like *P. leo*, *P. atrox* formed social groups where female subadults were sheltered from the high mortality experienced by young males. Based on the conditions in which *P. leo* forms prides, open habitat and high lion and prey density are inferred. Aparently these conditions only existed for the final 3,000 years of Pleistocene faunal entrapment at RLB.

PHYLOGENETIC RELATIONSHIPS AND BIOGEOGRAPHY OF TRICONODONTIDAE (MAMMALIA)

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Triconodontidae, known from the earliest Cretaceous of Western Europe and the Late Jurassic through Late Cretaceous of North America, are noteworthy in being some of the latest-surviving mammals with the serially tricusped molar configuration that characterizes certain advanced, non-mammalian synapsids and is the plesiomorphic pattern for mammalian molars. Previous cladistic analyses of dental and mandibular characters provide a robust phylogeny for the group, with new results clarifying the interrelationships within the family.

Results support monophyly of the two subfamilies Triconodontinae and Alticonodontinae; the position of Barremian *Jeholodens* remains uncertain. Triconodontinae (*Triconodon* (*Trioracodon*, *Priacodon*)) are known from both North America and Western Europe, with one genus common to both landmasses. Topology within the group suggests the possibility of an immigration event from East to West. Alticonodontinae (*Arundelconodon* (*Alticonodon* (*Corviconodon*, *Astroconodon*))) are strongly supported as a clade endemic to the latter part (Aptian-Campanian) of North America. Tree topology is consistent with the stratigraphic distribution of genera within the subfamily. However, origin of the subfamily remains unclear, given that they cannot be derived from the geologically older Triconodontinae.

A REASSESSMENT OF THE ORIGIN OF *M. CAUDOFEMORALIS LONGUS* IN CROCODILIANS AND IMPLICATIONS FOR ITS INTERPRETATION IN EXTINCT ARCHOSAURS

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M. caudofemoralis longus is the primary hindlimb retractor in nonavian archosaurs. *M caudofemoralis longus* has been described by numerous authors as taking origin either from the transverse processes of the caudal vertebrae, the bodies of the caudal centra, or a combination of the two. Dissections of approximately a dozen specimens of *Alligator mississippiensis* indicate that the actual origin of *M. caudofemoralis longus* is the lateral surfaces of the first 11-13 chevrons. However, a small portion of *M. caudofemoralis longus* does take origin from the ventral surface of the proximal caudal centra. These data indicate that both chevron length and transverse process width are important for determining the size and shape of *M. caudofemoralis longus*. Also, chevron morphology can be used to infer the extent of *M. caudofemoralis longus* in many fossil archosaurs because changes in morphology, such as the craniocaudally expanded mid and distal chevrons in diplodocid sauropods, can only occur where the chevrons do not have limb musculature originating from their lateral surfaces. Finally, though *M. caudofemoralis longus* does not originate from them, the presence of transverse processes on the caudals in *Alligator* were found to correspond with *M. caudofemoralis longus* in their extent. Therefore, using both the presence of transverse processes and chevron morphology, the extent and size of *M. caudofemoralis longus* musculature in many extinct archosaurs can be estimated with confidence.

FOSSIL ACQUISITION BY SCREEN WASHING

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We will present a new method of screen washing that can be utilized in the field or in the laboratory setting. This two-step process recovers fossils ranging in size from (>5 cm) to nano-sized (<1 mm) fossils .

Step one involves the utilization of different screen sizes at different locations in an inte-

gral washing unit. Potable re-circulating water with no additives, provided by a electric pump, breaks down the matrix. The unscreened matrix is held in an outer basket made of polymer, with the inner basket having a square mesh style that contains 8 mesh per 2.54 cm and a net opening width of 2460 microns. Fossils that are larger then 2460 micron are collected in this basket. The smaller sized matrix falls down to the final screen located at a level below. This screen is a square panel mesh style having 40 mesh per 2.54 cm. The net interior opening of the mesh is 380 microns, collecting fossils larger than 380 microns.

Step two involves the final break down of the clay matrix using potable water, with no additives and compressed air. This is accomplished by a bubblier placed in a converted storage container. A series of parallel air pipes are located in the base of the container, with holes at 2.54 cm on center along the length of the pipe which allow the release of air from a regulated air line. This line is connected to a portable or stationary air compressor. The clay ball matrix is held in suspension in a basket that is 22.8 cm x 33 cm x 3.8 cm. This basket has a square 40 mesh screen per 2.54 cm and a opening of 380 micron. The matrix when dry is sorted under a binocular microscope with a magnification of 1x-2x.

This process has been utilized on sandy, silty and clay-rich matrix from the upper Cretaceous and lower Tertiary sedimentary rocks of southwestern North Dakota with excellent results. This process has allowed us to wet-screen wash 340 kg. of matrix in 73 hours using 525 liters of water. The time component includes clean up of equipment an additional 190 liter of water was used for clean up. The washed matrix residue is returned to the area of collection for disposal.

PHENETIC DISTINCTIONS OF LAMBEOSAURINE RIBS FROM THIS SIDE OF HELL, WYOMING

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Lambeosaurine skeletal material discovered in 2001 in the This Side of Hell Quarry, in the Lance Formation in northwestern Wyoming is used in this research. An associated almost complete half-rack of left-ribs presents an opportunity to study morphological characters that may lead to a better understanding of the paleoecology of hadrosaurs. Detailed examination of these ribs suggests that hadrosaur ribs are useful for making phenetic distinctions between the two major suborders of the Hadrosauridae: hadrosaurinae and lambeosaurinae. This is the first detailed examination of morphological characters that differentiate between the ribs of hadrosaurine and lambeosaurine dinosaurs.

Ribs were measured from four major landmarks: tuberculum, capitulum, distal shaft end, and least width of the shaft. Measurements taken were from tubercular to capitular facet, capitular facet to distal tip, curvature of the entire rib, and circumference of the rib shaft at its least thickness.

Data collected supported the original hypothesis that hadrosaur ribs were specific at least to the tribal level. This research provides a new definitive post-cranial character that separates the lambeosaurine and hadrosaurine dinosaurs. This suggests that the concept of tribal specific ribs could be applied elsewhere to revise dinosaur systematics based on characters that may be symplesiomorphic.

MIOCENE OF FORT POLK, WESTERN LOUISIANA, 2002-2003

WILLIAMS, Michael, BOARDMAN, Grant, SCHIEBOUT, Judith A., KILBOURNE, Brandon, NGUYEN, Huy, Louisiana State Univ., Baton Rouge, LA.

Weather, war, and the crash of the space shuttle have curtailed Fort Polk and east Texas field work, leading to an emphasis on some of the less studied forms such as the lower vertebrates, on species for which large numbers of specimens are now available through screening, and on educational outreach. A half century ago, Dr. John A. Wilson from the University of Texas at Austin investigated east Texas Miocene terrestrial fossil sites and developed a system of successive vertebrate local faunas based mainly on mammals. His Cold Spring Local Fauna is the one most similar to Fort Polk faunas, although the stratigraphically lowest and most marine influenced such as Stonehenge, may eventually turn out to be more similar to his older and more marine influenced Burkeville L.F. Small forms, including the herpetofauna are being recovered by screening from old and new sites. During the winter of 2002-2003, an unsuccessful attempt was made to relocate the classic Burkeville site. In the almost 50 years since the area was last examined, the previously open location appears to have been overgrown. The space shuttle debris recovery efforts prevented spring 2003 fieldwork in the east Texas Burkeville area.

Occurrence of more than one species based on isolated teeth of *Copemys* at a single screening site (Stonehenge), cannot be documented either on size or morphology differences. The *Copemys* are probably a new species, with tooth size smaller than other published *Copemys* possibly a result of their being from an environment previously not sampled.

Three reports have been prepared on paleontological research on Fort Polk supported by the U.S. Army, and a new kind of deliverable is being prepared. One- to four-minute videoclips are now being produced for most taxa in the fauna. Sketches of some of the animals in environments judged appropriate from our research are being developed. Eventually the videos can be used in Internet or on-site displays or incorporated into a longer video or DVD.

STRAIN IN THE MANDIBULAR SYMPHYSIS OF ALPACAS AND THE EVOLUTION OF SYMPHYSEAL FUSION IN CAMELIDS

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Ossification or fusion of the mandibular symphysis is a derived condition in mammals and has evolved in several mammalian lineages (e.g., primates, artiodactyls, perissodactyls). Although the state of symphyseal fusion has been well documented among extant mammals, its functional and adaptive significance is still debated. Symphyseal fusion in anthropoid primates is thought to have evolved to counter loads associated with increased recruitment of balancing-side muscle force during the mastication of tough foods. More importantly, symphyseal fusion is associated with the delayed and pronounced recruitment of the balancing-side deep masseter which causes the mandibular symphysis to experience lateral transverse bending or "wishboning".

Among selenodont artiodactyls, camelids are unique in having a fused symphysis. Compared to selenodont artiodactyls with unfused symphyses, camelid symphyses are more resistant to this loading regime because they have symphyseal fusion and relatively longer symphyses anteroposteriorly. Moreover, electromyographic data from the masticatory muscles of alpacas show that, like anthropoid primates, they have the delayed activity of the balancing-side deep masseter during the power stroke. To further test whether the camelid symphysis wishbones during the power stroke of mastication, we recorded in vivo strain data from the symphyses of alpacas (*Lama pacos*). Rosette strain gauges were attached to the labial aspect of the symphysis of four individuals, and strains were recorded while the animals chewed hay.

Preliminary analysis indicates that in addition to other loading regimes, a significant amount of symphyseal strain is associated with wishboning. Because dietary reconstructions of early camelids (e.g., *Poebrodon*) suggest that these animals consumed coarse vegetation as compared to other Eocene artiodactyls, the convergence of fusion in anthropoids and camelids implicates a tough diet as a common factor in the evolution of symphyseal fusion.

LATEST CRETACEOUS DINOSAURS IN THE SAN JUAN BASIN, NEW MEXICO

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The Naashoibito Member of the Kirtland Formation contains the Alamo Wash local fauna, one of the few late Maastrichtian terrestrial vertebrate assemblages in the southern United States. Although some workers have advocated an early Maastrichtian or even an early Paleocene age for this unit, the presence of Lancian index taxa such as the multituberculate *Essonodon browni* support a late Maastrichtian age assignment.

Until recently, the composition and distinctiveness of the Alamo Wash local fauna has been muddied because certain dinosaur specimens, including *Parasaurolophus*, *Pentaceratops* and the holotype of *Naashoibitosaurus ostromi*, recovered from the underlying upper Campanian De-na-zin Member, Kirtland Formation, were misreported as originating from the Naashoibito Member. Also sauropods have been reported from the De-na-zin Member. Titanosaurid teeth are abundant in the Naashoibito Member and are marked by distinctive apical wear facets. Putative sauropod teeth from the De-na-zin Member lack these diagnostic wear patterns. Previous assignments of sauropod bones to the De-na-zin Member were the result of incorrect reporting of locality data.

Recent intensive surface collecting and screenwashing of numerous microfossil sites in the Naashoibito Member have added considerably to the known diversity of dinosaurs from this unit. Additional specimens include isolated teeth that can be referred to *Tyrannosaurus* cf. *T. rex, Richardoestesia isosceles, R. gilmorei*, cf. *Saurornitholestes*, and *Troodon* sp. *Troodon* is the most abundant small, toothed theropod, a dinosaur that is extremely rare or absent in older San Juan Basin faunas.

The Alamo Wash local fauna is taxonomically distinct from older faunas of the San Juan Basin. For dinosaurs, this distinction is characterized by the presence of *T.* cf. *T. rex, Torosaurus, Troodon*, and titanosaurid sauropods in the Naashoibito Member and their absence in older units. These faunal differences support a substantial hiatus separating it from older San Juan Basin faunas.

AN INVESTIGATION OF TRIASSIC LAND VERTEBRATE FAUNACHRONS (LVFS) USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

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To examine faunal/floral turnover during the mid-Late Triassic, a robust chronology is essential: consequently, we have created a GIS database to test the validity of existing vertebrate biostratigraphies. Our GIS database included faunal, floral, climatic and lithological parameters mapped onto continental and formation outcrop maps. This work represents the first to introduce the concept of extended timescales into what is primarily a static spatial technique. Here we use GIS to test the robustness and utility of the LVF concept, examining whether associations between LVF localities can be made on the basis of genuine faunal/floral correlations or if other factors are responsible for the apparently shared composition of the assemblages.

GIS spatial analysis revealed that supposed index fossils for each LVF are often not temporally restricted in the western Northern Hemisphere. In particular, *Mastodonsaurus*, *Paleorhinus*, *Metoposaurus* and *Rutiodon* coexist with other LVF index taxa, thereby weakening the stability of the Berdyankian, Otischalkian and Adamanian LVFs. Floral records (genera) are usually endemic or temporally widespread, yet some taxa do appear to be restricted to the Carnian or Carnian-Norian and have the potential to act as index taxa (although not strictly in the manner of North American Floral Zones). There is no consensus on whether Late Triassic climates were zonal or monsoonal, and this dichotomy hampers investigations into climatic biases. Lithological indicators suggest bias towards humid environments can be seen in certain North American floral/faunal records. Generally fauna are found across a variety of ecological settings, yet there are occasional biases: for example *Mastodonsaurus*

appears to prefer high-energy environments.

This study undermines LVF dating of mid-Late Triassic continental deposits. Further strengthening of biostratigraphical criteria are needed if questions of faunal/floral turnover at this crucial point in Earth history are to be rigorously addressed.

AN ASSESSMENT OF CHANGE IN MAMMALIAN DISPARITY ACROSS THE CRETACEOUS-TERTIARY BOUNDARY USING DENTAL MORPHOSPACE

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The mammalian faunal turnover at the Cretaceous-Tertiary (K-T) boundary has long been recognized as the dramatic beginning of the Age of Mammals. Some workers, using an extensive database from North America, recognized rapid and significant increases in both taxonomic diversity and morphologic disparity (measured in estimated body size) within the first million years of the Paleocene. The current study takes an alternative approach by concentrating on the well sampled faunas from the terrestrial sediments of the Hell Creek and Tullock Formations in a single geographic area, northeastern Montana (Garfield County). The high-resolution chronostratigraphic framework in this study system places the Flat Creek local fauna within the last 400,000 years of the Cretaceous and places the Hells Hollow local fauna within the first 200,000 years of the Paleocene. Using these faunas, the taxonomic diversification and change in body size of mammals across the K-T boundary have been previously described, but explicit characterization of their morphologic disparity has not been attempted. Here, I use dental morphology as a proxy to examine patterns of morphologic disparity within these faunas and across the K-T boundary.

Using landmark-based geometric morphometrics, this study quantifies the dental morphospace occupied by therians in both faunas. The lack of homology between multituberculate and therian molars currently precludes the inclusion of the former, but future studies will address this aspect of the fauna using alternative methodologies. Standardized two-dimensional projections of upper and lower molars were digitized for sets of homologous landmarks and superimposed using Procrustes-based methods. Procrustes distances between taxa were used to arrive at morphologic disparity in each fauna. The resulting increase in morphologic disparity across the K-T boundary is significant, but not as dramatic as the results reported by other workers. The discrepancy suggests that peak morphologic diversification lagged at least several hundred thousand years behind the K-T extinction, as some have hypothesized for peak taxonomic diversification.

ARE MANUS-ONLY SAUROPOD TRACKWAYS EVIDENCE OF SWIMMING, SINKING, OR WADING?

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"Manus-only" and "manus-dominated" sauropod trackways, which exclusively or preferentially preserve forefoot impressions, have been recorded from Middle Jurassic to Lower Cretaceous localities in many countries. Since their initial description in 1944, manus-only trackways have been interpreted as direct evidence of swimming behavior in sauropods. The absence of pes impressions has been explained as a partially buoyant trackmaker propelling itself with its forelimbs. A more recent interpretation suggests that manus-only trackways are "undertracks" produced by a walking animal whose relatively small forefeet sink through an exposed substrate, deforming underlying sediment layers. Neither explanation, however, is consistent with the posteriorly positioned center of mass implied by sauropod osteology.

We present a new interpretation of manus-only trackways that invokes a partially submerged, but otherwise typical sauropod trackmaker. A sauropod in shoulder-deep water experiences a forward shift in its center of mass by virtue of its body shape, which allows the tail to be submerged while the head and neck are held out of water. Although partial submersion decreases effective weight, a much larger proportion of the load is borne by the manus, which in all sauropods has less than half the surface area of the pes. Measurements of partially submerged scale models confirm that the manus experiences more than twice the pressures felt by the pes; this may lead to the manus creating impressions where the pes does not. This effect applies generally but is most pronounced in *Brachiosaurus*, the sauropod with the most forwardly positioned center of mass. Asymmetry of manus prints or occasional preservation of pes prints can be explained by variations in water level, substrate consistency, or neck/tail carriage. Our results do not imply that sauropods could not swim or create undertracks, but that these do not best explain the manus-only sauropod trackway pattern.

HOMOLOGIES OF PAIRED FINS AND TEETH ACROSS THE AGNATHAN-GNATHOSTOME TRANSITION

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Studies on vertebrates from the Early Devonian (Lochkovian) MOTH site, Mackenzie Mountains, Canada, along with recent work by others, suggest revision of homologies previously taken for granted. Among these are that pectoral and pelvic fins are serial homologs, that pelvic fins characterize only gnathostomes, and that marginal jaw teeth are homologous in bony fishes and chondrichthyans.

Brochoadmones and *Kathemacanthus* show that pectoral and pelvic fins are end members of separate paired-fin series, not part of a single series. The pectoral series is maximally expressed near its posterodorsal end, continuing anteroventrally as a series of paired prepectoral spines. The pelvic series is maximally expressed posteriorly, continuing far anteriorly as a series of paired prepelvic spines. In these fishes and in early bony fishes such as *Cheirolepis*, pectoral and pelvic fins differ, the pectoral being lobate and slightly dorsal and the pelvic being long-based and ventral. Studies of thelodonts and a revised interpretation of osteostracans and anaspids further suggest that precursors of both pectoral and pelvic fins occurred in jawless vertebrates. Osteostracans and conventional thelodonts have supra-branchial pectoral-fin precursors, while anaspids and fork-tailed thelodonts have posteroventral pelvic-fin precursors. Märss and Ritchie showed evidence that at least one thelodont had precursors of both pairs.

Claims of the existence of true teeth among primitive craniates and of homology between teeth and the internal denticles of thelodonts are not supported by the distribution of undoubted teeth among early gnathostomes. Recent papers by Young and by Smith and Johanson show that tooth-like structures are found in some highly derived placoderms, yet teeth have not been reported from primitive members. Acanthodian-like fishes preserved at the MOTH locality include many species that were completely toothless. There is, moreover, no fossil record for undoubted chondrichthyan teeth until later in the Early Devonian. It now seems possible that the marginal jaw teeth of chondrichthyans and those of bony fishes are not homologous.

THE FUNCTION OF GASTROLITHS IN DINOSAURS—NEW CONSIDERATIONS FOLLOWING STUDIES ON EXTANT BIRDS

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Many living birds swallow stones regularly to aid in trituration and mixing of foodstuff in their stomach. This behavior and function has been proposed for several groups of dinosaurs too, but it is unclear if the mere presence of gastroliths alone is sufficient evidence for such a function. A comprehensive survey of gastroliths was therefore undertaken in the largest living bird, *Struthio camelus*, and placed in a phylogenetic context relative to other living birds. The analysis of stomach contents of more than 300 free-ranging ostriches from farms in South Africa and Germany indicates that gastroliths amount to 20% to 50% of the stomach contents by weight and constitute about 1% of the body mass.

The abrasion rate of different rocks was examined in several in vivo experiments. Most rock types disintegrate in the gizzard within a few days to weeks. Only vein quartz is more resistant and therefore accumulates in the gizzard. As a result of the continuous grinding action and high abrasion rates, ostrich gastroliths almost never develop any surface polish, the vast majority of the examined stones being dull. In this they differ from alleged sauropod gastroliths found in Jurassic and Cretaceous formations in the United States.

A literature survey of 19 extant species of birds (Anseriformes, Galliformes, Columbiformes, and Passeriformes) indicates a mean gastrolith mass of 0.5% of body mass. These values agree with those for several non-avian theropods, such as ornithomimids or *Caudipteryx*, suggesting that the extensive use of stones in digestion is not an autapomorphy of the crown group birds, but rather evolved much earlier along the avian stem lineage. In contrast, the record of gastroliths associated with sauropods is patchy, and in all confirmed cases the stones weigh significantly less than 0.1% of estimated body mass. The role of gastroliths in sauropod food processing must therefore have been minimal, or at least was not analogous to that in living birds.

NEW SMALL MAMMAL RECORDS FROM THE EARLY MIOCENE OF UGANDA

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Field work at the Napak CC and Bukwa localities (Uganda), under the direction of L. MacLatchy and R. Kityo, has yielded new specimens of rodents and a lagomorph. Napak CC has a provisional radiometric date of 19 Ma, and Bukwa a date of 22 Ma. These sites are currently being redated. Napak CC has produced a mandible fragment with the lower incisor of large sciurid. The incisor is deep and slender, as is characteristic of the late Miocene Kenyan taxon *Kubwaxerus pattersoni*, and the extant African Giant Squirrels, *Epixerus* and *Protoxerus*. The Napak CC squirrel is distinct from the only other known taxa of early Miocene African sciurids, *Vulcanisciurus africanus* (from Kenya and Uganda) and an undescribed taxon from Kenya. The Ugandan sciurid is likely a new taxon of African Giant Squirrel. Screen-washing at Bukwa has produced molars of a tiny phiomyid rodent and a single lagomorph tooth. The phiomyid is morphologically distinct from phiomyids previously illustrated by R. Lavocat from excavations at Bukwa in 1968. The new Bukwa taxon has not been reported from early Miocene collections from Kenya or Namibia. The Bukwa lagomorph is an incomplete cheektooth. Size suggests assignment to *Kenyalagomys minor*, an ochotonid previously described from the early Miocene of Kenya. The Bukwa lagomorph cannot be assigned confidently to either the Family Ochotonidae or Leporidae, but is significant because it is the only fossil lagomorph reported from Uganda.

REVIEW OF EARLY CRETACEOUS (APTIAN/ALBIAN) BOREOSPHENIDAN MAMMALS FROM TEXAS

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CT evaluation of the Early Cretaceous primitive boreosphenidan mammal *Slaughteria eruptans* disclosed a permanent tooth hidden beneath a deciduous premolar in the lower jaw and prompted revision of tooth assignments. What had been considered m1 is now known to be a deciduous premolar, the tooth following being m1. These changes necessitate revised comparisons among the Trinity Group boreosphenidans *Holoclemensia, Pappotherium, Kermackia, Trinititherium*, and others from Texas, including undescribed specimens, and with other boreosphenidans such as *Montanalestes*. Prior to its designation as a holotype, the jaw of *Slaughteria* was referred to *Pappotherium*, a taxon described from a partial maxilla. The jaw was thought to be compatible with the maxilla based on size and occlusal relationships. The tooth now shown to be the only permanent molar of *Slaughteria* differs from some isolated lower molars from the Trinity Group that have been referred contentiously to *Pappotherium* and *Holoclemensia*.

NARIAL ANATOMY OF ANKYLOSAURIAN DINOSAURS: OSTEOLOGY AND

SOFT-TISSUE RECONSTRUCTION

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The narial regions of ankylosaurian dinosaurs are unusual and derived. In most ankylosaurs, the region of the bony nostril, corresponding to the region of the nasal vestibule, is enlarged. Vestibular enlargement is not always apparent externally because of overgrowth of the narial region by bones derived from the skin (i.e., osteoderms). CT scans of juvenile *Pinacosaurus* confirm that the bony nostril (as defined by the margins of the premaxilla and nasal) is very large. In fact, in most ankylosaurs, the apparent size and orientation of the external nasal opening is dictated largely by the extent of osteoderm formation within the narial skin. For example, the seemingly divergent ventral displacement of the nasal openings in *Ankylosaurus* probably simply reflects more extensive (perhaps allometric) ossification within the narial skin. On the one hand, interpretation is complicated by the presence of osteoderms in the narial region. On the other hand, these osteoderms aid interpretation in that their highly sculptured surfaces contrast markedly with the smooth bone surface of the nasal vestibule, allowing relatively clear assignment of anatomical domains. For example, the external surfaces of the nasal osteoderms in *Pinacosaurus* bear ornamentation patterns characteristic of skin-covered bone, whereas their internal surfaces are smooth, reflecting their having been lined with moist nasal epithelium. Many ankylosaurs have apertures in the narial region in addition to the airway. In virtually all ankylosaurs, a caudolateral aperture conducts large blood vessels into the narial region; fossae directly rostral to this vascular opening are consistent with the presence of a mass of erectile tissue. This mass helps corroborate a position of the fleshy nostril at the rostroventral margin of the narial region. Some ankylosaurids have apertures that open into a large space within the premaxilla. The variability of these foramina (taken to an extreme in *Pinacosaurus*) supports their interpretation as pneumatic foramina.

INTERPRETATIONS OF NORTH AMERICAN CRETACEOUS DINOSAUR DIVERSITY TRENDS

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A considerable literature exists that purports to show that dinosaur diversity was gradually and inexorably declining through the Late Cretaceous (especially Campanian-Maastrichtian). To evaluate these claims, a tabulation of all published dinosaur occurrences for the North American Cretaceous was undertaken. Preservational categories are noted (from articulated skeletons to bone scrap) for each geographic and stratigraphic occurrence. Listings of all dinosaur taxa for each age/stage produced conservative and liberal tallies of fossil diversity through time. Conservative tabulations only consider dinosaur taxa that are considered valid by most or all workers, but liberal tallies add those taxa that are more controversial or are not yet fully documented (e.g., abstracts). Both tabulations show similar trends over time, but each produced significantly different absolute numbers of genera and species. Judithian and Lancian compilations show the greatest number of dinosaur taxa, respectively. There is a general relationship between the number of dinosaur taxa and the number of dinosaur-bearing formations for each age/stage. The Dinosaur Park Formation of Alberta has become the standard of reference against which other dinosaur-bearing formations have been compared, but the unparalleled preservation and diversity in these strata make such comparisons unclear. If the Dinosaur Park Formation did not exist, the Hell Creek fauna would be the most diverse known for the Cretaceous. Supposed diversity patterns seem to be more closely related to the distribution of dinosaur-bearing strata and taphonomic issues associated with each dinosaur-bearing lithofacies. Considering the overall scarcity of well-preserved dinosaur faunas in the geologic record, it seems unlikely that the fossil record of dinosaurs is adequate to say much about actual biodiversity through time, especially on a global scale. Faunal compilations for North America do not seem to provide any clear basis for waning dinosaur diversity through the Campanian-Maastrichtian.

THE FIRST OCCURRENCE OF *ORODROMEUS MAKELAI* POSTCRANIA FROM THE LATE-CAMPANIAN JUDITH RIVER FORMATION OF EASTERN MONTANA

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The discovery of postcrania of *Orodromeus makelai* in material collected from Phillips County, Montana, is the first such occurrence in the Judith River Formation. The report of *Orodromeus* teeth in the Judith River Formation is corroborated here by examination of the proximal femur, tibia, and distal metatarsals of the specimen using morphological characters from previous studies. The specimen exhibits a constricted femoral neck, lateral disposition of the lesser trochanter relative to the greater trochanter, a blunted aspect to the cnemial crest, a triangular midshaft of the tibia, and a partially load-bearing first pedal digit. The synthesis of all these characters implies a placement between *Heterodontosaurus* and *Gasparinisauria*. The additional character of a close association of the proximal tibial condyles indicates an affinity with either *Lesothosaurus*, *Hypsilophodon* or *Orodromeus*.

Referral of the specimen to a close relative of *Lesothosaurus* or *Hypsilophodon* is discouraged due to the lack of known occurrence of either taxon in the global record of the Upper Cretaceous. Furthermore, the stratigraphic level of the Phillips County site is time equivalent to the Willow Creek Anticline type locality of *Orodromeus makelai*. The most parsimonious conclusion therefore is to refer the postcrania to *Orodromeus makelai*.

NEW DATA ON ENAMEL MICROSTRUCTURE IN MESOZOIC MAMMALS: PATTERNS AND UPDATES.

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It is presently unclear whether enamel prisms arose several times during mammalian evolution or arose only once with several reversals to prismless structure. At least two undisputed reversions are known—in the monotreme clade from *Obdurodon* to *Ornithorhynchus* (via *Monotrematum*?), and (perhaps more than once) within the clade from archaeocete to a variety of odontocete whales. A variety of functional and developmental circumstances are involved, and simple thinning and loss of enamel may not be the only factor in simplifying enamel structure. In archaeocetes, for example, Hunter-Schreger bands are ubiquitous whereas extant *Platanista* and *Inia* have them despite differences in molar morphology and function; furthermore, extant *Pontoporia* has relatively thin enamel (~90 μm) with radial prisms whereas *Phocoenoides* has relatively thick (200-250 μm), yet prismless enamel. Finally, new data on various Mesozoic mammals demonstrate a more complicated distribution of prismatic and prismless enamel than previously understood, including symmetrodont enamel only 40-49 μm thick with fully developed prisms. New data on taxa from *Prokennalestes* to *Vincelestes* require different scoring and polarities than those in recently published phylogenies.

A NEW SKELETON OF THE AETOSAUR *STAGONOLEPIS WELLESI* (ARCHOSAURIA: CRUROTARSI) FROM PETRIFIED FOREST NATIONAL PARK AND PRELIMINARY RESULTS FROM A SIGNIFICANT NEW BONEBED FROM THE LOWER CHINLE FORMATION (LATE TRIASSIC) OF ARIZONA

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Ongoing paleontological site inventories in Petrified Forest National Park in east-central Arizona have resulted in the discovery of a significant vertebrate fossil assemblage. Preliminary investigations, as well as past investigations, have determined that this is a multitaxic accumulation within proximal overbank mudstones consisting mainly of large suchian archosaurs and labyrinthodont amphibians. Aetosaur remains are common, represented by three taxa, *Desmatosuchus*, *Paratypothorax*, and *Stagonolepis*. *Stagonolepis* is best represented with a relatively complete skeleton already recovered, as well as several other specimens. Initial preparation of this material shows it to belong to the species *S. wellesi* with this taxon being determined here to be valid. *S. wellesi* is distinct from *S. robertsoni* by the development of enlarged dorsal eminences of the posterior dermal armor. The assignment of lateral cervical spikes to *S. wellesi* by previous workers is considered erroneous with those elements most likely pertaining to *Paratypothorax*, which co-occurs with *S. wellesi* at several localities in the southwestern United States. This quarry is stratigraphically significant because it occurs either just below or within the Sonsela Member of the Chinle Formation providing a glimpse of a poorly documented fauna. The ambiguity of the placement is currently being worked on in association with the complex channel avulsion sequences associated with the Sonsela-Rainbow complex of other workers. The presence of several associated skeletons, which are rare in the Chinle Formation, and the presence of possible dinosaurian material imparts additional significance to the site. This would represent one of the earliest known occurrences of dinosaurs from Petrified Forest National Park. Overall this site has the potential to provide insights on terrestrial vertebrate associations and ecology near the Carnian-Norian boundary interval of Arizona, which is otherwise largely only known from aquatic assemblages.

BIOLOGICAL APATITES: A COMPARISON OF BONE AND TOOTH MINERALIZATION

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Two distinct size ranges of nanocrystalline calcium phosphate phases occur in mammals: Mineral crystallites in bone and tooth dentin are 10s nm x 10s nm x a few nm and intimately intermixed with strands of collagen fibers, whereas crystallites in tooth enamel are about 10x larger than in bone or dentin, and are associated with very little collagen. Bioapatites with different functions also are characterized by different hydroxyl (OH) concentrations. Moreover, it appears that (OH) is controlled by a biologically imposed particular "state of crystallinity", a term that refers to both crystallite size and atomic order/disorder within the unit cells of the crystal. All biological apatites traditionally have been referred to as (carbonated) hydroxylapatite, even though there is growing evidence that bone mineral does not contain any hydroxyl groups, and that the mineral in dentin contains little or no (OH). Thus, even though bone mineral is apatitic (confirmed by multiple structural analytical techniques), it is incorrect to refer to it as hydroxylapatite (i.e., $Ca_5(PO_4)_3(OH)$, a mineral that contains hydroxyl groups). We have used laser Raman microprobe spectroscopy to analyze bones and teeth of various modern species (human, beaver, boar, water buffalo, coyote, mouse), as well as a mammoth tusk. The spectra provide molecular-structural fingerprints that allow us to explore differences in the mineral-to-collagen ratio and in the abundance of (OH) (inferred from band area ratio of the 3573 Dcm^{-1} O-H stretch band to the 960 Dcm^{-1} P-O stretch band). In addition, we can derive indirect information about the carbonate concentration (inferred from band area ratio of ~1071 Dcm^{-1} P-O band to the ~960 Dcm^{-1} P-O band), the presence of fluorapatite or francolite (inferred from the exact band position of the putative 960 Dcm^{-1} P-O band), and the degree of atomic ordering within the unit cell, e.g., the regularity of the shape and position of the PO_4 tetrahedra (inferred from the width of the 960 Dcm^{-1} P-O band). We have found striking similarities among those parameters in the minerals in bone, dentin, and enamel, respectively, for the modern species studied.

THE EFFECTS OF STRIDE LENGTH AND GAIT ON QUADRUPEDAL VERTEBRATE TRACKWAY PATTERNS

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The exact maker of fossil vertebrate trackways is rarely, if ever, known, so a number of general assumptions have to be made about the trackmaker and the way it moved. These assumptions have been made on the basis of studies of modern animals and hold good for a wide variety of animals so it seems likely that they would also work for fossil vertebrates. However, the body plan of some extinct animals is very different from that of any modern animals, so, for these animals, modern analogues may be less reliable.

Vertebrate trackways may be defined on the relative positions of manus and pes. For exa mple, the manus impression may be consistently in front of or behind the pes impression or, it may be regularly overstepped. For instance, one of the defining characters of pterosaur trackways is that the manus impressions fall just behind the pes impressions. On the other hand, the variation in emplacement of sauropod manus impressions is generally attributed to a change in gait, with a longer stride length, reflecting greater speed, leading to overstepping of the manus.

Other extinct animals, such as dicynodonts, had a different body plan, unusual amongst modern amniotes; they had a long body and short legs and tail but, unlike some modern mammals that might seem to fit this description (e.g. mustelids or pygmy hippos), they are thought to have had semi-erect back legs and sprawling front legs. They also probably utilised a walking gait rather than the bounds of mustelids and other semi-erect mammals such as squirrels. This study investigated the effects that assumptions about stance and gait have on trackway patterns, that is, the apparent sequence of foot emplacement recorded in the trackway. Glenoacetabular lengths estimated from trackways of animals with exceptionally long bodies for their leg lengths are likely to be underestimates. In addition the relationship of trackway pattern to trackmaker speed is less straightforward for such animals than for most quadrupedal vertebrate trackways.

SYSTEMATIC AND BIOSTRATIGRAPHIC IMPLICATIONS OF A NEW ORNITHOCHERID PTEROSAUR FROM WYOMING

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A fragmentary dentary with tooth crowns, collected from the Breakfast Bench Locality at Como Bluff, represents the first record of a toothed ornithocheirid pterosaur from the Rocky Mountain region. The teeth are caudally recurved and inflected medially as in *Anhanguera araripensis*, *A. santanae*, and *A. piscator* from the Aptian-Albian Santana Formation, implying a close phylogenetic relationship. This counters suggestions of a close resemblance between the new specimen and *Istiodactylus latidens* from the Wealden Formation of England. In order to investigate the placement of the new specimen in relation to Ornithocheiridae and to other pterosaurs, a new species-level cladistic analysis of Pterosauria was performed incorporating 160 characters (most new), 48 pterosaur species, and three outgroup taxa (*Euparkeria*, *Marasuchus*, and *Scleromochlus*). The data confirmed and supported a number of well known clades, including Anurognathidae, Campylognathoididae, Ctenochasmatoidea, Ornithocheiridae, and Azhdarchoidea. The resulting phylogeny is largely congruent with previous hypotheses, except that *Nyctosaurus* and *Pteranodon*, together with *Chaoyangopterus*, are recovered as sister taxa to Azhdarchidae, rather than as ornithocheirids. *Cearadactylus* is positioned as a basal ornithocheirid, not a ctenochasmatid. The strict consensus of 1792 equally parsimonious trees is highly resolved, indicating a strong phylogenetic signal despite a large proportion of missing data, The presence of an ornithocheirid in the uppermost, carbonaceous strata of the Morrison Formation in southern Wyoming supports the interpretation of this succession as Early Cretaceous (possibly Aptian-Albian), and indicates an intraformational unconformity up to 35 m.y. in duration.

NEW MIDDLE CENOZOIC MAMMALS FROM THE LAGUNA DEL LAJA REGION (CURA MALLÍN FORMATION, SOUTH CENTRAL CHILE)

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Widespread fossils in volcaniclastic sediments of the Andean Main Range in central Chile have significantly advanced our understanding of South American mammal evolution. Ensuing paleontological discoveries have also provided key geochronologic information for deciphering the complex tectonic history of this segment of the Cordillera.

Our previous work in this region largely has been within the Abanico Fm. from ~33.5-35.3° S. Here we report discoveries in strata likely laterally equivalent to this unit near Laguna del Laja (37.5° S), a region previously unexplored paleontologically. Well-preserved specimens have been recovered within three very distinct sections in both members of the Cura-Mallín Fm. across a wide area SE of the lake. Although the beautifully exposed Cenozoic strata (previously thought to span the Eocene-Miocene) are spectacularly folded and faulted (obscuring relationships between sections), the fossils show little indication of significant temporal differences. The entire sequence is thus probably temporally short and roughly middle Miocene in age (based on the new fossils). Samples from throughout the section currently being processed for $^{40}Ar/^{39}Ar$ analysis will provide additional independent chronologic information.

Fossils have been recovered from ~500 m of stratigraphic section at Cerro Los Pinos, the upper two-thirds of which are incorporated into a sweeping S-fold. Notable finds include partial lagostomine chinchillid crania, an echimyid closely resembling *Acarechimys*, and teeth of a large, enigmatic rodent. From a tight anticline farther east we recovered notoungulate skulls including a hegetotheriine resembling *Hegetotherium* and an interatheriine resembling *Protypotherium*, a sparassodont, plus several other taxa. Just above these horizons, within strata mapped as Trapa Trapa Fm., we recovered lower jaws of a large rodent and a small-bodied mammal with procumbent and splayed anterior teeth. Various rodents and a pachyrukhine skull comparing closely with *Paedotherium minor* occur in gently dipping strata (Cura-Mallín Fm.) immediately west of the second section.

CETACEA AND SIRENIA FROM THE EOCENE WADI ESH-SHALLALA FORMATION OF JORDAN.

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Ongoing investigation of the fossil vertebrates from Eocene strata in Jordan has yielded new remains of Tethyan marine mammals (archaeocete Cetacea and Sirenia). These were obtained from the Wadi Esh-Shallala Formation in the Thuleithuwat Hills and Qa Faydat ad Dahikiya in the eastern desert of Jordan. The middle Eocene fauna of the Thuleithuwat Hills includes an astragulus of a protocetid and a posterior rib of a protosirenid sea cow. Foraminifera associated with mammals in the lower third of the Thuleithuwat Hills are middle Lutetian in age (planktonic foraminiferal zone P10). Qa Faydat ad Dahikiya vertebrate remains show more advanced stage of evolution in both Archaeoceti and Sirenia. *Basilosaurus isis* is present and a new dorudontine taxon is represented by vertebrae and teeth. Pachyosteoclerotic distal rib and rib fragments represent the sirenian group in the late Eocene of Qa Faydat ad Dahikiya, with a close affinity to Dugongidae. These Jordanian discoveries are important because they occupy an intermediate geographic location between eastern and western Tethyan Eocene marine mammal provinces.

A NEW CAENAGNATHID SPECIMEN FROM THE KAIPAROWITS FORMATION (LATE CAMPANIAN) OF UTAH

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Recent excavation in Grand Staircase-Escalante National Monument, southern Utah, has revealed a diverse dinosaurian fauna including a small theropod showing strong affinities with the Caenagnathidae. The specimen preserves a nearly complete, articulated left manus, one articulated pedal phalanx and ungual, and a series of associated but damaged pedal elements and distal metatarsals. Comparisons with *Chirostenotes pergracilis* reveal numerous diagnostic characters including unguals that display an extremely pronounced dorsal lip. The proportional length of the first, second, and third metacarpals, as well as the phalanges of the third digit, mirror those present in *Chirostenotes pergracilis*. However, the third digit of the new specimen is notably longer and more robust than in either of the two specimens of *C. pergracilis* in which it is known. As a result, we feel that this specimen shows significant enough deviation to prevent assignment to this taxon. As no other definitively caenagnathid taxa preserve manal elements, and only one other taxon preserves pedal phalanges, a more specific taxonomic assignment of this specimen is unwarranted at this time.

Previous researchers have proposed the existence of two discrete, latitudinally arrayed faunal provinces in the Western Interior of North America during the Late Cretaceous. The Kaiparowits Formation in southern Utah helps to remedy a paleontological and geographical gap between the inferred northern and southern faunas that has obscured biogeographic reconstructions during this interval. The presence of the Caenagnathidae within this formation suggests that at least a portion of the dinosaurian diversity in Utah shows affiliation with the northern faunal province. This evidence, when combined with that of other vertebrate taxa associated with the southern province, is revealing the integrated and transitional nature of Utah ecosystems in the Late Cretaceous. Most importantly, the discovery of this new specimen vastly expands the southernmost extent of this formerly localized clade, nearly doubling the previously documented range of North American caenagnathids.

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