

**WEDNESDAY MORNING, NOVEMBER 3, 2004**

**ROMER PRIZE SESSION  
PLAZA BALLROOM A/B**

**MODERATORS: RYOSUKE MOTANI AND RAYMOND ROGERS**

8:00 **Welcome**

8:15 **Beck, A.: THE ORIGINS OF MAMMALIAN LOCOMOTION: NEW METHODS FOR RECONSTRUCTING POSTURE IN EXTINCT NON-MAMMALIAN SYNAPSIDS**

BECK, Allison, Univ. of Chicago, Chicago, IL

The Synapsida, composed of living mammals and their extinct ancestors, are colloquially known as the 'mammal-like reptiles.' The extensive fossil record captures numerous transitional forms recording the transition from Permian, reptile-like pelycosaur to primitive therians of the Triassic. A major part of this transition involved a change from a sprawling posture to one similar to the crouched posture of living small mammals such as the opossum. Despite our understanding of the postural endpoints, the question remains: What was the locomotory posture of taxa that are phylogenetically intermediate between pelycosaur and modern mammals? Two major notions of postural change have been proposed, both supported by functional morphologic analyses and comparison to living mammals and reptiles. One suggests that intermediate taxa were capable of a dual-gait, much like modern crocodylians. The other outlines a series of increasingly upright intermediates. Neither hypothesis has been quantitatively evaluated. Here I set up a framework for interpreting function in extinct vertebrates, and apply it to reconstructing posture in extinct non-mammalian synapsids.

Linear and angular measurements were taken on the limb and girdle bones of extant iguanian and varanid lizards, crocodylians, therian mammals and monotremes, and again on fossil synapsids. Multivariate and bivariate analyses were used to correlate suites of morphologic features with posture in the living forms. The data for fossil taxa were then filtered through these morphological correlates and examined for patterns. Fossil taxa that are morphologically similar to modern taxa can be inferred to have similar locomotory posture, and reconstructions can be constrained beyond previous concepts. The quantitative results demonstrate that intermediate synapsids followed the latter pattern, evolving through a series of increasingly upright forms. These results show, however, that both the forelimb and hindlimb became more upright earlier in synapsid evolution than previously thought. Future work will incorporate quantitative analyses of qualitative data to more fully understand synapsid postural evolution.

8:30 **Burris, J.: MORPHOLOGY AND PHYLOGENETIC IMPLICATIONS OF RECENT AND FOSSIL CARCHARHINIFORM SHARK VERTEBRAL CENTRA**

BURRIS, John, Michigan State Univ., East Lansing, MI

The cross-sectional anatomy of secondary calcifications of shark vertebral centra has featured in phylogenetic hypotheses, although never in a rigorous cladistic framework. In this study, the internal calcification patterns, along with the external morphology, of fossil and Recent shark centra of the Order Carcharhiformes have been coded and subjected to a cladistic analysis to address the utility of centrum features for revealing relationships. 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 characters include centrum proportions, the presence and distribution of cartilage canals, and the size, shape, and spacing of the foramina for the basidorsal and basiventral arch components. The internal calcification features evaluated include the morphology and spacing of the four intermedialia, the four noncalcified areas, and the four diagonal calcifications.

Centrum characters were analyzed both separately and combined with other morphological characters from previous analyses. Results of the cladistic analysis show that shark centrum characters are useful for elucidating phylogeny. Tree topology was very similar for both analyses, and similar to recent molecular databased phylogenies. The addition of centrum data to shark phylogenetic analyses will allow for a more objective means of determining the interrelationships of fossil and extant carcharhiniform sharks than studies based on teeth alone, with their well-documented difficulties. 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.

8:45 **Ehret, D.:** SKELETOCHRONOLOGY AS A METHOD OF AGING OLIGOCENE *GOPHERUS LATICUNEUS* AND *STYLEMYS NEBRASCENSIS*, USING *GOPHERUS POLYPHEMUS* AS A MODERN ANALOG

EHRET, Dana, Univ. of Florida Dept of Geological Sciences, Gainesville, FL

The use of skeletochronology in many reptile groups has become a commonplace method of incremental growth analysis over the last twenty years. This method has been largely overlooked as a feasible alternative to scute annuli counts or carapace length measurements in tortoises. Incremental growth layers in other reptiles and amphibians have been correlated to annual growth cycles. In bone thin sections, a light, wide band represents a season of rapid growth, and a thin, dark band represents a season of slow growth or stasis, making up a single year's growth. Growth layers are analyzed by taking determined-thickness thin-sections from humeral shafts of specimens.

Information gathered from *Gopherus polyphemus* specimens, from north central Florida, provides the groundwork for the use of skeletochronology in the fossil tortoise species *Gopherus laticuneus* and *Stylemys nebrascensis*, from the Nebraska badlands. Information derived from incremental growth assessment includes approximate age of the individual. In turn, this data can be used as a starting point to determine the population dynamics of a group of individuals. Other aging techniques (i.e., scute annuli counts and shell dimensions) can be misleading, and are highly population specific. Skeletochronology is an accurate method of aging that can be applied to both fossil and modern tortoise populations.

9:00 **Fox-Dobbs, K.:** SURVIVING THE LATE PLEISTOCENE EXTINCTION: WERE MARINE RESOURCES A DIETARY BUFFER WITHIN THE VULTURE GUILD?

FOX-DOBBS, Kena, Univ. of California Santa Cruz, Santa Cruz, CA

The late Pleistocene extinction decimated terrestrial megafaunal communities in North America, but did not affect marine mammal populations. In coastal ecosystems the carnivore and scavenger species that fed on marine megafauna may have been buffered from the extinction and survived into the Holocene. Here, I use stable isotope data to test this hypothesis by characterizing the feeding preferences of the largest members of the Pleistocene vulture guild. I analyze two regionally extinct species (*Teratornis merriami* - teratorn; *Coragyps occidentalis* - western black vulture) and one extant species (*Gymnogyps californianus* - California condor) from southern California. All three species were abundant in this area until the Pleistocene-Holocene boundary, after which the teratorn and western

black vulture disappeared along with the megafauna. Modern condors have been observed scavenging both marine and terrestrial resources, and this dietary flexibility may have been the key to their survival.

Carbon and nitrogen ratios are much higher in marine than in terrestrial ecosystems, and as such provide a clear marker of the relative contributions of these resources to animal diets. To track the influence of marine resources in the ancient vulture guild I analyzed the isotopic ratios of collagen from bones collected from several late Pleistocene sites. I used isotope data from multiple abundant herbivore and carnivore megafaunal species to characterize terrestrial resources. Carbon and nitrogen isotope values for all teratorn and western black vulture individuals are within the terrestrial range of values, and therefore do not imply any significant marine resource utilization. The condors are split into two groups of individuals; those with lower isotope values indicating a terrestrial-based diet, and those with higher values indicating a strong marine influence. Unlike the teratorn and western black vulture, Pleistocene condors were able to feed across the terrestrial-marine interface. These findings suggest that the survival of vulture species into the Holocene was more strongly correlated to a marine versus terrestrial diet.

9:15 **Hall, M.:** A NEW APPROACH FOR INFERRING ACTIVITY PATTERN IN AVIANS USING THE ORBIT AND SCLEROTIC RING

HALL, Margaret, SUNY, Stony Brook School of Medicine, Stony Brook, NY

Activity pattern (e.g., nocturnal, diurnal, and arrhythmic) is a significant component of an animal's ecology, but the evolution of activity patterns among terrestrial vertebrates is poorly studied. Data on the activity patterns of fossil vertebrate taxa are required to reconstruct the basal character states of vertebrate groups. In addition, these data are significant for reconstructing the paleobiology of individual fossil taxa. In order to determine to what extent activity pattern can be reconstructed in fossil taxa, anatomical correlates of activity pattern in extant taxa must be identified. Avians are useful for this reason because activity pattern and gross eye shape are strongly correlated. For example, photopic-adapted eyes have larger axial lengths relative to their corneal diameters, an adaptation for increasing focal length, which enlarges the image and heightens visual acuity. In addition, scotopic-adapted eyes exhibit enlarged corneal diameters relative to eye length, an adaptation for maximizing the number of photons captured and increasing sensitivity over diverse, particularly low, light levels.

This study compares soft-tissue measurements of the avian eye to the associated bony structures, the orbit and scleral ossicles. Study groups include nocturnal, diurnal, and arrhythmic taxa, represented by Strigiformes, Caprimulgiformes, Apodiformes, Psittaciformes, Falconiformes, and Columbiformes. Analysis of the bony anatomy reveals that scotopic-adapted eyeballs with larger corneal diameters are surrounded by larger sclerotic ring diameters than those of photopic-adapted eyeballs, showing virtually the same relationship between bony anatomy shape and activity pattern as was observed for soft-tissue anatomy. Therefore, bony anatomy can be used in lieu of soft tissue to discriminate between activity patterns, suggesting the possibility of interpreting the activity patterns of extinct avians and non-avian dinosaurs.

9:30 **Holliday, J.:** CHARACTER CHANGE IN CARNIVORA: SPECIALIZATION, STASIS, AND THE QUESTION OF DIRECTIONAL BIAS

HOLLIDAY, Jill, Florida State Univ., Tallahassee, FL

In mammalian carnivores, hypercarnivory is a meat-specialist dietary niche characterized phenotypically by a distinct dental morphology, including relative shortening of the rostrum, relative elongation of the carnassial blade, and relative reduction of the post-carnassial dentition. Hypercarnivory has evolved numerous times within the order Carnivora, including members of such disparate lineages as felids, nimravids, hyaenids, mustelids, and canids. This repeated evolution of the hypercarnivore

phenotype facilitates comparative study of patterns in character change. Previous work using sister group comparisons has shown that hypercarnivores are limited in their subsequent morphological diversification. Furthermore, once taxa achieve this specialist phenotype, they do not appear able to reverse to a less-specialized morphology or to move into alternative niches; rather, character change is generally in a forward direction (towards increasing specialization). In order to understand and explain these limitations, I examine possible mechanisms that could generate the observed patterns. In particular, I test for the presence of a directional bias in morphological character change as lineages move towards hypercarnivory, and compare rates of forward change, reverse change, and stasis in specialist vs. non-specialist lineages.

9:45 **Lindenau, C.:** TOOTH ENAMEL MICROSTRUCTURE OF SOUTH AMERICAN LITOPTERNS (MAMMALIA)

LINDENAU, Christa, Institut für Palaeontologie, Bonn, Germany

The study of tooth enamel shows convergent evolution between South American and holarctic ungulates concerning Hunter-Schreger bands (HSB) and modified radial enamel (mRE). The presence of mRE in derived members of each group allows the distinction from more plesiomorphic members.

The litopterns include the camel-like Macrauchenioidea and the horse-like Proterotherioidea. Within the Macrauchenioidea dental specialization occurs: they develop hypsodont teeth. While modifying the tooth morphology the enamel microstructure is also changed. The inner radial enamel of early brachyodont genera gets reorganized into a significant layer of mRE with thick interrow sheets in derived hypsodont forms. In contrast the sister group Proterotherioidea shows no tendency for either hypsodonty or mRE. But the latter enamel type is known also from highly specialized holarctic taxa that evolved hypsodont teeth, such as the Equoidea. As the proterotheriines represent the South American analog of the horses, it is even more surprising that the mentioned features are missing.

HSB (prisms decussating in layers) evolved several times convergently among many different mammalian lineages. The usual orientation of the bands is transverse but in some Placentalia they bend upwards intersecting the occlusal surface at a nearly right angle. Within the litopterns this modification can be seen in some of the lower molars. But another peculiarity occurs: all upper molars show on the buccal side HSB bending downwards at each style, independent of the crown height. As the morphology of the ectoloph in most genera is strongly crested, the bands run approximately parallel to the cutting edges.

The modified orientation of HSB is related to tooth function. With prisms running perpendicular to the occlusal surface the abrasion of the enamel is reduced. The adaptation of HSB running parallel to the cutting edges may be to prevent cracking, but it is not yet well understood.

10:00 **BREAK**

10:15 **Reed, D.:** CALLIBRATING PALEOENVIRONMENTAL ANALYSIS USING MODERN MICROMAMMAL ASSEMBLAGES FROM SERENGETI, TANZANIA

REED, Denne, National Museum of Natural History, Smithsonian, Washington, DC

Several methods developed for the analysis of paleoenvironments, such as the taxonomic habitat index, taxonomic ratios, and paleobiodiversity have not been tested under known conditions before being applied to fossil assemblages. This is particularly true for micromammals, whose presence in fossil assemblages is often mediated by predators that act as accumulating agents and may bias the abundance of different taxa.

In this paper, modern micromammal assemblages from the Serengeti National Park, Tanzania are used to test methods of paleoenvironmental analysis. The focus rests on a dominant predatory mode by which micromammals enter the fossil record, as the egested prey of owls.

Large faunal collections made from owl roosts in various habits within the Serengeti were analyzed and the shifts in taxonomic abundance from one roost to the next compared against the habitats that surround the roosts. The surrounding habitats are mapped in detail using satellite imagery in conjunction with ancillary data on hydrology, soils, and topography digitized into a geographical information system (GIS).

Taxonomic composition in the prey assemblages were not found to differ significantly between two species of owl, *Tyto alba* and *Bubo africanus*, but more subtle biases in relative abundance are noted. Despite the overall similarity of the region (a tropical savanna woodland) differences in taxonomic relative abundance correlate with measures of woody vegetation cover depending on the analytical method used.

Fossil micromammals have been used as paleoenvironmental indicators at many localities and are part of the general toolkit for reconstructing past terrestrial environments. The findings presented in this paper are relevant to interpreting assemblages created by different predators and toward accurate assessment of environment and environmental change. Variability and spatial scaling are also important issues addressed in this study by comparing variability within and between similar habitat types.

10:30 **Rybczynski, N.:** EFFECT OF INCISOR SHAPE ON WOODCUTTING PERFORMANCE IN TWO BEAVERS (CASTORIDAE, RODENTIA)

RYBCZYNSKI, Natalia, Canadian Museum of Nature, Ottawa, ON, Canada

The modern beaver, *Castor*, harvests trees and woody vegetation for food and nest-building purposes. The fossil record indicates that *Dipoides* was also a woodcutting beaver, and that *Castor* and *Dipoides* occurred sympatrically, implying some degree of “woodcutting niche” partitioning. Cranial and behavioral evidence suggests that *Castor* may have been better able to exploit woody vegetation than *Dipoides*. The skull of *Castor* appears more specialized for powerful gnawing. In addition, wood-artifact evidence suggests that *Castor* could harvest sticks with relatively fewer cuts than *Dipoides*. This study considers the relationship between woodcutting performance and incisor shape. In anterior view, the *Dipoides* lower-incisor tip is rounded, whereas that of *Castor* is straight. I examined the functional significance of these differences using an experimental approach with physical models. Lower incisors of both *Dipoides* and *Castor* were modeled in steel and mounted in an apparatus that measured cutting forces during woodcutting. Four types of fresh wood were used: sweetgum, oak, pine, and red cedar. Results indicate that for a given cut-width, the *Dipoides* incisor-model required smaller average applied force than the *Castor* incisor-model. I also collected qualitative observations on the relationship between cut-width and wood fracture-behavior and identified difference in cutting effectiveness at larger cut-widths. The results suggest that maximum relative bite-size would be larger for *Castor* than *Dipoides* in all woods sampled except redcedar. In redcedar the results predict that maximum relative bite-size of *Castor* and *Dipoides* would be similar. These findings are consistent with the hypothesis that *Castor* was a generalist tree-predator, and suggest that *Dipoides* may have specialized on trees whose wood-fracture properties were similar to red cedar.

10:45 **Stromberg, C.:** THE ‘GREAT TRANSFORMATION’ AND EVOLUTION OF HYPSONDONTY IN EQUIDS: TESTING A HYPOTHESIS OF ADAPTATION

STROMBERG, Caroline, Swedish Museum of Natural History, Stockholm, Sweden

The independent acquisition of high-crowned cheek teeth (hypsodonty) in several ungulate lineages (e.g. camelids, equids) in the early-middle Miocene of North America has classically been used as an indication that savanna vegetation spread during this time (the ‘Great Transformation’). Implicit in this interpretation is the untested assumption that hypsodonty was an evolutionary response to feeding in open habitats, either due to a change in food source (from browse to graze) or to increased incorporation of airborne grit in the diet. I examined the adaptive explanation for hypsodonty in equids using criteria pertaining to process and pattern of adaptations set up in the comparative methods literature. Specifically, I tested the criterion that hypsodonty appeared coincident with or just after the spread of open, grass-dominated habitats in the Great Plains of North America.

Phytolith (plant opal) analysis is a paleobotanical tool that has mainly been employed in archaeobotany. In this study, I adapted traditional methods for use in Tertiary paleoecology. Ninety-nine phytolith assemblages extracted from sediment samples from Montana, Nebraska, and Colorado were thus used to establish the first continuous record of middle Eocene-late Miocene vegetation change in the north to central Great Plains. This record was compared to the fossil record of equids from the same area in a phylogenetic context.

The study showed that habitats dominated by C<sub>3</sub> grasses were established in the central Great Plains by early late Arikareean, at least 4 my ( $\geq 21.9$  Ma) prior to the emergence of hypsodont equids (Equinae). Nevertheless, the adaptive hypothesis for hypsodonty in equids could not be rejected, since the earliest savanna-woodlands roughly co-occurred with members of the grade constituting the closest outgroups to Equinae (“*Parahippus*”) showing (sub)mesodont dentition. Explanations for the slow evolution of full hypsodonty may include weak and changing selection pressures and/or phylogenetic inertia. These results suggest that care should be taken when using functional morphology to infer major environmental changes.

11:00 **Therrien, F.:** PALEOENVIRONMENTS AND MAGNETOSTRATIGRAPHY OF THE MAASTRICHTIAN SANPETRU FORMATION (ROMANIA): IS THE DISAPPEARANCE OF DINOSAURS INDICATIVE OF THE K/T BOUNDARY?

THERRIEN, Francois, Johns Hopkins Univ. School of Medicine, Baltimore, MD

The Sanpetru Formation (Hateg Basin, Romania) has long been thought to span the Cretaceous-Tertiary (K/T) boundary due to the apparent absence of dinosaur remains in the uppermost 200 m of the formation. Although the disappearance of dinosaurs coincides with important lithological changes, no investigation of the nature of the paleoenvironmental changes, of their possible impact on the disappearance of dinosaurs, nor verification of the inferred age of the formation with methods independent of fossil preservation have ever been conducted.

Samples were collected in a 1,000 m-thick composite stratigraphic section of the Sanpetru Formation for paleopedologic and magnetostratigraphic analyses. Study of the Sanpetru overbank deposits reveals the presence of different habitats: ponds, wetlands, seasonal wetlands, and proximal and distal dry floodplains. Pedogenic features, such as carbonate nodules with intergrowth of iron oxides, slickensides, and deeply-penetrating roots, and paleosol geochemistry indicate that the Maastrichtian climate of Romania was subhumid with a strong seasonality of precipitation. The distribution of pedotypes in the Sanpetru stratigraphic section reveals that an important paleoenvironmental change from a mosaic of wetlands and dry floodplains to exclusively wetlands occurs in the upper Sanpetru Formation. Such dramatic changes coincide with river competence increase and change in paleocurrent directions, and were induced by tectonism. Magnetostratigraphy of the Sanpetru Formation reveals that the deposits are probably early-to-middle Maastrichtian in age; therefore, the paleoenvironmental changes and coincident dinosaur “disappearance” did not occur at the K/T boundary. Combined with the recent

discovery of dinosaur remains in distinctive dry floodplain facies stratigraphically equivalent (or superior) to the uppermost wetland deposits of the Sanpetru section, these results suggest that the apparent disappearance of dinosaurs in the Sanpetru Formation is not associated with the terminal Cretaceous extinction but rather reflect a preservational artifact, due to taphonomic and/or paleoecological causes.

11:15 **Trujillo, K.:** STRATIGRAPHY AND CORRELATION OF THE MORRISON FM. (UPPER JURASSIC-LOWER CRETACEOUS) WITH EMPHASIS ON SOUTHEASTERN WYOMING: IMPLICATIONS FOR VERTEBRATE PALEONTOLOGY

TRUJILLO, Kelli, Univ. of Wyoming, Laramie, WY

The Morrison Formation of southeastern Wyoming is a very important and prolific fossil-bearing unit. This study was primarily initiated to determine whether local and long-distance correlations within the formation are reliable, as well as to understand the local stratigraphy. The methods used included radiometric dating, lithostratigraphy, and biostratigraphy.

A radiometric age range was obtained for the upper part of the Morrison Formation in southeastern Wyoming which constrains this part of the formation to the Late Jurassic. This does not, however, preclude an Early Cretaceous age for the uppermost strata of the formation in this region. These new radiometric data also demonstrate that primary volcanic ash was indeed a part of the input to the formation.

Lithostratigraphic correlations within southeastern Wyoming were demonstrated to be valid. Previously suggested long-distance temporal correlations, however, including those based on a regional change in clay mineralogy, were shown to be unreliable. Fossil fern spores from the uppermost Morrison Formation in southeastern Wyoming were identified that may be indicative of an Early Cretaceous age. Complications exist, however, with biostratigraphic zonation using palynomorphs that may render them ineffective for age determinations in the Late Jurassic and Early Cretaceous. Also, several studies that use biostratigraphic data to constrain the age of the Morrison Formation were shown to be flawed. In addition, the age range obtained in this study shows that the mammalian faunas of Quarry 9 at Como Bluff and the Purbeck Group of southern England were most likely diachronous.

This study concludes that although local correlations within the Morrison Formation probably are reliable, until precise radiometric dates can be obtained across the depositional area paleontologists and stratigraphers need to be extremely cautious in attempting long-distance correlations. Once a radiometrically based stratigraphic framework for the entire formation is established, workers can then place the biostratigraphic data into context and make useful comparisons both within the formation and worldwide.

11:30 **Tykoski, R.:** ONTOGENETIC STAGE ASSESSMENT AND THE POSITION OF COELOPHYSOIDEA WITHIN BASAL THEROPODA

TYKOSKI, Ronald, Univ. of Texas At Austin Vertebrate Paleontology Lab, Austin, TX

Recent analyses of basal theropod phylogeny benefited from greatly increased taxonomic and character sampling. The resulting hypotheses found Ceratosauria was paraphyletic in its traditional sense, and placed Coelophysoidea basal to Ceratosauria + Tetanurae. However, the analyses did not address the impact of the ontogenetic stage of pertinent coelophysoid specimens on character scoring. Instead, all taxa were treated as if they were known from adult specimens, or characters were selectively deleted *a priori* when deemed too ontogenetically variable.

I employ a method to estimate ontogenetic stage of individual specimens of multiple coelophysoid taxa. A character-specimen matrix is created to find the most parsimonious hierarchy of specimens

based upon shared ontogenetic transformations. The resulting ontogram depicts the degree of specimens' ontogenetic development relative to other specimens of their own and closely related taxa. Juvenile, sub-adult, and adult stages are recognized by natural breaks on the ontogram, and sequences of ontogenetic transformations are mapped relative to one another. This technique is suitable for any clade of closely related taxa likely to share similar ontogenetic pathways.

Coelophysoid specimens were re-examined, and data from new specimens were incorporated into an analysis of basal theropod phylogeny in which results of the ontogenetic analysis were applied to character scoring. In one test, characters expressed only late in ontogeny were treated as missing data in taxa known only from pre-adult specimens. The resulting hypothesis strongly supports inclusion of Coelophysoidea within Ceratosauria. The removal of late ontogeny-dependent characters resulted in the exclusion of Coelophysoidea from Ceratosauria. This suggests that accurate assessment of a specimen's ontogenetic stage is vital to phylogeny reconstruction, and *a priori* deletion of ontogeny-dependent characters is detrimental to obtaining accurate phylogenetic hypotheses.

11:45 **Wedel, M.:** SKELETAL PNEUMATICITY IN SAURISCHIAN DINOSAURS AND ITS IMPLICATIONS FOR MASS ESTIMATES

WEDEL, Mathew, Univ. of California, Berkeley, CA

The vertebrae of most sauropods and theropods have large foramina that lead to internal chambers. In life, these chambers housed pneumatic diverticula similar to those of birds. Many authors have commented on the weight-saving construction of saurischian vertebrae, but no one has quantified how much mass was saved by skeletal pneumatization. To determine the volume of air in pneumatic vertebrae of sauropods and theropods, I analyzed cross-sections from CT scans and photographs of cut specimens. I propose the Air Space Proportion (ASP) as a measure of the proportional volume of air in pneumatic bones. The ASPs of a large sample of sauropod and theropod vertebrae range from 0.32 to 0.89, with a mean of 0.60. This means that, on average, air occupied more than half of the volume of pneumatic saurischian vertebrae. Three other features of the ASP values are noteworthy. First, these values are very similar to the range and mean of ASPs for pneumatic long bones of extant birds. Second, the brachiosaurid sauropod *Sauroposeidon* has the highest ASP values, up to a remarkable 0.89. A high ASP is an autapomorphy of *Sauroposeidon*, and may have evolved to lighten its long neck. Finally, ASPs appear to be independent of the internal complexity of the vertebrae. The mean values for all taxa other than *Sauroposeidon* fall between 0.50 and 0.60, regardless of whether their vertebrae are camerate or camellate. This indicates that the evolution of complex internal structures from simple ones involved a redistribution rather than a reduction of bony tissue within the vertebrae.

ASP data may be used to account for skeletal pneumaticity in volumetric mass estimates. In *Diplodocus* and *Tyrannosaurus*, skeletal pneumatization is calculated to have lightened the animals by 7-10%—and that does not include the extraskelatal diverticula, pulmonary air sacs, lungs, or tracheae. If all of these air reservoirs are taken into account, the specific gravities of *Diplodocus* and *Tyrannosaurus* are 0.80 and 0.82, respectively. These values are higher than published values for birds, but lower than those for squamates and crocodylians.

12:00 **Zanno, L.:** THE PECTORAL GIRDLE AND FORELIMB OF A PRIMITIVE THERIZINOSAUROID (THEROPODA: MANIRAPTORA): NEW INFORMATION ON THE PHYLOGENETICS AND EVOLUTION OF THERIZINOSAURS

ZANNO, Lindsay, Univ. of Utah Utah Museum of Natural History, Salt Lake City, UT

Recent discovery of a dense, paucispecific bonebed from the Early Cretaceous Cedar Mountain Formation, central Utah, has yielded new information on the morphology and evolution of



therizinosaurs. The site, known as the Crystal Geyser Quarry, is dominated by distarticulated remains of a new, basal therizinosauroid. Although the majority of therizinosaurs are represented by a fragmentary fossil record, portions of the pectoral girdle and forelimb are known from nine other therizinosaur taxa, making these elements some of the most useful in elucidating phylogenetic relationships. Detailed description of the pectoral girdle and forelimb of the Crystal Geyser therizinosaur provides the basis for the first species-level phylogenetic investigation of this enigmatic group to include derived members. This analysis, consisting of 32 characters arrayed among 13 taxa, posits the Crystal Geyser taxon as the most basal member of the clade yet discovered. It further supports a monophyletic Therizinosaurioidea on the basis of seven unambiguous synapomorphies. Contrary to previous hypotheses, this analysis suggests that Therizinosauridae is more appropriately defined as the derived clade including *Nothronychus*, *Erlicosaurus*, *Neimongosaurus*, *Therizinosaurus*, and *Segnosaurus*. Equally strong support is recovered for a clade containing these five genera plus '*Alectrosaurus*' and *Erliansaurus*.

The sequence of character development in the pectoral girdle and forelimb throughout the evolutionary history of therizinosaurs illustrates a number of structural modifications likely corresponding to the loss of predatory function in derived members of the clade. The morphology of primitive therizinosauroids characterized by the Crystal Geyser taxa *Beipiaosaurus*, and *Alxasaurus* suggests that Early Cretaceous taxa already exhibited the beginnings of a trend toward increased robustness and range of motion, together with a decrease in the grasping abilities of the manus. These evolutionary trends' greatly elaborated in later, more derived forms are likely linked to a complete loss of predatory function by the Late Cretaceous, associated with the advent of exclusively herbivorous habit among these aberrant theropods.

## PREPARATOR'S SYMPOSIUM GOVERNOR'S SQUARE 14

**CONVENORS: MARILYN FOX, BRYAN SMALL AND GREGORY W. BROWN**

8:15 **Madsen, S. and Hopwood, R.: THE PODROCKER—A KINDER, GENTLER WAY TO FLIP  
LARGE BLOCKS**

MADSEN, Scott, Dinosaur National Monument, Jensen, UT; HOPWOOD, Ronald, Lady Lake, FL;  
GRAY, Dale, USFS, Vernal, UT

Flipping very large blocks in the field often presents difficulties. This talk examines the problems and solutions encountered in a very complicated excavation at Dinosaur National Monument. The 2-plus ton block was situated on a 70 degree bedding plane on the flank of an extremely steep ravine with no solid anchor points on the slope above. Due to rugged terrain, use of heavy equipment was out of the question. The block had to be rotated over onto a very narrow and unstable shelf in a controlled fashion without crushing the delicate bone on the top side of the block or causing the block itself to bear any weight, and be made airworthy for later transport. The PODROCKER, a structurally stable bed with a curved underside and flat top surface (like a cylinder bisected across its long axis) was devised. Built in place with the flat surface lashed to the block with ratchet straps, it allowed the jacket to be slowly rotated out (rolled) to a horizontal position with no risk of launching the specimen down the ravine. Heavy-duty pneumatic car jacks with a series of custom built wooden spacers of various lengths were used to separate and lift the block out and away from the outcrop; the PODROCKER itself held the weight of the jacket at all times. As the frame and jacket rotated out past its center of gravity, forward momentum was controlled using chain hoists and slings anchored to mobile home tie-down anchors set deep in the sediment of the slope above. Once the flat surface of the PODROCKER had come to a

horizontal position, eye-bolt anchor points for the slings on the PODROCKER could be reversed for use with a helicopter; the total weight of the jacket and PODROCKER frame was nearly 5700lb. This concept can be easily modified to fit many scenarios but is probably best suited for blocks lying on steep bedding planes.

8:30 **Fremd, T., Smith, M., Foss, S. and Dunn, R.:** A NEW PALEONTOLOGICAL RESEARCH AND CURATION FACILITY AT JOHN DAY FOSSIL BEDS NATIONAL MONUMENT, OREGON, PART III: BRINGING ENTOMBED BIOTAS TO LIFE

FREMD, Theodore, SMITH, Matt, FOSS, Scott, DUNN, Regan, National Park Service, Kimberly, OR

The Thomas Condon Paleontology Center (TCPC) was built to serve many research, laboratory, and curatorial purposes. Throughout the design of this facility, emphasis was placed on enabling public understanding of the scientific process and associated documentation in a field setting. The final phase of planning this research center involved exhibit development for the primary public areas, which include a spacious lobby with viewable laboratory, accession, and curatorial storage as well as a classroom, theatre, and a dedicated exhibit “gallery.” The temporally extensive paleontological resources preserved at the John Day Fossil Beds will be presented in a series of eight time “slices” using data from important localities spaced roughly 5 million years apart. We constructed and described scenes for 8 artistic renditions, taking features such as cardinal direction, season, time of day, vegetation, landscape, animal occurrence and behavior into account. These descriptions and initial sketches were then subjected to a formal peer review process by 35 specialists. Critiques in this process of converting raw scientific data into rich, detailed depictions have run the gamut from questions of dispersal mechanisms of pyroclastic flows, landscape morphology, and appearances of plant communities to detailed anatomical and behavioral reconstructions of members of extinct mammalian clades. The associated exhibit cases for each of the 8 time slices have been constructed atop and/or within very large rock casts taken from molds made at actual John Day Basin field localities that epitomize the interval. An additional space in the gallery will house summary exhibits concerning the significance of our paleontological discoveries to topics such as co-evolution, adaptation, phylogenetic reconstructions, and climate change. Within the lobby, other topics to be featured in individual cases are fossilization, radiometric dating, biostratigraphy, paleosols, taphonomy, and interagency land management. Additional displays with explanations of fieldwork, laboratory preparation, and curation and will serve importantly in the understanding of ongoing paleontological research.

8:45 **Fox, M., Yarborough Fitzgerald, V.:** A REVIEW OF VERTEBRATE FOSSIL SUPPORT SYSTEMS

FOX, Marilyn, YARBOROUGH FITZGERALD, Vicki, Yale Peabody Museum of Natural History, New Haven, CT

Proper storage of paleontological specimens is as important to their long-term usefulness as is good preparation. One aspect of proper storage is adequate support for fossil bones, which although they may appear strong lack the internal strength of living bone. Fossil bone can and does break under its own weight without external support. This can include support for specimens stored within specimen trays, as well as for those large or fragile specimens that require more elaborate bedding jackets. For smaller specimens within trays support is often polyethylene foam cut to fit the bone. Bedding or storage jackets for large bones are generally plaster and fiberglass or resin and fiberglass with additional supports of either metal pipe or wood. This presentation offers a review of currently practiced storage support methods, and reviews their advantages and disadvantages.

9:00 **Masek, R.:** CARVING MISSING BONES IN RIGID URETHANE FOAM

MASEK, Robert, Univ. of Chicago, Chicago, IL

Reconstructing missing bones, or parts of bones, is the most time consuming and expensive operation when mounting or restoring fossil vertebrate skeletons. Most skeletons are only partially preserved or are composed of individuals of various sizes. A wood carving machine designed for reproducing or reversing sculpting or plaques in non-castable material such as wood, can be used to quickly reproduce or reverse bones in rigid urethane foam. If your sculpting skills are less than desirable, this machine might be what you are looking for. The wood carving machine was used with excellent results to reproduce the missing wing bones of an African pterosaur.

9:15 **Groenke, J.:** MAKING BIGGER BETTER: A LOW-COST, TIME-SAVING ALTERNATIVE FOR CREATING DIMENSIONALLY ACCURATE CASTS 120-160% OF ORIGINAL SIZE

GROENKE, Joseph, Stony Brook Univ., Dept of Anatomical Sciences, Stony Brook, NY

The theropod *Majungatholus*, the sauropod *Rapetosaurus*, the crocodyliform *Mahajangasuchus* and other taxa from the Late Cretaceous of Madagascar consist of associated juvenile postcranial remains, and associated adult cranial remains ~25-35% larger in proportion; 3D reconstructions are thus difficult. I used the expanding urethane product Hydrospon with fillers as an effective cost- and time-saving alternative to sculpting or rapid-prototyping the postcranial elements. Casts of 100% Hydrospon expand with high dimensional accuracy and surface detail to 160% of original specimen size. Because expansion itself is non-uniform until maximum size is attained, I tested five fillers at varying concentrations to determine if dimensionally accurate expansions of less than 160% were possible.

Accurate expansions of ~120-160% of original specimen size were achieved. Fillers varied in their ability to maintain dimensional accuracy and in their effective minimum expansion. The best fits for predicting expansion based upon the ratio of g filler:100g Hydrospon were with the air abrasive product CarboBlast ( $R^2=0.98$ ,  $n=5$ ) and Nytal 300 brand talc ( $R^2=0.95$ ,  $n=2$ ). Tests with wheat gluten ( $n=2$ ), plaster ( $n=6$ ) and aluminum oxide ( $n=6$ ) also yielded acceptable correlations ( $R^2=0.83-0.93$ ), but had minimum expansions above the target of 125-135%. Regression equations predict that 4.436g of CarboBlast is required per 100g of Hydrospon for each percentage unit decrease between 160-137%; 4.427g of Nytal 300 is required between 160-129%.

High concentrations of filler thicken overall consistency. Mixtures approaching saturation are difficult to stir or manipulate, and must be applied to silicone molds with a spatula rather than brushed or poured. Filler concentration can be varied throughout a given cast if differential expansion simulating allometry is desired. Precision of expansion is not equal to that of rapid-prototyping or sculpting. Even with high filler concentrations Hydrospon maintains superb detail, providing a realistic look to expanded casts that is difficult to rival with rapid-prototyping or with sculpting.

9:30 **Keillor, T.:** A DINOSAUR FLESH-MODEL RECONSTRUCTION: REFERENCE MATERIALS AND TECHNIQUES

KEILLOR, Tyler, Brookfield, IL

The flesh reconstruction of a dinosaur bust at the University of Chicago Dinosaur Lab was facilitated by abundant reference material, and the tools and materials to take an idea from concept to reality.

The original fossil material of a new theropod was prepared at the lab, and the subsequent skull reconstruction served as the armature for the flesh model sculpture. The look of keratinous skin was explored based on skull texture. Access to the bird and reptile collections at the Field Museum in Chicago provided comparative reference material. Comparative reference was an essential aid to visualize the relationship between bone and overlying soft tissue structures. Searches of the World Wide

Web provided additional comparative reference images and information, as did several prominent paleoartists. Careful consideration of living forms tempered the modeling of the plasticene clay head.

The finished sculpture was covered in its entirety with layers of silicone rubber. Dividing walls were avoided altogether, as the finished rubber mold was cut open in sections with a keyed mold knife. A mother mold was made with a quick-setting, thixotropic polyurethane paste. The molding technique yields a nearly seamless cast. Dental acrylic was cast into the tooth impressions of the mold. Translucent polyurethane was cast into the rest of the head. The polyurethane was pigmented in small batches, and brushed into the mold to pre-paint the cast with intrinsic coloration. The translucency of the material is particularly effective to reproduce lifelike keratinous tissue, and soft tissue of the mouth. The head was backfilled with rigid polyurethane foam. Glass eyes were set in place, and acrylic paints used for the final coloration.

While the opportunity to see a discovery through from fossil to flesh-model does not present itself often, the fabrication of a life reconstruction is an important method to engage, inform, and inspire the public.

9:45 **BREAK**

10:00 **Person, J.:** A POWERFUL TOOL FOR PHYLOGENETIC SEARCHING AND HIERARCHICAL ORGANIZING

PERSON, Jeff, Oklahoma Museum of Natural History, Univ. of Oklahoma, Norman, OK

A new numbering system, separate from the specimen numbers, called Pnumbers, used for phylogenetic searching and hierarchical organizing, is introduced and explained. The Pnumber is a large, nested numeric code, tied to Linnaean taxa and categories, that assigns a number to each level of identification from the class to genus level. The Pnumber is a coding system for enhancing the power of data retrieval. The Pnumber system allows for both broad and specific hierarchical taxonomic searches of the database and also allows for hierarchical taxonomic sorting. The Pnumbers are generated through an authority file initially based on the appendix in Robert Carroll's book, *Vertebrate Paleontology and Evolution*. The authority file at the Oklahoma Museum of Natural History is the only one of its kind, in that it includes all the classes of vertebrates, and allows for easy addition or subtraction of taxa. The Pnumber system has been in use at the Oklahoma Museum of Natural History since 1988.

10:15 **Davidson, A.:** LIQUID TO SOLID AND BACK: PHASE CHANGE IN ADHESIVES

DAVIDSON, Amy, American Museum of Natural History, New York, NY

All adhesives used in fossil preparation are applied as flowing liquids which set into solids, but through different setting mechanisms. Some solid adhesives can be made to flow again. A basic understanding of phase-change behavior on a molecular level enables the preparator to define the behavior they want for a particular specimen, and to choose the most appropriate adhesive.

This paper will present a basic introduction to solution, reaction and melt/freeze setting mechanisms. Gross behavior during phase change such as set time, solvent retention, shrinkage, expansion, migration, exothermy, resolubility and swelling, cold-flow and the relationship between adhesion and cohesion will be linked to inter and intra-molecular bonding. Specific specimens with different phase-change behavior requirements will be presented as illustrations of the adhesive selection process.

10:30 **Brown, G.:** CYCLODODECANE: VANISHING SUPPORT FOR THE PREPARATION LABORATORY

BROWN, Gregory, Univ. of Nebraska State Museum, Lincoln, NE

Providing temporary support for specimens during preparation is critically important. For relatively robust macrofossils, traditional methods employing separators and plaster bandages or reinforced resins work well, however such methods are generally not appropriate for delicate microfossils. Partial embedment in polyethylene glycol (PEG or Carbowax) is often used to provide such support for microfossils, but not without cost. Although PEG has a low melting point and is water soluble, complete removal from the specimen after preparation is often difficult or impossible, and any residue can severely limit the effectiveness of subsequent consolidation or adhesion.

Cyclododecane (CDD) is another low melting-point waxy hydrocarbon with distinctive properties that make it an especially attractive alternative to PEG for microfossil support, as well as a host of other applications in the preparation laboratory. Principle among these properties is the ability of CDD to sublime completely over time at room temperature, essentially eliminating the primary drawback of PEG.

As a temporary support for micro-prep, a specimen can be partially embedded in melted CDD in a suitable tray or container. When cooled, CDD returns to its solid state, allowing the specimen to be safely held and supported during preparation. The ability of CDD to sublime not only in air but also by diffusion through the specimen makes post-prep removal especially easy and safe while exposing the specimen to minimal physical jeopardy. Solubility properties of CDD also limit unwanted interactions with commonly used consolidants. Where a thin film is required, CDD can also be applied as a saturated solution in an appropriate solvent.

Other applications for cyclododecane include its use as a temporary backing for thin or comminuted bone in the lab or in the field, a temporary sealant for openings and exposed cellular bone during molding, and a temporary vibration-dampening consolidant during aircast preparation.

Although not known to be particularly toxic, as with all chemicals, always know and follow MSDS handling recommendations.

10:45 **Williamson, L., Arenstein, R., Carroll, N., French, J. and McGrew, A.:** PRACTICAL TIPS FOR THE APPLICATION OF CYCLODODECANE AND CREATING QUICK, FUNCTIONAL STORAGE SUPPORTS

WILLIAMSON, Leslie, ARENSTEIN, Rachael, CARROLL, Norine, FRENCH, Jennifer, MCGREW, Angela, National Museum of the American Indian, New York, NY

The National Museum of the American Indian has recently completed a five-year Collections Move Project in which 800,000 objects have been successfully moved from the old storage and research facility in the Bronx, NY and re-housed at the new Cultural Resources Center in Suitland, MD. This short video presentation was created by NMAI Move Project Conservation staff for the Object Specialty Group Tips Session at the 2003 American Institute for Conservation Conference. The theme of the OSG session was "Creativity in Conservation" and so we modeled our presentation on the doyenne of creativity, Martha Stewart. The first section presents tips on application techniques for cyclododecane and the second section includes techniques for making some quick and easy supports for object storage. We chose a video format as no one really wanted to stand in front of a room of 300 people with molten wax and sharp knives!

Cyclododecane (a cyclic alkane hydrocarbon C<sub>12</sub>H<sub>24</sub>) is a wax-like substance that passes from a solid state directly to a vapor at room temperature, disappearing and leaving virtually no trace. The ability of this material to sublime has led to its increasing use in the field of art and artifact conservation to temporarily stabilize objects for treatment and transport. Cyclododecane's properties also suggest great potential for use on vertebrate fossils as an alternative material for temporary

backings and fills, consolidation and mold making. The substance cools quickly however, making its application a challenge, which is hopefully ameliorated through these tips.

The section on rehousing focuses on the construction of supports for archaeological or ethnographic artifacts but these materials and techniques could be easily adapted for use in storing paleontological specimens.

Accompanying handouts with detailed information on technique and materials are available in PDF format to download on the AIC-OSG website in the Information section under Tips and Treatments. Copies of the video are also available for loan through the AIC-OSG lending library.

## 11:00 ROUND TABLE DISCUSSION AND CYCLODODECANE WORKSHOP

### POSTERS ASSOCIATED WITH PREPARATOR'S SYMPOSIUM

(Authors will be present from 11:00-12:15)

#### Booth

- Pierce, M., Rinehart, L., Heckert, A., Lucas, S. and Hunt, A.: ROTATION OF AN UPPER TRIASSIC GHOST RANCH, NEW MEXICO WHITAKER (COELOPHYSIS) QUARRY BLOCK: TURNING OVER A FRAGILE 12,000 LB ROCK**  
PIERCE, Michael, RINEHART, Larry, HECKERT, Andrew, LUCAS, Spencer, HUNT, Adrian, New Mexico Museum of Natural History, Albuquerque, NM  
New Mexico Museum of Natural History's *Coelophysis* Quarry block C-8-82 is from the Upper Triassic Rock Point Formation of the Chinle Group at Ghost Ranch, New Mexico. Its maximum dimensions at the outset of the project were ~2 m long, ~1.4 m wide, and ~1.2 m thick. The volume was ~2 m<sup>3</sup>, and the mass was estimated as ~5,440 kg (~12,000 lb). The conglomerate and siltstone that compose the block are extremely friable, and have intersecting desiccation cracks and joints throughout. The premium fossil horizon is only ~30 cm deep in the block and the highest quality bone is located at the bottom of this horizon. Therefore, we turned the block over before preparation so the prepared fossils would reside on a 30 cm-thick slab, rather than a nearly 1 m-thick boulder, and so the best of the material would be most readily exposed.  
We describe here the design, construction, and use of a large wooden rocker to gently roll the block 180 degrees. Material costs for the rocker were under \$300. Jacks, nylon ratchet-straps, and an electric winch constituted the balance of the hardware already available at NMMNH. Analysis of nonconcurrent forces, rolling resistance, traction, material strengths, and minimization of vibration and flexing of the specimen were essential to the successful roll. The block was rolled on a time scale of less than 1 minute with no damage to its jacket or contents. Time invested in the project totaled 100 hours.
- Hanley, G.: PORTABLE ALUMINUM SCREEN TABLE FOR USE IN REMOTE PALEONTOLOGICAL AND ARCHAEOLOGICAL EXCAVATION SITES**  
HANLEY, Guy, Minot State Univ., Minot, ND  
A screen table designed to be used at remote excavation sites was recently constructed at the Cyril Moore Science Center of Minot State University and utilized by an Antarctic research team during the 2003 field season. The entire table needed to be light enough to be carried to remote locations by backpack, be extremely durable for use in harsh environmental conditions, be usable for either dry or wet screening, and be easily assembled and operated by individuals wearing parkas and gloves. Aluminum sheet was fabricated into two rectangular, open bottom enclosures, one able to be nested

inside the other. One enclosure was fitted with stainless steel mesh with an approximate sieve size of 20 mm. The second enclosure was fitted with stainless steel screen with a 4 mm mesh. This second enclosure also has attachments for pivoting front legs, stationary rear legs, and handles large enough to accommodate gloved hands. Legs and handles were fabricated from 1 inch (2.54 mm) square tube stock. A flexible nylon screen with 1 mm mesh was added to allow recovery of small fossils. This screen was provided with aluminum handles to allow removal of washed matrix and replacement screening was included in a roll within the leg assembly. When disassembled, all parts including tools for assembly, fit within the two enclosures, forming a large briefcase sized object of approximately 45 pounds (20 kg) in weight. Design and fabrication was completed by Guy A. Hanley, Curator of Collections at the Cyril Moore Science Center.

3. **Silva, H. and Kellner, A.: USING POLYESTER RESIN IN THE FIELD TO RECOVER FRAGMENTARY SPECIMENS**

SILVA, Helder, KELLNER, Alexander, Museu Nacional/UFRJ, Rio de Janeiro, Brazil

Quite frequently a fossil vertebrate is found by parts of the skeleton eroding at the surface. In several cases those bones are too damaged to support the stresses involved in the collecting and transportation processes. Not uncommon they are left in the field or lost due to their fragility. Here we describe a simple procedure that can be used in the field to recover badly damaged fossils. We have applied this procedure with great success on a sauropod dinosaur femur collected at the Confusao site (municipality of Tesouro), a new locality recently discovered in the state of Mato Grosso. The material was preserved in a conglomerate that is correlated to the Bauru Group. The femur (MN 6813-V) is approximately 110cm long and had the distal half partially exposed due to the periodical flooding of the Confusao river. It has a developed lateral bulge which is regarded a titanosauriform feature. The distal portion including the articulation, was preserved mostly as an impression in the rock, together with some parts of the cortex. This portion of the femur was too friable to be collected as one piece. After a general cleaning of the surface we covered the fragile portions of the distal part of the femur (including the impression) with several thin layers of polyester resin that were gently applied with a brush. We used 0.75% of methyl ethyl ketone catalyst in the polyester resin and wait until each layer was slowly cured. Subsequently one thick resin layer with gauze was used in order to make this region more resistant and strong enough to hold itself. The remaining part of the collecting process followed the traditional procedures, including the use of plaster for the jacket. Among the factors to be paid particular attention during the application of this procedure is the proportion of the catalyst, since the polymerization process may result in expansion or contraction of the resin, that could ultimately damage the fossil. The fractures present on the bone surface have to be evaluated too, since they might allow the penetration of the resin in the surrounding rock. In the later case the excess of the resin will have to be removed during the preparation process.

4. **Mullison, C. F.: FOSSIL PREPARATION WORKBENCH ERGONOMICS AND MICROSCOPE OBJECTIVE LENS FOCAL LENGTH**

MULLISON, C. Frederick, Academy of Natural Sciences, Philadelphia, PA

Changing the seating position of the Microscope Fossil Preparator by increasing the working distance between the eyes and hands can help address existing repetitive stress injuries and perhaps even retard their onset. A 200mm (surgery) lens doubles the lens to subject distance over the 100mm standard lens. Longer microscope objective lens focal lengths necessitate changes in the height and layout of the fossil preparation workbench.

5. **Potapova, O.:** CONSERVATION AND RESTORATION OF A 26,000 YEARS OLD COLUMBIAN MAMMOTH *MAMMUTHUS COLUMBI* (FALCONER), 1857) TUSK FROM THE MAMMOTH SITE, SOUTH DAKOTA

POTAPOVA, Olga, The Hot Springs Mammoth Site, Inc., Hot Springs, SD

The complete Columbian mammoth tusk was discovered at the Mammoth Site in 1978, when the excavation crew worked in the northeast part of the sinkhole under the supervision of the Dr. Larry Agenbroad. Due to lack of storage, the tusk was stabilized on its surface, plaster jacketed, and placed into backfill in the northeast area of the Bone Bed.

In 2003, the jacketed tusk, which exceeded nine feet (301.4 cm) in length, was removed from the backfill for restoration in the Laboratory and subsequent exhibit.

The tusk (78-089) demonstrated a high level of deterioration and had three 2 to 5 inches gaps in plaster jacket filled with broken fragments. The socket remained intact and was filled with 15 lb solid calcium-carbonated matrix. About 75% of the tusk surface was covered by soft sediment. The restoration started from cleaning soft and calcium-carbonated sediments from the surface. The upper part of the plaster jacket was carefully removed, as were broken fragments of ivory. When cleaned, the preservative Butvar 98/Ethanol was applied to the surface, which appeared to be slightly moist and needed to be sealed. This allowed the tusk to dry out gradually without shrinking and destroying the surface layers of dentin. Some places of the tusk surface were in extremely poor condition and were stabilized by using Paleo Bond Penetrant (PB002). After the drying process, the Paleo Bond stabilizer was completely removed from the surface using acetone, and the tusk was covered by two layers of Butvar 98/Ethanol.

Gaps in the tusk caused by fragmentation were filled with liquid plastic (Smooth Cast 320), and reinforced with oak and polyurethane foam sticks for structural support. Metal rods were used to support the tusk's tip. Ivory fragments were placed on the newly reconstructed surfaces. Cracks were filled with Paleo Sculp and Paleo Poxy materials. The rotten places of the old plaster jacket were thinned and reinforced with new materials (burlap with plaster of Paris, and Scotchcast Plus bandages). Nine staff members, volunteers and intern students devoted 350 hours to complete the tusk preparation.

6. **Bader, K. and Burnham, D.:** PRODUCTION OF A LIGHTWEIGHT DISPLAY OF THE DEVIL'S CORKSCREW

BADER, Kenneth, BURNHAM, David, Univ. of Kansas, Lawrence, KS

The Devil's Corkscrew (*Daimonelix*) is the common name for bizarre spiraled structures found in the Miocene deposits of western Nebraska. These large burrows, with depths up to 3 meters and diameters up to 15 centimeters, are known to contain skeletons of the fossorial beaver, *Paleocastor fossor*. *Daimonelix* are showcased at the University of Kansas Natural History Museum and have been the subject of scientific interest since their discovery in the 1892. At the request of another institution, a three-dimensional panel-mounted cast of the *Daimonelix* was recently produced from a composite of several specimens. A unique method was used to solve the problems of weight and assembly of the large casts. This method also produced highly detailed casts of the burrow and *in situ* skull of the beaver. The burrow was molded in five segments using a combination of silicone products. Two layers of polyurethane plastic were brushed into the mold resulting in a thin, outer shell. Urethane foam with a density of 15 pounds per cubic foot was poured and allowed to expand filling the shell. The resulting segments were interlocked with metal pins and textured epoxy putty was used to fill the seams. Finally, matrix from the original burrow locality was glued to the surface of the cast and a hand-painted cast of a *Paleocastor* skull from another burrow was inserted into the cast of the living chamber. This lightweight



mount was supported with plywood backing and the bottom coil was used as a footing. The resulting cast was readily assembled offsite and could be easily transported for use in public displays.

7. **Young, J., Jabo, S., Kroehler, P. and Carrano, M.:** CONSERVATION AND REMOUNTING OF THE SMITHSONIAN'S *STEGOSAURUS STENOPS* EXHIBIT, USNM 8612

YOUNG, Jennifer, JABO, Steven, KROEHLER, Peter, CARRANO, Matthew, Smithsonian Institution, Washington, DC

A survey of the Dinosaur Hall at the Smithsonian's Natural History museum identified several vertebrate exhibit mounts in need of conservation. Antiquated mounting techniques, had combined with heat, humidity and the high traffic flow of visitors in the hall to create an unstable environment for some of our inherently fragile specimens. In an ongoing effort to protect and restore these display fossils, Triceratops was restored in 2001, and Stegosaurus stenops (USNM 8612) was removed from exhibit in Spring 2002.

The mount, created by Charles Gilmore 85 years ago, had the bones resting in direct contact with their metal armature, commonly attached by screws drilled directly into the elements. Deterioration of the fossils was marked by bone fragments frequently found on the floor under the mount, broken bones held together solely by their armature, and repairs documenting multiple breaks in many bones. Upon removal from exhibit, each bone was repaired, restored, molded, and cast. Experiments with different materials led to new molding techniques. In addition to replicating the existing elements, preparators sculpted, molded, and cast throat ossicles missing from the original mount. Hollow hydrocal gypsum cement casts, reinforced with fiberglass cloth were filled with 8-pound expanding foam and remounted with an internal armature in June 2003. This new mount is not only more anatomically accurate than its predecessor, but more responsive to its display environment. Stegosaurus is now posed in a reactive stance in front of our *Allosaurus*, which now seems prepared to attack.

Once the bones were molded, they were returned to the collections where they are being fit into custom padded jackets. All of the dermal plates that would not fit into padded drawers are now cradled. These conservation efforts provide protection as well as added accessibility to research staff and visitors and we are now focused on rehabilitating our *Camptosaurus* specimens.

8. **Cunningham, D., Gedeon, A. and Houle, M.:** THE RESOLUTION OF PROBLEMS INVOLVED IN THE CONSTRUCTION OF A *POSTOSUCHUS KIRKPATRICKI* MOUNT

CUNNINGHAM, Doug, GEDEON, Andrew, HOULE, Matthew, Museum of Texas Tech Univ., Lubbock, TX

There were numerous problems encountered in combining casts of *Postosuchus kirkpatricki* from four different sources to create an accurate, full size mount for the new paleontology exhibit at the Museum of Texas Tech University. A portion of the pelvis was from a specimen from the University of Michigan Museum of Paleontology; the forelimbs, pes, and the manus were from the University of North Carolina, Charlotte; the majority of the remaining post-cranial material was from the Petrified Forest National Park; and the skull and other parts were from the holotype at the Museum of Texas Tech University. The design of the display case, differences in sizes of the material, and design of the pose required versatility in the construction of the mounted cast.

Lengthening, shortening, thickening, and thinning of various parts, such as the pubis and humeri, was necessary to create a specimen where all the parts were of matching size. These modifications were done using a variety of epoxies, tools, techniques, and reference specimens. The use of an epoxy resin that could be heated and manipulated allowed modification of cast specimens to correct for the

distortion of the original specimen. It also allowed for fine-tuning the orientation and articulation of various parts.

The prefabrication of the display case required the design of a mounting system that would allow the cast to be installed after the case was completed. Articulating the mount was accomplished using an armature that allowed installation to a base that was installed during prefabrication. The design of the armature was adapted and modified to accommodate the pose that was desired. A variety of tools proved to be very important in the articulation and mounting of the specimen. These modifications allowed the creation of the most accurate mounted cast of *Postosuchus* to date.

9. **Hand, S., Clark, J., Beard, C. and McDaniel, J.:** MEASUREMENT OF THE HOLOTYPE SKELETON OF *TYRANNOSAURUS REX* USING COHERENT LASER RADAR ACHIEVING SUB-MILLIMETER RESULTS

HAND, Steven, CLARK, James, Maglev, Inc., McKeesport, PA; BEARD, Christopher, Carnegie Museum of Natural History, Pittsburgh, PA; McDANIEL, Jeffrey, ExtrudeHone, Irwin, PA

The holotype skeleton of *Tyrannosaurus rex* is precisely measured in place at Carnegie Museum of Natural History, using two networked Coherent Laser Radar systems resulting in micron level accuracies. The generation of four and a half million point measurements into a point cloud is the first step in digitizing and 3D modeling the full size exhibit and its individual components. These models are then used for dimensional analysis, animation (using inverse kinematics to set degrees of freedom in joints) and replication in any scale (either direct or inverse) for solid free-form or mold generation using 3D printing technology. These activities are described in detail along with discussion of the successes and restrictions encountered during this work.

10. **Southward, J., Crawford, M. A., and Jones, C.:** POSSIBLE SOLUTIONS FOR PALEONTOLOGY COLLECTIONS STORAGE: CUSTOM-FITTED MOUNTS AND MATERIALS

SOUTHWARD, Jude, Denver Museum of Nature & Science, Denver, CO; CRAWFORD, MA, Matthew Crawford Art Conservation Studio, Ft. Collins, CO; JONES, Cheri, Denver Zoological Association, Denver, CO

This paper will focus on the design of custom-fitted mounts and materials that may be appropriate for the storage of Paleontology collections. The Denver Museum of Nature & Science (DMNS) received grant funds during 1998 to 2000 from the Institute of Museum and Library Services to provide optimum storage conditions for oversize osteology specimens in the mammal collection of the Zoology Department. The specimens included oversize bison skulls, marine mammal skulls, and the skeletal material of large game animals collected in Botswana during a field expedition in 1969. One of the main project activities was the building of custom-fitted mounts for specimens.

The overall objective in designing the mounts was to improve protected access to the specimens, while at the same time moving away from the use of wood and wood products that are prone to off-gassing volatile organic compounds. Additionally, since many of the specimens are heavy, another major objective was to design mounts that would be lightweight and easy for staff and volunteers to handle for routine monitoring of object condition. The mounts also needed to be streamlined to reduce overcrowding and be comprised of materials that could easily be fabricated using in-house expertise and tools. The custom-fitted mounts designed for the Osteology specimens may also be appropriate for Paleontology collections. The materials selected for the custom-fitted mounts include twin-walled corrugated polycarbonate sheet, high-density polyethylene sheet, recycled high-density polyethylene non-reinforced lumber, polyethylene foam, and Tyvek sheeting.

11. **Mawyin, C., Groenke, J., Boyer, D. and Bloch, J.:** NOVEL USE FOR CYCLODODECANE IN ACID PREPARATION OF RECENTLY RECOVERED PALEOCENE LIMESTONES FROM THE WESTERN CRAZY MOUNTAINS BASIN, MONTANA

MAWYIN, Cristina, GROENKE, Joe, BOYER, Doug, Stony Brook University, Stony Brook, NY; BLOCH, Jonathan, University of Florida, Gainesville, FL

In 2003, field expeditions to south-central Montana recovered fossiliferous Paleocene limestones from several localities. Intensive processing of these deposits at Stony Brook University's fossil preparation lab is beginning to reveal a diverse microfauna including reptiles and mammals. Further, elements recovered from these limestones frequently represent parts of associated or articulated skeletons, giving these deposits the potential to contribute data on composition of Paleocene faunas and skeletal structure of preserved taxa.

Here we report on a novel utilization of cyclododecane in the formic acid preparation of these discrete limestone blocks. Surface cracks in bone and matrix can be treated with plastic, but heterogeneity in matrix composition often results in extensive subsurface fissuring. These cracks can cause blocks to fractionate, threatening associations of skeletal elements and allowing acid to etch subsurface bone not readily protected by plastic. Heated, liquid cyclododecane delivered with pipettes has a viscosity suitable to fill subsurface areas prior to cooling and hardening. Hydrophobic and non-reactive in acid, it provides an effective bulk filler to prevent expansion of cracks, and thus restricts etching to the surface of the block. Room temperature sublimation makes cyclododecane superior to other fillers, which must be mechanically removed after preparation. Slow sublimation limits loss between acid runs, but periodic reapplication is required as acid makes new cracks and attacks contacts between cyclododecane and matrix. We have also used cyclododecane to fill areas where etching beneath exposed surface bone has occurred, thus maintaining positional information of skeletal elements until removal is desired. A lowered risk of damage or etching and better preservation of associations translates into more confident and refined analyses of the recovered skeletal material.

12. **Arenstein, R., Davidson, A. and Kronthal, L.:** AN INVESTIGATION OF CYCLODODECANE FOR MOLDING FOSSIL SPECIMENS

ARENSTEIN, Rachael, National Museum of the American Indian, Bronx, NY; DAVIDSON, Amy, American Museum of Natural History, New York, NY; KRONTHAL, Lisa, American Museum of Natural History, New York, NY

Cyclododecane (a cyclic alkane hydrocarbon  $C_{12}H_{24}$ ) is a wax-like substance that passes from a solid state directly to a vapor at room temperature, disappearing and leaving virtually no trace. The ability of this material to sublime has led to its increasing use in the field of art and artifact conservation to temporarily stabilize objects for treatment and transport. This poster will provide a basic introduction to cyclododecane including its physical properties, health and safety issues and a synopsis of its use on museum artifacts.

Cyclododecane's properties also suggest great potential for use on vertebrate fossils as an alternative material for temporary backings and fills, consolidation and mold making. Conservators and Fossil Preparators together focused on the potential uses of cyclododecane for molding as a:

1. Thin barrier coating that functions as a separating layer
2. Fill to prevent silicone penetration into deep voids
3. Temporary consolidant for porous matrix
4. Dam to contain the silicone or isolate areas for spot molding

The rate of sublimation for samples mixed with several different bulking agents as well as in solvent was also investigated.

**WEDNESDAY AFTERNOON, NOVEMBER 3, 2004**

**TECHNICAL SESSION I  
PLAZA BALLROOM A/B**

**MODERATORS: PATRICK O'CONNOR AND CHRISTINE LIPKIN**

1:30 **Erickson, G., Makovicky, P., Currie, P., Norell, M., Yerby, S. and Brochu, C.:**  
TYRANNOSAURID LIFE-HISTORY PARAMETERS AND THE EVOLUTION OF GIGANTISM IN  
*TYRANNOSAURUS*

ERICKSON, Gregory, Florida State Univ., Tallahassee, FL; MAKOVICKY, Peter, The Field Museum, Chicago, IL; CURRIE, Philip, The Royal Tyrrell Museum of Paleontology, Drumheller, AB, Canada; NORELL, Mark, The American Museum of Natural History, New York, NY; YERBY, Scott, Stanford Univ., Stanford, CA; BROCHU, Christopher, Univ. of Iowa, Iowa City, IA

How evolutionary changes in body size are brought about by variance in developmental timing and/or growth rates (aka heterochrony) is a topic of considerable interest in evolutionary biology. Notably, extreme size change leading to gigantism occurred within the Dinosauria on multiple occasions. Whether such change was brought about by accelerated growth, delayed maturity, or a combination of both processes is unknown. Increased phylogenetic resolution within non-avian dinosaur groups and the newfound capacity to reconstruct their growth curves make it possible to quantitatively address these questions. Here we studied growth patterns within the Tyrannosauridae and determined the developmental means by which the 5,000+ kg *T. rex*, came to be among the largest terrestrial carnivorous animals. Our results for *T. rex* revealed: maximal growth rates of 2.1 kg/day, skeletal maturity in two decades, and longevity up to 28 years. Comparison with data from other tyrannosaurids shows that accelerated exponential stage growth rates were the key to the great stature of *T. rex*.

1:45 **O'Connor, P.:** POSTCRANIAL PNEUMATICITY AND PULMONARY HETEROGENEITY IN ARCHOSAURS: EVOLUTION OF THE FLOW-THROUGH LUNG IN NONAVIALAN THEROPOD DINOSAURS AND BIRDS

O'CONNOR, Patrick, Ohio Univ., Athens, OH

Numerous recent studies have focused on reconstructions of dinosaurian pulmonary anatomy and possible physiological characteristics (e.g., thermoregulatory abilities) of different pulmonary designs. Pneumatic features of the postcranial skeleton, the inferred osteological correlates of pulmonary air sacs, feature prominently in some studies. In conjunction, a number of authors have hypothesized the step-wise acquisition of different components of a pulmonary air-sac system in theropod dinosaurs. In most scenarios, only derived coelurosaurs (i.e., close relatives of Avialae) possess an avian-style pulmonary apparatus that includes both cranial and caudal air sacs. The analysis of well-preserved fossil material is necessary to test these ideas and strengthen inferences related to higher-level pulmonary organization, particularly with respect to specific components of the pulmonary air-sac system.

In this study I examined the pulmonary air-sac system in extant birds, including pneumatic invasion of different portions of the postcranial skeleton, and compared these data with site-specific pneumaticity in nonavialan theropod dinosaurs. An examination of a near-complete, remarkably-preserved abelisaurid theropod dinosaur reveals unequivocal evidence of pneumatic invasion of bone. Furthermore, this

specimen provides a glimpse into the higher-level organization of the pulmonary system in theropod dinosaurs. Here I report the existence of pneumatic features throughout the entire precaudal vertebral series in *Majungatholus atopus*, indicating the presence of cervical and abdominal air sacs. This highlights a fundamental similarity of air sac organization between extant birds and noncoelurosaurian theropods, and implies the existence of the basic avian pulmonary bauplan in taxa only distantly related to birds and their maniraptoran relatives. The presence of both cranial and caudal components of an air sac system in noncoelurosaurian theropods indicates that the anatomical prerequisites of the avian flow-through lung had a lengthy history within the theropod lineage and were not limited to derived nonavian theropods and basal birds.

2:00 **Sipla, J., Georgi, J. and Forster, C.: THE SEMICIRCULAR CANALS OF DINOSAURS: TRACKING MAJOR TRANSITIONS IN LOCOMOTION**

SIPLA, Justin, GEORGI, Justin, FORSTER, Catherine, Stony Brook Univ., Stony Brook, NY

The semicircular canals are vestibular organs which register changes in angular acceleration experienced by the head. Rotations detected by the canals are integrated at the neurophysiological level with the somatosensory and proprioceptive systems, resulting in reflex stabilization of the head and visual field.

Using computed tomography, the morphology of the bony semicircular canals of dinosaurs can be assessed. Biomechanically important characteristics such as circumferential arc length and planar orientation can be measured and used to infer canal sensitivity and function. Specimens from all major dinosaur clades were analyzed and comparisons were made with extant birds and crocodiles.

We note a correlation between enlargement of the anterior semicircular canal and locomotor preference in dinosaurs. Even diverse bipedal species such as *Psittacosaurus* and *Tyrannosaurus* are found to possess vertical enlargement of the anterior semicircular canal relative to the posterior canal. Quadrupedal species ranging from *Euoplocephalus* to *Chasmosaurus* exhibit a crocodylian condition with less pronounced enlargement of anterior and posterior canal dimensions. Among advanced theropod dinosaurs such as *Dromaeosaurus*, we note vertical hyper-elongation and oblique reorientation of the anterior canal in conjunction with gross enlargement of the flocculus, a cerebellar structure responsible for integration and modulation of vestibular signals and eye position—a pattern consistently found in terrestrial birds.

We hypothesize that anterior semicircular canal expansion in dinosaurs is associated with the sensory and coordination requirements of terrestrial bipedal locomotion. The anterior semicircular canal is maximally sensitive to the detection of nose-down, vertex-up rotations in the sagittal plane, as might occur during touchdown of the hindlimbs during bipedal locomotion. Decoupling of the forelimbs from locomotion is argued to subject the head to higher-amplitude pitch rotations, reflected in improved sensitivity of the anterior semicircular canal and resultant improvements in motor integration.

2:15 **Tsuihiji, T.: THE NECK OF NON-AVIAN MANIRAPTORANS: HOW BIRD-LIKE WAS THE CERVICAL MUSCULATURE OF THE “BIRD-LIKE” THEROPODS?**

TSUIHIJI, Takanobu, Yale Univ., New Haven, CT

A highly complex musculature characterizes the avian neck. In order to infer phylogenetically when such myological features were acquired, osteological correlates of the axial muscles were identified in the cervical vertebral columns of several non-avian maniraptorans. Both plesiomorphic archosaurian and derived avian conditions are observed in dromaeosaurids and *Archaeopteryx*. For example, the Munich specimen of *Archaeopteryx* preserves a very thin, rod-like element that probably represents an atlas rib, which extant birds do not retain as a free element. Therefore, although *Archaeopteryx* is often regarded

as the oldest “bird,” its neck is not yet totally avian-like in this respect. The presence of a long, holocephalous atlas rib appears to represent an archosaurian plesiomorphy as it is found in more basal dinosaurs such as *Camarasaurus* and some ornithopods, as well as in pseudosuchians including phytosaurs. In extant crocodylians, a long and robust atlas rib serves as the origin of *m. rectus capitis lateralis* while in Aves this muscle arises from the anterior cervical centra instead. Therefore, the origin of this muscle may have changed within Dinosauria as the atlas rib became reduced, with the condition in *Archaeopteryx* possibly representing a transitional stage. On the other hand, several posterior cervical vertebrae of *Velociraptor* have a laterally-projecting process on the prezygapophysis. This process may be a homologue of the avian tuberculum ansae that serves as the origin of *m. ascendens cervicalis*, suggesting that this muscle might have already been well-developed in the posterior cervical region of this dromaeosaurid. More derived avialans such as *Hesperornis* and *Ichthyornis* may have already developed the avian-like *m. ascendens cervicalis* along the entire neck, but still lack prominent cristae lateralis, suggesting that the well-developed, interdigitating tendinous system of *mm. intertransversarii* seen in Aves may have been absent in these two taxa. These observations suggest that the derived avian conditions arose in a step-wise fashion in basal members of Maniraptora.

2:30 **Zelenitsky, D.:** A CLADISTIC ANALYSIS OF THEROPOD OOTAXA

ZELENITSKY, Darla, Univ. of Calgary, Calgary, AB, Canada; CURRIE, Philip, Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada

Close associations of skeletal remains and eggs have significantly increased our knowledge of the parentage of dinosaur eggs in the past decade. Importantly, many of these skeletal associations have been those of theropods. A cladistic analysis of ootaxa was conducted with an ingroup consisting of *Preprismatoolithus*, *Elongatoolithus*, *Macrooolithus*, *Prismatoolithus*, *Macroelongatoolithus*, *Protoceratopsidovum*, *Parvooolithus*, and eggs of extant avians. *Megaloolithus* was the outgroup. On the basis of embryonic remains, *Preprismatoolithus* probably belonged to allosauroids, whereas *Elongatoolithus* and *Macroelongatoolithus* belonged to oviraptorids, *Prismatoolithus* to troodontids, and *Megaloolithus* to sauropods. A branch-and-bound search discovered a preferred tree showing this internested pattern: (*Preprismatoolithus* ((*Elongatoolithus* + *Macrooolithus* + *Macroelongatoolithus* ))(*Prismatoolithus* + *Protoceratopsidovum*) (*Parvooolithus* + modern bird eggs))), which, when considering the parentage of the eggs, is comparable to results based on skeletal data. The results also show that the parataxonomic entities ornithoid-ratite, dinosaurid-prismatic, and Prismatoolithidae represent unnatural groupings, and that the ootaxon *Protoceratopsidovum* (meaning egg of *Protoceratops*) is a misnomer.

2:45 **Schweitzer, M., Wittmeyer, J. and Horner, J.:** A NOVEL DINOSAURIAN TISSUE EXHIBITING UNUSUAL PRESERVATION

SCHWEITZER, Mary, WITTMAYER, Jennifer, North Carolina State Univ., Raleigh, NC; HORNER, John, Montana State Univ., Bozeman, MT

In the summer field season of 2003, the Museum of the Rockies recovered elements of the oldest recorded *Tyrannosaurus rex* from the Hell Creek formation in Eastern Montana. Examination of bony tissues from the femur of this animal revealed the presence of a novel tissue, never before reported in dinosaurs. This thin tissue layer is completely distinct from the cortical and endosteal bone external to it. It is highly vascular and the bone matrix surrounding the vessels exhibits random structure. Ground thin sections of the bone confirm this distinctive nature, by revealing a sharp demarcation between the laminar endosteal bone and the new tissue, with a concurrent dramatic increase in vascularity. We hypothesize that the tissue observed may be the functional analogue of avian medullary bone, a

specialized bone type that serves as short term storage for calcium reserves used in the formation of eggshells. This ephemeral bone tissue is not produced by extant reptiles or mammals, but forms in response to increased estrogen levels produced by ovulating female birds. Medullary bone provides the first objective means of assigning gender to a dinosaur, and additionally, demonstrates that this animal was in reproductive phase.

3:00 **Ishigaki, S., Watabe, M., Tsogtbaatar, K. and Barsbold, R.:** FOOTPRINT EVIDENCES OF GREGARIOUS THEROPOD DINOSAURS FROM THE UPPER CRETACEOUS OF SHAR TSAV, SOUTH GOBI AIMAG, MONGOLIA

ISHIGAKI, Shinobu, Hayashibara Museum of Natural Science, Okayama, Japan; WATABE, Mahito, Hayashibara Center for Paleobiological Research, Okayama, Japan; TSOGTBAATAR, Khishigjaw, BARSBOLD, Rinchen, Mongolian Paleontological Center, Ulaanbaatar, Mongolia

More than 13000 footprints of dinosaur were discovered in Shar Tsav, South Gobi Imag, Mongolia, by a Hayashibara Museum of Natural Sciences-Mongolian Paleontological Center Joint Paleontological Expedition in 1995 and detailed research had been made in 1996 and 2001. Trackmakers of the majority of the footprints of the site are theropod dinosaurs of various sizes. The length of theropod footprints ranges from 6 to 70cm. The remarkable feature of this tracksite is the appearance of 9 groups of parallel trackways consisting of theropod footprints. Within each group, the footprints are similar in size, morphology, stride, direction and substrate conditions. These facts suggest that they were imprinted at the same time, the trackmakers had similar body size and foot shape (probably belong to a single species), and they formed a pack moving together at a similar speed. There is evidence of gregarious behavior in middle to small-sized theropod trackways, but not in large ones consisting of footprints with length(FL) larger than 35cm.

At least five pieces of evidence of gregarious behavior were obtained in small-sized footprints (FL:8 to 12cm), and at least four in middle-sized ones (FL:22 to 34cm). The number of the trackmaker individuals forming a pack ranges from 5 to 80 at the minimum in the small-sized forms, 2 to 21 in the middle-sized forms. Trackways of the middle-sized footprints arranged laterally to the moving direction are often observed. This suggests that the individuals in a moving pack formed an arrangement laterally spread to each other with a right angle to the moving direction, not a linear fore-and-aft one.

In one case of a small theropod pack, it is suggested that more than 80 individuals ran together changing the direction from N to ENE, indicating their stampede behavior. The size and shape of the footprints of this group are conformable to the size and shape of the foot of *Avimimus*. Several skeletal remains of *Avimimus* were discovered from the locality. This might be evidence of the behavior of the animal.

3:15 **BREAK**

3:30 **Bittencourt, J. and Kellner, A.:** THE PHYLOGENETIC POSITION OF *STAUROKOSAURUS PRICEI* FROM THE TRIASSIC OF BRAZIL

BITTENCOURT, Jonathas, KELLNER, Alexander, Museu Nacional/UFRJ, Rio de Janeiro, RJ., Brazil

*Staurikosaurus pricei* consists of a partial skeleton recovered from the Triassic Santa Maria Formation which phylogenetic position since its description in 1970 is controversial, with this taxon being regarded as a non-dinosaurian archosaur, a basal dinosaur, a carnivorous prosauropod, a primitive theropod (sister-group to Ceratosauria + Tetanurae) or a basal saurischian (sister-group to Sauropodomorpha + Neotheropoda). In order to assess its phylogenetic position some parts of the

holotype were prepared in detail revealing new anatomical information. Furthermore, a data matrix was constructed, including nine dinosaurian taxa (plus two outgroups) and 113 characters (mostly obtained from the literature). The inclusion of *S. pricei* in the ingroup was assumed *a priori* based on several characters regarded as synapomorphic of Dinosauria such as the femoral head more distinctly set off from the bone shaft, the reduction of the tuberosity that laterally bounds the ligament of the femoral head, and the posterior process of the distal tibia ventrally projected (ascending process of the astragalus inserting beneath the tibia). The resultant topology was the following: (Crurotarsi, *Marasuchus* (Ornithischia ((Neotheropoda (*Chindesaurus* (*Staurikosaurus*, *Herrerasaurus*))), (*Saturnalia* (*Thecodontosaurus* (*Plateosaurus*, *Riojasaurus*)))))). Based on the reduction of the iliac brevis fossa and the shortening of the posterior dorsal centra, *S. pricei* was positioned within the Herrerasauridae along with *Herrerasaurus* plus *Chindesaurus*. The presence of short and distally rounded pre and postacetabular processes of the ilia supports a closer relationship between *Staurikosaurus* and *Herrerasaurus* than either with *Chindesaurus*. Among several characters uniting Herrerasauridae with Neotheropoda, three are observed in *Staurikosaurus*: the presence of a developed intramandibular joint, the neural spines of the dorsal vertebrae higher than long and the prezygapophysis of the posterior caudals elongated. This set of derived traits allows the classification of *Staurikosaurus pricei* as a theropod dinosaur.

3:45 **Sadleir, R., Barrett, P. and Powell, P.: ANATOMY AND SYSTEMATICS OF *EUSTREPTOSPONDYLUS OXONIENSIS* (DINOSAURIA: THEROPODA): EVOLUTIONARY IMPLICATIONS**

SADLEIR, Rudyard, Univ. of Chicago Committee on Evolutionary Biology, Chicago, IL; BARRETT, Paul, The Natural History Museum, London, United Kingdom; POWELL, Philip, The Natural History Museum, Oxford, United Kingdom

Most recent work on theropod phylogeny has concentrated on the interrelationships of taxa that lie close to the ancestry of birds (coelurosaurians), whereas only a relatively small number of studies have investigated the evolution of more primitive theropods, such as basal tetanurans. Ghost lineages implied by theropod phylogenies suggest that the Middle Jurassic was an important time in tetanuran evolution, witnessing the initial radiation and diversification of the clade. However, Middle Jurassic theropod specimens are rare and often incomplete.

The holotype specimen of *Eustreptospondylus oxoniensis*, from the Oxford Clay (Callovian) of Oxfordshire (UK), represents the most complete Middle Jurassic theropod specimen from Europe. Although several articles have dealt with the anatomy and systematics of *Eustreptospondylus*, none are comprehensive and therefore, their utility in assessing the position of this taxon among theropods is limited. Nevertheless, the geologic and geographic provenances of *Eustreptospondylus* are important in shedding light on basal tetanuran evolution.

In the course of this study, the anatomy of *Eustreptospondylus* was re-assessed in detail and new information was incorporated into an existing, detailed analysis of basal theropod phylogeny. This study suggests that *Eustreptospondylus* was a basal member of the Spinosauroidea. It exhibits several anatomical features that appear to be incipient versions of the highly specialised character states that are found in more derived members of the clade (e.g. development of the premaxillary/maxillary embayment). The results of this work also suggest that Spinosauroidea may have originated in the Middle Jurassic of Europe, dispersing later to Gondwana. In addition to known proxies of osteogenic immaturity, several other previously unidentified features support the hypothesis that the holotype was a juvenile or sub-adult individual. These features highlight the potential utility of this specimen in understanding the developmental processes that underlie theropod character evolution.



4:00 **Lipkin, C. and Sereno, P.: THE FURCULA IN *TYRANNOSAURUS REX***

LIPKIN, Christine, Chicago, IL; SERENO, Paul, Univ. of Chicago, Chicago, IL

The form and articulation of the furcula in *Tyrannosaurus rex* has been a topic of debate. The only indisputable evidence for the presence, shape, and articulation of the furcula of *Tyrannosaurus rex* belongs to an articulated postcranial skeleton discovered in 2001, in a huge sandstone concretion in the Lance Formation (Maastrichtian) of eastern Wyoming. The bones of the mid section of this specimen (UCPC V1) are preserved in articulation with little transverse or dorsoventral distortion. These bones include the dorsal vertebrae and the associated ribs, gastralia, furcula, pectoral girdles, and forelimbs. The furcula is positioned between the right and left pectoral girdles in articulation with the acromial processes of the scapulae. The clavicular rami are broken away at the edge of the concretion on both sides. The right ramus is more complete, its ventral margin and distal most tip preserved *in situ* in the block. The left ramus is broken at mid length.

The furcula is U-shaped or, more accurately, lyre-shaped in anterior view and has rounded dorsal and ventral margins. A transverse depression, or trough, is present on the anterior side of the central body. There is no development of a hypocleideal process or rugosity at the ventral apex and no median line of fusion. The posterior side of the central body appears flat or very slightly concave. The intrafurcular angle is approximately 45 degrees, as measured from the ventral half of the clavicular rami. The furcula most closely resembles that of *Gorgosaurus*. UCPC V1 provides unambiguous evidence that the furcula in *Tyrannosaurus rex* is a symmetrical, lyre-shaped bone readily distinguishable from gastralia or posteriormost dorsal ribs.

4:15 **Kirkland, J., Zanno, L., Deblieux, D., Smith, D. and Sampson, S.: A NEW, BASAL-MOST THERIZINOSAUROID (THEROPODA: MANIRAPTORA) FROM UTAH DEMONSTRATES A PAN-LAURASIAN DISTRIBUTION FOR EARLY CRETACEOUS (BARREMIAN) THERIZINOSAUROIDS**

KIRKLAND, James, Utah Geological Survey, Salt Lake City, UT; ZANNO, Lindsay, Univ. of Utah, Salt Lake City, UT; DEBLIEUX, Donald, Utah Geological Survey, Salt Lake City, UT; SMITH, David, Brigham Young Univ., Provo, UT; SAMPSON, Scott, Univ. of Utah, Salt Lake City, UT

Abundant remains of a previously unknown, primitive therizinosauroid are being recovered from the Crystal Geyser quarry in east-central Utah. The quarry is at the base of the Lower Cretaceous Cedar Mountain Formation, in beds directly overlying the Upper Jurassic Morrison Formation. The paucispecific bonebed is both taphonomically complex and aerially extensive, spanning nearly two acres, with densities in excess of 100 elements per cubic meter. The Crystal Geyser theropod will likely be the best represented therizinosauroid and one of the most thoroughly documented maniraptorans based on the abundance of well-preserved elements which represent multiple growth stages. Therizinosauroid characters present in this taxon include edentulous rostral end of dentary; elongate cervical vertebrae with continuous, deep ventral depressions; well developed, angular internal tuberosity on proximal end of humerus; laterally diverging preacetabular process of ilium; and solid medial face of proximal fibula. As with *Beipiaosaurus*, the Crystal Geyser taxon retains the primitive tridactyl theropod pes. Derived therizinosauroid characters absent in this taxon include dorsolateral shelf on the dentary, teeth increasing in size anteriorly, ventrally inflated basisphenoid, loss of iliac fossa for m. cupedicus, abbreviated metatarsals, and reduced articular surface of astragalus. Both the fused (semilunate) and unfused condition of distal carpals one and two are recognized in the Crystal Geyser carpus. Phylogenetic analysis indicates that this taxon is the basal-most recognized therizinosauroid. Close comparisons of our cervical vertebrae with the partial cervical vertebra described as *Thecocoelurus*

indicates the presence of an unrecognized therizinosauroid in the upper Wealden Group of Britain. Together with *Beipiaosaurus* from the Lower Cretaceous of Asia, this evidence indicates a pan-Laurasian distribution of therizinosauroids prior to the development of a Beringean migration corridor between North America and Asia.

4:30 **Hwang, S., Norell, M., Ji, Q., and Gao, K.-Q.:** A NEW TROODONTID FROM THE LOWER YIXIAN FORMATION OF CHINA AND ITS AFFINITIES TO MONGOLIAN TROODONTIDS

HWANG, Sunny, NORELL, Mark, American Museum of Natural History, New York, NY; JI, Qiang, Chinese Academy of Geological Sciences, Beijing, China; GAO, Ke-Qin, Peking Univ., Beijing, China

An almost complete, new taxon of troodontid, CAGS-IG01-004, was recently collected from the lower, sandy portion of the Yixian Formation (Lower Cretaceous); compounding the value of the specimen is its three-dimensional state of preservation.

The skull of CAGS-IG01-004 possesses a number of avialan features. The unusually small teeth are constricted between the root and crown as in other troodontids, but are devoid of serrations as in the Mongolian troodontid *Byronosaurus*. The dorsal and ventral rami of the maxilla and the ventral process of the lacrimal are very slender. There is no apparent articulation point for the postorbital on the frontal. The laterodorsal process of the squamosal directly contacts the frontal-parietal suture and its lateroventral process is very long.

The jugal and quadratojugal of CAGS-IG01-004 is missing, but comparison with two different undescribed taxa from Ukhaa Tolgod (Djadokhta Formation, Upper Cretaceous, Mongolia) suggests that these taxa and CAGS-IG01-004 do not have a postorbital, and that the squamosal, jugal, and quadratojugal are rearranged to compensate. In one Ukhaa Tolgod taxon (IGM 100/1323), the lateroventral process of the squamosal is very long and probably articulated with the quadrate/quadratojugal junction as in other troodontids, but the jugal is very long and its dorsal process also contacts the quadrate. In the other Ukhaa taxon, the laterodorsal process of the squamosal contacts the frontal-parietal suture. In both Mongolian taxa, the dorsal process of the jugal contacts the quadrate rather than the postorbital. It appears that the posterior of the orbit was not closed in these three taxa, but open, as in avians. There is also evidence that CAGS-IG01-004 and the second Ukhaa taxon have an avialan-like quadratojugal that does not contact the squamosal. The skull of IGM 100/1323 is especially similar to that of CAGS-IG01-004, even having teeth of the same number and morphology. CAGS-IG01-004 and the two Ukhaa troodontids may form a new monophyletic clade of troodontids that are more closely related to avialans than any theropods yet discovered.

4:45 **Novas, F., Canale, J. And Isasi, M.:** GIANT DEINONYCHOSAURIAN THEROPOD FROM THE LATE CRETACEOUS OF PATAGONIA

NOVAS, Fernando, CANALE, Juan, ISASI, Marcelo, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina

Exploration conducted in Bajo de Santa Rosa (a productive fossil locality in Rio Negro Province, Northern Patagonia) resulted in the discovery of a new theropod dinosaur. Fossils come from the Allen Formation (Campanian-Maastrichtian), which also yielded remains of fishes, turtles, hadrosaurs, ankylosaurs, and titanosaurs. The only theropod named from this unit is *Quilmesaurus curriei*, a probable abelisauroid.

We add here the finding of a large (~6 m long), but gracile deinonychosaurian represented by several cranial and poscranial elements. The frontal resembles that of *Troodon* and *Sinornithosaurus* in being triangular-shaped in dorsal view, and together with the postorbital define a wide and rounded orbital

cavity. Jaws are elongate and low, with 25 tooth alveoli on the dentary. As in other deinonychosaurians, the cervical vertebrae centrum exhibits cranial articular surface almost at the same plane as the ventral one, neural spine of dorsal vertebrae transversely enlarged at their distal extremity, manual ungual phalanges strongly curved and with prominent extensor tubercle, phalanx 2 of pedal digit 2 with constricted ‘neck’ between both proximal and distal articular surfaces, and with a caudoventrally projected ‘heel’. Bizarre traits of the new animal concern with teeth morphology, which are conical and circular in cross-section, and devoid of serrations and carinae. In regards with the postcranial skeleton, a notable disparity in transverse width of pedal phalanges 2.2 and 1.4 suggests a marked asymmetry in foot construction.

The new discovery, along with the Patagonian maniraptorans *Patagonykus*, *Alvarezsaurus*, and *Unenlagia*, as well as the Malgalasy *Rahonavis*, support the interpretation that an important adaptive radiation of derived coelurosaurians took place in Gondwana at least from Turonian through Maastrichtian times.

5:00 **Witmer, L., Ridgely, R. and Sampson, S.: THE EAR REGION, CEREBRAL ENDOCAST, AND CEPHALIC SINUSES OF THE ABELISAURID THEROPOD DINOSAUR *MAJUNGATHOLUS***

WITMER, Lawrence, RIDGELY, Ryan, Ohio Univ., Athens, OH; SAMPSON, Scott, Univ. Utah, Salt Lake City, UT

Detailed study of the skull of the abelisaurid theropod dinosaur *Majungatholus*, based on CT scanning and 3D visualization of specimens discovered from the Late Cretaceous of Madagascar, allows new insights into cephalic soft tissues. Separate elements of a disarticulated skull were scanned, and anatomical structures of interest (e.g., osseous labyrinth, cerebral endocast, pneumatic sinuses) were extracted (segmented) and rendered in 3D. These datasets were then registered with a 3D surface model of an articulated cast, allowing the segmented soft tissues to be viewed in place in the whole skull. The virtual endocast reveals, as perhaps expected given the taxon’s position as a basal neotheropod, that the brain did not fill the endocranial cavity and that the general organization was primitive; the cerebellar flocculus is small. Likewise, the labyrinth of the inner ear is fairly typical for non-coelurosaurian theropods. The orientation of the lateral semicircular canal suggests that the alert head posture was basically horizontal, corresponding to the position of maximal binocular overlap. Identification of anatomical domains (e.g., adductor, tympanic, ocular, oropharyngeal), coupled to comparisons with extant outgroups, clarifies soft-tissue reconstruction. For example, the boundaries of the epithelial middle ear sac can be identified, and show that the median pharyngeal pneumatic system probably communicated with the middle ear. The dorsal and caudal tympanic recesses present in many higher theropods are absent, but the rostral tympanic recess is present and has an unusual caudal expansion within the braincase. The frontal bones have a sinus (perhaps unique among theropods) that is almost certainly of pneumatic origin, deriving probably from the antorbital diverticulum in the lacrimal bone. The frontal sinus is variable in extent and is nearly absent in the individual with the largest cornual process (‘horn’). The lacrimals and particularly the nasals are extensively pneumatized by more typical antorbital diverticula such that the volume of the antorbital sinus and its diverticula exceeded the volume of the main nasal cavity itself.

5:15 **Carrano, M., Sampson, S., and Loewen, M.: NEW DISCOVERIES OF *MASIAKASAUROS* *KNOPFLERI* AND THE MORPHOLOGY OF THE NOASAURIDAE (DINOSAURIA: THEROPODA)**

CARRANO, Matthew, Smithsonian Institution Dept of Paleobiology, Washington, DC; SAMPSON, Scott, LOEWEN, Mark, Univ. of Utah, Salt Lake City, UT

The Noosauridae is a poorly understood but widespread Gondwanan clade of abelisauroid theropods, deriving from the Cretaceous of Argentina (*Noasaurus*, *Velocisaurus*), India (*Laevisuchus* et al.), Madagascar (*Masiakasaurus*), and possibly Europe and Africa. Known members are fragmentary, recording less than half of the skeleton. The skull is particularly poorly known, a regrettable fact given the highly unusual nature of the jaws and dentition.

New materials of *Masiakasaurus*, discovered in the Upper Cretaceous Maevarano Formation of Madagascar, broaden our understanding of the anatomy and phylogenetic position of this taxon and the Noosauridae. These specimens include a postorbital, frontal, quadrate, partial braincase, axis and intercentrum, additional cervicals and dorsals, ischia, fibulae, phalanges, and unguals. New skull elements confirm that the skull roof is relatively unornamented compared to that of abelisaurids. The nearly complete foot of *Masiakasaurus* lacks a 'raptorial' pedal ungual and phalanx, and we suggest that the elements identified as such in *Noasaurus* in fact belong to the manus.

Together, these materials support a sister-taxon relationship between Noosauridae and Abelisauridae, and resolve the formerly ambiguous distribution of numerous derived characters. Noosaurid diversification probably occurred prior to the Albian, providing ample opportunity for the clade to reach most Gondwanan landmasses prior to their tectonic breakup. Resolution within Noosauridae is insufficient to support any particular biogeographic hypothesis, and must await additional discoveries. Fortunately, the distinctiveness of noosaurid skeletal morphology enhances the possibility of identifying even fragmentary specimens.

5:30 **Horner, J. and Padian, K.: AGE AND LONGEVITY OF *TYRANNOSAURUS REX***

HORNER, John, Montana State Univ., Bozeman, MT; PADIAN, Kevin, Univ. of California, Berkeley, Berkeley, CA

*Tyrannosaurus rex* is the most commonly found North American Late Cretaceous theropod; more than 30 skeletons have been recorded. One of the most common questions asked about *T. rex* skeletons is how old they were at maturity or death. Histological analysis of seven individuals provided an opportunity for the first time to assess the age represented by the bone cortex, to estimate the average individual age of these skeletons, to determine whether they represented fully grown individuals, and to predict their individual longevity. Though a substantial age range (15-25 years) is projected for the range of specimens, *T. rex* appears to have reached effectively full size well before 20 years.

Some of the seven specimens that we analyzed did not quite reach full size; others do not seem to have survived long after achieving it. Three of them appear to have effectively ceased active growth two or three years before death, though their cortical radius continued to increase annually by 0.5-0.7%. Four other specimens appear to have still been growing, but LAG interval decreases suggest that each of them would have reached effectively full size in another one to three years. Evidence from the femora and tibiae suggest, therefore, that *T. rex* reached full size by 16-3 years, but the sample is small, and individual variation may have affected age at maturity. Our study indicates that *T. rex* grew quickly to adult size, and that its growth dynamics are similar to large mammals and would appear to indicate high basal metabolic rates to sustain this growth. Further samples may reveal whether these dinosaurs commonly lived much beyond the attainment of adult size.

5:45 **Deck, L., Chapman, R. and Andersen, A.: CONSERVATION OF VERTEBRATE FOSSILS AND COLLECTIONS DATA USING VIRTUALIZATION**

DECK, Linda, CHAPMAN, Ralph, Idaho Museum of Natural History, Pocatello, ID; ANDERSEN, Art, Virtual Surfaces, Inc, Mt. Prospect, IL

Most fossils held in vertebrate paleontology collections are at a significant risk of deterioration. This starts once specimens are found and removed from the field and continues at various rates, often accelerating significantly due to problems with storage facilities, intermittent movement within collections units, and use for research and exhibition. The heightened political and economic instability existing in the world today poses additional dangers to collections such as wholesale destruction of buildings associated with wars (such as in the loss of *Spinosaurus*), terrorism, or catastrophic accidents. Finally, collections can be lost or significantly damaged due to neglect and theft, often exacerbated by massive budget cuts to Museums. This is a major concern because all fossils contain unique information about the organisms they record and because most taxa are represented by a relatively few significant specimens.

To combat the potentially catastrophic loss of information and data that could occur if specimens either deteriorate or are lost, we suggest a major effort be made to capture the data contained in significant specimens using three-dimensional scanning technology. We use as a model a project underway at the Idaho Museum of Natural History (IMNH) where major collections are being scanned in large numbers to capture the data they contain. The methods used include surface and CT-scanning and other technologies that may also be useful, such as rapid prototyping. The resulting data are being held in the Virtual Idaho Museum of Natural History (VIMNH). The VIMNH will provide virtual access to the scanned specimens from anywhere in the world in full three-dimensional form. These specimens can be accurately measured and examined in sufficient detail to allow most research aspects to be accomplished using the virtual specimens. As a bonus, virtualization makes these specimens much more useful for exhibition and outreach.

## **TECHNICAL SESSION II PLAZA BALLROOM F**

### **MODERATORS: GUILLERMO ROUGIER AND DARIN CROFT**

#### **1:30 Macrini, T. and Rowe, T.: CRANIAL ENDOCASTS OF MONOTREMES**

MACRINI, Thomas, ROWE, Timothy, The Univ. of Texas at Austin, Austin, TX

The brains of extant monotremes are described in the literature but their endocranial endocasts are not. A thorough understanding of which central nervous system (CNS) features are visible on endocasts of extant taxa is required to make inferences about the brains of extinct taxa. To study monotreme endocranial evolution, digital cranial endocasts were extracted from high-resolution X-ray CT scans of four individuals of the three extant taxa. We consulted published descriptions and illustrations of monotreme brains to determine which external features of the CNS are represented on the endocasts. In addition, we compared the monotreme endocasts with those taken from a variety of other fossil and extant mammals and non-mammalian cynodonts. Volumetric data were also collected to obtain encephalization quotients.

Echidna brains are gyrencephalic and many of these gyri and sulci including the rhinal fissure are represented on endocasts. Some features on the ventral surface of the echidna brain such as the olfactory tracts and the pons are not clearly visible on the endocasts. The platypus brain is lissencephalic and therefore few sulci or gyri are present on the neocortex region of the endocasts. However, the median sulcus is very prominent, much more so than for echidnas. The vermis of the cerebellum in monotremes is obscured by venous sinuses on the dorsal surface of the endocasts. The mesencephalon is not visible on either the exterior of monotreme brains or endocasts. A similar condition is present in multituberculates, triconodonts, and many therians. In contrast, the midbrain is exposed on the dorsal

surface of endocasts of *Kennalestes*, *Barnunlestes*, *Zalambdalestes*, at least some macroscelidids, and possibly the non-mammalian cynodont *Probainognathus*.

A lissencephalic cortex is plesiomorphic for Mammalia. Gyrencephaly is a possible apomorphy for Tachyglossidae, having also evolved independently among various therians. Reduction of the olfactory bulbs is a potential apomorphy of Ornithorhynchidae, possibly correlated with reduced olfactory turbinates as a result of aquatic habitat-use.

1:45 **Rougier, G. and Apesteguia, S.:** THE MESOZOIC RADIATION OF DRYOLESTOIDS IN SOUTH AMERICA: DENTAL AND CRANIAL EVIDENCE

ROUGIER, Guillermo, Univ. of Louisville, Louisville, KY; APESTEGUIA, Sebastian, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina

Despite the relatively poor South American mammalian record, recent discoveries from the Jurassic, Cretaceous and Paleocene allow the reconstruction of some of the major events in the Mesozoic mammalian fauna. The core of the evidence comes from Patagonia (Argentina) with minor extra-Patagonian additions. The Jurassic and Early Cretaceous record is restricted to triconodonts, tribosphenic australosphenidans and the nearly tribosphenic *Vincelestes*. The Late Cretaceous record is yet to provide a tribosphenic mammal and the faunas are dominated instead by non-tribosphenic cladotheres, dryolestoids in particular.

The earliest South American dryolestoids are from the Cenomanian-Turonian Candeleros Formation where two closely related species are represented by jaws and skull material; both of them have single rooted molars and a low postcanine count. The Campanian record is more abundant with two localities in northern Patagonia, Los Alamitos and Cerro Tortuga. Several lineages are represented, including probable true Dryolestidae, Quirogatheiridae, Casamiquelidae, Mesungulatidae and Reigitheridae. All these taxa seem to have a relatively low number of molariforms, probably 4. The molar size of the Campanian dryolestoids range in size from under one millimeter to almost one centimeter and their inferred diet would range from insectivory to fairly dedicated herbivory. Non-dryolestoid components of these faunas (multituberculates, gondwanatherians, triconodonts?) are neither abundant nor diverse. A few dryolestoid molars are known from the Bolivian Late Cretaceous. The Maastrichtian dryolestoids are well represented in several localities of the central Patagonian La Colonia Formation. Only reigitherids and large to mid-size mesungulatids have been found. Despite an abundant collection, the diversity is poor. Multituberculates are present but gondwanatherians have not yet been found. The latest record of a dryolestoid is represented by the large-sized *Peligrotherium* from the mid-Paleocene Salamanca Formation which seems to represent a very derived member of the Reigitheridae radiation that survived the K-T extinction.

2:00 **Maga, M. and Maas, M.:** THE FIRST UNAMBIGUOUS METATHERIAN FROM THE PALEOGENE OF CENTRAL TURKEY

MAGA, Murat, MAAS, Mary, Univ. of Texas, Austin, TX

Despite discoveries of marsupials in Paleogene age rocks of central Asia, Europe, and Africa over the last two decades, the Old World record of this group, known largely from dental material, remains poor. Here we report a metatherian skeleton from the Uzuncarsidere Formation in central Turkey. The probable age of these continental rocks, overlain by Lutetian marine limestones, is early to early middle Eocene. AUJM 2002-25 includes the mandible, majority of splanchnocranium, and bulk of the appendicular and axial skeletal elements. It is much larger than any other Old World Paleogene metatherian. Body mass estimates based on modern marsupials put this fossil between 1-2 kg.

AUJM 2002-25 shares with other metatherians a robust, medially inflected angle of the dentary, a prominent preglenoid process of the jugal, and the 3P4M cheek teeth formula of primitive marsupials. Neither upper nor lower incisors are preserved. The canines are robust. The two-rooted premolars increase in size from anterior to posterior. The molars increase in size from M1 to M3 and m1 to m4. Except for the ultimate two molars, the cheek teeth are worn almost flat. The upper molars have a wide stylar shelf bearing five cusps, and a shallow V-shaped centrocrista. Lower m4, which is dominated by a massive protoconid, is the most prominent tooth in the dentition. The robust posterior teeth and flat occlusal wear suggest powerful, crushing feeding habits.

The postcranial skeleton is characterized by a suite of features most consistent with terrestrial habits. The humerus is robust with a well-developed deltoid crest, and wide distal aspect. The olecranon is longer and more powerful than any extant didelphid. The intermembral index is 77.2, within range of extant terrestrial didelphids. The os epipubicum is articulated with the pelvis. The femur is straight and robust with a prominent third trochanter. The distal tibia has the typical *Didelphis*-like spiral shaped articular surface. The calcaneum shows the primitive calcaneofibular facet on the lateral side of the external articular surface.

2:15 **Crompton, A. and Lieberman, D.:** FUNCTIONAL SIGNIFICANCE OF THE INFLECTED MANDIBULAR ANGLE

CROMPTON, Alfred, LIEBERMAN, Daniel, Harvard Univ., Cambridge, MA

An inflected mandibular angle is a marsupial synapomorphy. Other than Maier's view that the mandibular angle serves in the conduction of sound in the neonate, no suggestion for biomechanical function for this structure exists.

This skeletal character is associated with the unique muscular configuration in marsupials. With the exception of koalas, the marsupial medial pterygoid muscle is divided into two distinct anatomical units: superficial and deep. The deep is homologous with the undivided medial pterygoids of placental mammals, whereas the superficial medial pterygoid is neomorphic. The dorsal surface of the inflected mandibular angle serves as the site of insertion for this muscle.

To test the hypothesis that this novel anatomical configuration has a functional consequence, we recorded the jaw kinematics and the electrical activity (EMG) in the two portions of medial pterygoids, as well as a set of adductor muscles, in four species of marsupial: opossum, red kangaroo, potoroo and wombat. The activity patterns in the two regions of the marsupial medial pterygoid are different. The medial pterygoid muscles are partially responsible for the control of hemi-mandibular rotation in species with a mobile mandibular symphysis (opossums, potoroos, kangaroos) and transverse jaw movements in forms with a fused symphysis (wombats). This pattern of EMG activity in marsupials differs significantly from that of placental herbivores.

We hypothesize that koalas, with a fused mandibular symphysis, no superficial medial pterygoid, and transverse jaw movements, will have a different motor pattern during mastication from other marsupials. This species has an inflected mandibular angle early in development, but it is resorbed during later ontogeny. Therefore, the motor pattern, and the neuromuscular control of feeding, of koalas will be convergent on that of placental herbivores.

2:30 **Luo, Z.-X., Wible, J., Ji, Q. and Yuan, C.-X.:** MORPHOLOGICAL DIVERGENCE AND EARLIEST EVOLUTION OF MARSUPIAL AND PLACENTAL MAMMALS

LUO, Zhe-Xi, WIBLE, John, Carnegie Museum of Natural History, Pittsburgh, PA; JI, Qiang, YUAN, Cong-Xi, Chinese Academy of Geological Sciences, Beijing, China

Eutherians (including extant placentals) and metatherians (including extant marsupials) have dominated the terrestrial biotas of the Earth for 65 million years during the Cenozoic, culminating in a great diversity of some 4600 species today. Their earliest evolutionary history can now be traced to *Eomaia scansoria* and *Sinodelphys szalayi*, the earliest-known representatives for these lineages, from the Lower Cretaceous (~125 Ma) of China. These exquisite and nearly complete fossils provide evidence on the ancestral anatomical characteristics from which crown placentals and marsupials have evolved. Metatherians can be diagnosed by several apomorphies in the anterior dentition, whereas eutherians can be distinguished by a limited number of upper molar features. However, other traditional 'diagnostic' dental features that were useful for separating Late Cretaceous and Tertiary eutherians and metatherians have homoplastic distributions among some Early Cretaceous taxa that can be referred to either eutherians or metatherians by derived ankle and wrist characters. *Eomaia* and *Sinodelphys* help to establish the evolutionary sequence in which apomorphic ankle and wrist characters of eutherians and metatherians evolved before the distinctive molar characteristics of either lineage. Both *Eomaia* and *Sinodelphys* possessed some carpal, tarsal, and phalangeal characters otherwise only known in extant scansorial mammals. *Sinodelphys* and other early metatherians are derived in several tarsal features for inversion and eversion along a mobile trans-tarsal joint, and in having enlarged hamate and triquetrum in the carpus to reinforce manual grasping. By contrast, *Eomaia* and other early eutherians have tarsal features for effective flexion and extension of the pes. The initial divergence of metatherians and eutherians was accompanied by differentiation of manual and pedal structures that may have facilitated their exploration of new, diverse niches inaccessible to the terrestrial eutriconodonts, multituberculates, and spalacotheriids in the Early Cretaceous mammalian assemblage.

2:45 **Eiting, T., Rowe, T. and Ketcham, R.:** QUANTITATIVE ANALYSIS OF THE MAMMALIAN SKULL: A NEW METHOD FOR STUDYING THE INTERNAL NASAL ANATOMY OF *MONODELPHIS DOMESTICA* (MARSUPIALIA, DIDELPHIDAE)

EITING, Thomas, ROWE, Timothy, KETCHAM, Richard, Univ. of Texas at Austin, Austin, TX

The gray short-tailed opossum, *Monodelphis domestica*, is a proven laboratory test animal. From a paleontological perspective, this taxon is useful in approximating the anatomy of basal mammals because it retains many characters thought to be primitive among Mammalia. Recent high resolution X-ray CT (HRXCT) scans of the skull of *Monodelphis* have yielded valuable data that contribute to our understanding of this taxon and the anatomy of poorly studied regions of the mammalian skull. The nasal capsule, for example, has previously not been examined thoroughly, in part because the internal osteology of this region has been difficult to study non-destructively.

A new technique is presented here for analyzing scanned specimens in 3D as well as calculating various data for individual nasal turbinates and the passageways they encompass. We have used a program called Blob3D to carry out these analyses. Blob3D is an "in-house" program developed in the HRXCT Facility at the University of Texas at Austin, in the Interactive Data Language (IDL). It operates by separating desired components from unwanted noise based on grayscale differences, after which a number of interactive 3D editing tools allow further refinement. Then, by segmenting the nose region from the rest of the skull, 3D movies and numerous data, ranging from passageway volumes to turbinate surface areas, may be extracted.

The internal nasal anatomy of *Monodelphis* can now be seen and studied in a non-destructive manner. Analysis in Blob3D confirms that the anterior-most maxilloturbinate provides most of the surface area for respiratory epithelia, while the posterior endoturbinates mainly support olfaction. The data we have generated indicate that the olfactory and respiratory passages each occupy about 40% of the nasal chamber, while the nasal gland comprises the remaining 20%. Finally, the surface areas of the



nasal turbinates increase the area available to their respective epithelia by more than double the area that would be available if the epithelia only covered the internal walls of the nasal capsule.

3:00 **Longrich, N.:** AQUATIC SPECIALIZATION IN MAMMALS FROM THE LATE CRETACEOUS OF NORTH AMERICA

LONGRICH, Nicholas, Univ. of Calgary, Calgary, AB, Canada

Following the end-Cretaceous mass extinctions, a wide range of mammals evolved to exploit aquatic habitats, but aquatic mammals have never been documented from the Mesozoic. Recently, however, a number of extraordinary mammalian tail vertebrae from the Late Cretaceous (Campanian) Judith River Group of Alberta were discovered in the collections of the Royal Tyrrell Museum. Unusual features include their large size (1.4-2.6cm long), great width, and extreme dorsoventral compression. They most closely resemble the caudal vertebrae of the beaver and platypus. As in beavers, the broad, convex intervertebral articulations constrain lateral movement but facilitate hinging in the vertical plane. The tail was probably oarlike and dorsoventrally compressed to facilitate swimming, as in beavers, the platypus and the Amazon giant otter. The only mammals from these deposits which are large enough to account for these vertebrae are the stagodont marsupials *Eodelphis browni* and *E. cutleri*, which might have weighed as much as 1-2 kg. Stagodonts resemble some otters in displaying heavy tip wear of the teeth, and the dentition of the unusually large Maastrichtian stagodont *Didelphodon vorax* has previously been identified as convergent upon the sea otter *Enhydra*. It is proposed that the stagodonts represent a Cretaceous radiation of specialized, semiaquatic mammalian predators. The large size of stagodonts and their unusual abundance in fluvial deposits are consistent with these hypotheses. Stagodonts therefore appear to represent the earliest known instance of aquatic adaptation in Mammalia. Identification of these mammals as members of the aquatic fauna reinforces the view that the dinosaurs remained the dominant large terrestrial vertebrates in North America until the end of the Cretaceous. Stagodonts did not survive the close of the Maastrichtian, but they hint at a relatively high degree of morphological and ecological specialization in Mesozoic mammals which may have set the stage for the radiations to follow in the Tertiary.

3:15 **BREAK**

3:30 **Wyss, A., Charrier, R., Croft, D. and Flynn, J.:** PALEONTOLOGICAL RECONNAISSANCE OF THE CENTRAL ANDEAN MAIN RANGE BY HELICOPTER: ADDITIONAL NEW CENOZOIC MAMMAL FAUNAS FROM CHILE

WYSS, Andre, Univ. of California Santa Barbara, Santa Barbara, CA; CHARRIER, Reynaldo, Univ. of Chile, Santiago, Chile; CROFT, Darin, Case Western Reserve Univ. School of Medicine, Cleveland, OH; FLYNN, John, Field Museum, Chicago, IL

A several thousand km<sup>2</sup> swath of the central Andean Cordillera was prospected by helicopter during 2004, permitting rapid survey of large areas in remote or difficult to access regions. This led to the recovery of fossils from several parts of the range, and the identification of sites worthy of future attention.

Well-preserved mammal specimens were recovered from two areas north of Laguna del Laja. The first occurs immediately N of the lake near 37° 10' S, some 40 km NNW of where we reported fossil mammals previously. Fossils are derived from several volcanoclastic and fluvial horizons in western cliff-forming exposures of the Cura-Mallin Fm. north of the lake. A second set of localities was discovered ~15 km to the NE, in exposures originally mapped as the Plan de Los Yeuques Fm., but doubtlessly pertaining to the Cura-Mallin Fm. instead. Preliminary faunal evidence (xenarthrans,

notoungulates, rodents) suggests that fossil bearing strata of these two regions are roughly temporally correlative with those SE of the lake (middle Miocene).

A thick sequence of volcanoclastic sediments within the Abanico Fm. from 35.0° S in the western reaches of Rio Teno drainage is remarkably fossiliferous. Just a few hours of collecting yielded more than a dozen exceptionally preserved skulls and jaws over several kilometers of strike, and across nearly one km of stratigraphic section. Preliminary identification reveals that a superposed sequence of faunas is almost certainly preserved in this section. The lowest horizons sampled are dominated by low-crowned ungulates, probably indicative of a pre-Tinguirirican SALMA fauna (?Casamayoran), whereas higher in the section rodents and hypsodont herbivores are common (likely Tinguirirican or younger).

The success of this venture emphasizes the nearly limitless potential that Cenozoic volcanoclastic sediments of the central Andes have for illuminating the history of South American mammals. Even after more than 15 years of intensive investigation, paleontologists are still just beginning to scratch the surface of these vast deposits.

3:45 **Madden, R., Kay, R., Heizler, M., Vilas, J. and Ré, G.: GEOCHRONOLOGY OF THE SARMIENTO FORMATION AT GRAN BARRANCA AND ELSEWHERE IN PATAGONIA: CALIBRATING MIDDLE CENOZOIC MAMMAL EVOLUTION IN SOUTH AMERICA**

MADDEN, Richard, KAY, Richard, Duke Univ., Durham, NC; HEIZLER, Matthew, New Mexico Tech, Socorro, NM; VILAS, Juan, RÉ, Guillermo, Univ. de Buenos Aires, Buenos Aires, Argentina  
<sup>40</sup>Ar/<sup>39</sup>Ar dating results for twenty-one tuffs and five basaltic lavas at Gran Barranca and type faunas for Vacan and Deseadan faunas in the Sarmiento Formation in Chubut and Santa Cruz provinces Argentina are within analytical error and with few exceptions consistent with stratigraphic superposition. Complications with the interpretation of Ar/Ar results for some tuffs relate to their very fine-grained texture, argon loss, and xenocrystic contamination. Volcanogenic sediments at Gran Barranca evidence two periods of intense pyroclastic activity, one between 36.5 and 39 Ma and another between 19 and 20 Ma. An important episode of basaltic activity occurred between 28.2 and 23.7 Ma. Magnetic polarity stratigraphies for five sections with Ar/Ar age results permit correlation to global geochronologies. Age models integrating sediment thickness, Ar/Ar dates and magnetic polarity stratigraphy for five operational lithostratigraphic subdivisions of the Sarmiento Formation suggest age calibrations for their contained fossils and constrain the temporal duration of important unconformities.

Barrancan levels in the Gran Barranca Member extend stratigraphically up from the base of the exposures and numerous tuffs within this interval range in age from between 41.0 to 38.2 Ma. The Mustersan interval at Gran Barranca in the lower Puesto Almendra Member ranges in age from between 38.0 and 36.4 Ma, based on Ar/Ar results dating a rich Mustersan assemblage and a tuff that overlays an *Astrapnotus* quarry. The Eocene-Oligocene transition occurs in the Vera Member (with the epoch boundary just below the Astrapnoteen plus Superieur level of Ameghino. This interval represents all or part of Chrons C15n, C15r and C13n. Deseadan taxa occur in association with the basalt complex dated to between 28.1 and 27.4 Ma at Gran Barranca. The fossil zone corresponding to the Colhuehuapian Land-Mammal Age spans the complete interval of Chron C6n (20.131 to 19.048 Ma), and the uppermost fossil zone at Gran Barranca or Pinturan is in Chron C5En (18.281 to 18.781 Ma).

4:00 **Carlini, A., Bond, M., Lopez, G., Reguero, M., Scarano, A. and Madden, R.: MAMMALIAN BIOSTRATIGRAPHY AND BIOCHRONOLOGY AT GRAN BARRANCA: THE STANDARD REFERENCE SECTION FOR THE CONTINENTAL MIDDLE CENOZOIC OF SOUTH AMERICA**

CARLINI, Alfredo, BOND, Mariano, LOPEZ, Guillermo, REGUERO, Marcelo, SCARANO, Alejo, Univ. Nacional de La Plata y Museo, La Plata, Argentina; MADDEN, Richard, Duke Univ., Durham, NC

The Sarmiento Formation at Gran Barranca is a 285m thick composite section containing over 43 different fossil-bearing levels. Based on the stratigraphic occurrences of standard index and guide taxa, there are at least six different faunal zones. The occurrences of *Notostylops*, *Astraponotus*, *Pyrotherium*, *Colpodon* and *Astrapothericulus* together with other mammalian guide taxa permit recognition of the standard sequence of middle Cenozoic South American Land-Mammal Ages at Gran Barranca. In addition, clear stratigraphic relationships between fossil mammals, dated tuffs and lavas, magnetic polarity intervals, and unconformities of constrained temporal duration, permit establishing a refined biochronology for assemblages and biozones.

The Barrancan is essentially as Cifelli established based on Simpson's collections and stratigraphy, and its upper temporal limit can be established. An assemblage of intermediate taxonomic composition occurs at the top of the Barrancan interval, if amenable to age control, may warrant recognition. The Mustersan is represented by two levels directly dated and bracketed by dates from overlying and underlying tuffs. An unconformity separates the Mustersan from overlying fossil levels. Knowledge of the Astraponoteen plus Superieur of Ameghino is significantly improved and stratigraphy suggest the age of the base of a Tinguirirican Land Mammal Age may be more precisely constrained at Gran Barranca. A rich pre-Deseadan and post-Tinguirirican level with guide taxa of both faunal units and primitive rodents must be accommodated. The Deseadan has been one of the least well-known parts of the section at Gran Barranca. Deseadan levels can be precisely located with respect to the basalt complex and associated unconformities. The rich Colhuehuapian levels are the best constrained temporally. The topmost fossil levels at Gran Barranca yield a Pinturan assemblage older than that of the type area.

#### 4:15 **Shockey, B., Croft, D. and Anaya, F.:** DISTINCTIVE FOSSORIAL ADAPTATIONS IN MESOTHERIIDS (MAMMALIA: NOTOUNGULATA)

SHOCKEY, Bruce, Valdosta State Univ., Valdosta, GA; CROFT, Darin, Case Western Reserve Univ., Cleveland, OH; ANAYA, Federico, Univ. Autonoma, Potosi, Bolivia

Although endemic South American ungulates have long been known to exhibit a broad range of locomotor habits, fossorial (i.e., digging) adaptations have not been widely acknowledged. Our study suggests that digging was a major activity for mesotheriid notoungulates.

We examined two species of mesotheriids: a trachytheriine, *Trachytherus spegazzinanus*, from Salla, Bolivia (late Oligocene), and a mesotheriine, *Plesiotypotherium* sp., from Casira, Bolivia (Mio-Pliocene?). Fossorial adaptations exhibited by both of these taxa include the following: modifications for great strength at the shoulder joint (large and distally extended ridges on the humerus for attachment of the deltoid and pectoral muscles), powerful elbow extension (elongate olecranon process), and powerful flexion-extension of the hand and digits (distally broad humerus with enlarged supinator crest and medially curved olecranon process). Both taxa also possess a large elbow sesamoid bone, though this is probably a plesiomorphic character within Notoungulata since it has also been noted in *Nesodon*, a middle Miocene toxodontid. Both mesotheriids examined have pentadactyl hands, a conserved trait found even in the latest-occurring mesotheriine, the Pleistocene *Mesotherium*.

The *Plesiotypotherium* specimen is unique among ungulates in exhibiting a robust, fused contact between the ischium and sacrum. This condition only occurs in other lineages associated with fossorial habits (e.g., moles and armadillos) and likely served to oppose the force of the forelimb's vigorous activity against the substrate. The ungual phalanges of the hand are bifurcated (as in fossorial pangolins and golden moles) but they lack the dorsal "stops" of many fossorial animals that prevent overextension

of the digits while breaking the substrate. Mesotheriids may have instead relied upon their hypertrophied incisors, which could have initially loosened the substrate for subsequent removal by the powerful forelimbs. Such incisor-assisted excavating occurs in many extant fossorial rodents.

4:30 **Croft, D. and Anaya, F.:** A NEW HEGETOTHERIID FROM THE MIDDLE MIOCENE OF QUEBRADA HONDA, BOLIVIA AND A PHYLOGENY OF THE HEGETOTHERIIDAE (MAMMALIA: NOTOUNGULATA: TYPOTHERIA)

CROFT, Darin, Case Western Reserve Univ., Cleveland, OH; ANAYA, Federico, Univ. Autónoma Tomás Frías de Potosi, Potosi, Bolivia

Bolivia preserves a rich record of middle to late Cenozoic mammal evolution. Despite the abundance of fossil mammal faunas, most have not been extensively collected nor adequately described. The middle Miocene Quebrada Honda locality of southern Bolivia (12-13 Ma; Laventan South American Land Mammal 'Age') represents one such fauna; of the two dozen species that have been reported from this site, only five have been discussed in the literature. Preliminary measures of faunal resemblance suggest that Quebrada Honda is slightly more similar to asynchronous high latitude 'Friasian' (s.l.) faunas than to the contemporaneous low latitude La Venta Fauna of Colombia, though these values will likely change as Quebrada Honda (and other middle Miocene faunas) are studied in greater detail. Additional data from this intermediate latitude fauna should provide valuable insights into the development of latitudinal provinciality within South America.

The present study was undertaken to characterize a common yet undescribed hegetotheriid notoungulate from Quebrada Honda. This hegetotheriid has been listed as *Hegetotherium* (subfamily Hegetotheriinae) in published faunal lists, but differs from this taxon (and all other members of the subfamily) in possessing a sharply trilobed m3, a feature generally regarded as a synapomorphy of the Pachyrukhinae. A preliminary phylogenetic analysis of the Hegetotheriidae was undertaken to determine the affinities of this new hegetotheriid and to test the monophyly of the two subfamilies. The analysis used 26 characters and nine ingroup taxa. A single most-parsimonious tree resulted, with an ingroup topology of (*Prohegetotherium* (*Hegetotherium* ((*Hemihegetotherium*, Quebrada Honda taxon) ((*Prosotherium*, *Propachyrucos*) (*Pachyrukhos* (*Paedotherium*, *Tremacyllus*)))))). Although the cladogram is well-resolved, several long ghost lineages are implied and certain character state transformations seem unlikely. Increasing the number of non-dental characters and improving geographic sampling of hegetotheriids may help resolve these issues in future analyses.

4:45 **MacFadden, B.:** DIET AND HABITAT OF TOXODONT MEGAHERBIVORES (MAMMALIA, NOTOUNGULATA) FROM THE LATE QUATERNARY OF SOUTH AND CENTRAL AMERICA

MacFADDEN, Bruce, Florida Museum of Natural History, Gainesville, FL

Late Pleistocene toxodonts (*Toxodon* and *Mixotoxodon*) have very high-crowned, evergrowing teeth and have been interpreted as grazers. Carbon isotopes from toxodont tooth enamel are analyzed from at least 13 low-elevation localities ranging in age from 38,500 to 5,517 radiocarbon years before present (late Pleistocene or Holocene). These  $\delta^{13}\text{C}$  data show statistically significant differences, which are interpreted to represent regional variation in diet and habitat as follows: (1) Buenos Aires Province, Argentina (~35 deg. S), with a mean  $\delta^{13}\text{C}$  of -8.7 per mil (N = 5, OR = -12.2 to -5.0 per mil) indicates an isotopically mixed, although primarily C3 diet. (2) Northern Argentina (~30 to 26 deg. S), with a mean  $\delta^{13}\text{C}$  of -4.4 per mil (N = 4, OR = -7.2 to -1.5 per mil) indicates a mixed diet with a major component of C4 grasses. (3) Bolivian Chaco (21 deg. S), with a mean  $\delta^{13}\text{C}$  of -0.1 per mil (N = 10, OR = -1.5 to 1.5 per mil) indicates a principally C4 grass diet. (4) Amazonia (Bolivia and Peru, 14 to 11' S), with a mean  $\delta^{13}\text{C}$  of -13.7 per mil (N = 6, OR = -15.1 to -11.0 per mil) indicates a C3 diet and extreme individual

$\delta^{13}\text{C}$  values as negative as -15.1 per mil suggest a forested, closed canopy habitat. (5) Bahia, Brazil (11 deg. S), with a mean  $\delta^{13}\text{C}$  of -8.6 per mil (N = 3, OR = -12.6 to -5.5 per mil) indicates an isotopically mixed diet. (6) Honduras (14 deg. N), with a mean  $\delta^{13}\text{C}$  of -9.3 per mil (N = 7, OR = -13.8 to -5.3 per mil) principally indicates a C3 diet and habitat, but with considerable individual variation.

Despite being high-crowned, presumed grazers, the carbon isotopic data indicate that these toxodonts had the evolutionary capacity of a broad range of feeding and habitat specializations depending upon available local plant communities ranging from closed-canopy C3 forest to open-country C4 grasslands. Evidence from the Amazon region (4 above) indicates the presence of C3 plants during the late Quaternary that are probably the precursors of the modern Neotropical rainforest.

5:00 **Wilson, G.:** MAMMALIAN FAUNAL DYNAMICS DURING THE LAST 1.8 MILLION YEARS OF THE CRETACEOUS IN GARFIELD COUNTY, MONTANA

WILSON, Gregory, Univ. of California, Berkeley, CA

An increasing amount of high-resolution data points to environmental perturbations and correlated biotic change in marine invertebrates and terrestrial plants prior to the Cretaceous-Tertiary (K-T) boundary. This study provides the first analysis of evolutionary and ecological change in mammalian communities during the last ~1.8 million years of the Cretaceous (~67.3-65.58 Ma) using a well-sampled succession of faunas from the Hell Creek Formation in Garfield County, Montana. Changes in species composition, richness, and relative abundances are temporally correlated with changes in paleotemperatures inferred from floral and isotopic proxies.

Results suggest mammalian communities exhibited both direct and indirect responses to fluctuating climates during the latest Cretaceous. From ~67.3 to 65.7 Ma, shifts in geographic ranges and relative abundances of species were as expected from background levels of climate change. In contrast, the extinction of ~22 species at or near the K-T boundary (~65.7-65.58 Ma) cannot be explained by the coincident cooling event alone. These fossil data are most consistent with a non-linear response pattern for the K-T extinction, resulting from long and short term environmental perturbations (e.g., climate change, sea-level regression, volcanism, an extraterrestrial impact), though the proposal for a single, short term cause of an extraterrestrial impact cannot be excluded.

5:15 **Davis, E., Barnosky, A. and Carrasco, M.:** EFFECTS OF TECTONIC ACTIVITY ON BETA DIVERSITY OF MAMMALS IN THE MIOCENE OF THE BASIN AND RANGE PROVINCE, WESTERN USA

AVIS, Edward, BARNOSKY, Anthony, CARRASCO, Marc, Univ. of California Berkeley, Berkeley, CA

Ecological theory predicts that the taxonomic richness of a study area will be dependent upon geographic size (following species-area equations) and habitat heterogeneity, among other factors. Evolutionary theory predicts that areas that experience frequent vicariance, or that have abundant potential barriers to dispersal, will foster higher richness through formation of endemic species. Modern species richness in the Basin and Range Province of the southwestern United States is consistent with these predictions, demonstrating extensive endemism within basins, which leads to a higher richness for the province (beta diversity), while maintaining similar local (alpha) diversities to less fragmented areas. We hypothesize that this high beta diversity can be traced to the initiation of tectonic processes that formed the Basin and Range. In order to test this hypothesis, we compare beta diversity within the Basin and Range to that in the Great Plains through the last 15 Ma using published mammalian faunal records compiled in the MIOMAP and FAUNMAP databases. Preliminary analysis of species occurrence data, not accounting for sampling differences, indicates that Holocene beta diversity within the Basin and

Range is higher than beta diversity at the onset of basin formation, while Miocene alpha diversity in the Basin and Range is consistently lower than in the Great Plains. These results support the theoretical predictions. However, differences in sampling and taphonomy preclude taking those results at face value; thus, we discuss methods of standardizing comparisons and calculating species accumulation curves for fossil data.

5:30 **Hulbert, R., Morgan, G. and Kerner, A.:** THE COLLARED PECCARY (*PECARI* CF. *TAJACU*) AND ASSOCIATED FAUNA FROM THE LATE PLEISTOCENE OF FLORIDA

HULBERT, Richard, Univ. of Florida Florida Museum of Natural History, Gainesville, FL; MORGAN, Gary, New Mexico Museum of Natural History, Albuquerque, NM; KERNER, Andreas, P.O. Box 540868, Orlando, FL

The current range of the collared peccary *Pecari tajacu* (Linnaeus) is from the southwestern United States to northern Argentina. Its northernmost, well-documented Pleistocene occurrence was previously Guatemala. Two extinct peccary genera, *Mylohyus* and *Platygonus*, were widely distributed in the U.S. during the Pleistocene, and both were common in Florida. Previous workers have hypothesized that *P. tajacu* did not disperse north of Middle America until the Holocene, after the extinction of *Mylohyus* and *Platygonus*.

The Peace River 5A local fauna (new name) derives from a small stretch of the Peace River in De Soto County, southern Florida. Underwater excavation of *in situ* sand and gravel beds has recovered a temporally-mixed assemblage of reworked, marine, Mio-Pliocene taxa derived from the Peace River Formation, and a very late Pleistocene fauna of freshwater and terrestrial vertebrates. The latter consists of a minimum of 27 taxa, of which 16 are extinct, including *Bison antiquus*, *Platygonus compressus*, *Tapirus veroensis*, *Holmesina septentrionalis*, *Glyptotherium floridanum*, *Mammut*, and *Mammuthus*. A partial right dentary with p4-m3 of a tayassuid (UF 162751) was collected *in situ* from the lowest layer of the deposit together with specimens of extinct Pleistocene megafauna. Its teeth are significantly smaller and morphologically different than those of *Platygonus compressus* and *Mylohyus fossilis*, and are indistinguishable from those of extant *Pecari tajacu*. A second specimen, an isolated m3 (UF 201286), of similar size and morphology as the m3 of UF 162751, was collected from the Suwannee River in northern Florida. It lacks the stratigraphic provenience and associated fauna of the dentary, but its age is most likely late Pleistocene. Together, the two specimens demonstrate that a third peccary, very close to if not conspecific with *P. tajacu*, was present across peninsular Florida during the Pleistocene, and that competitive exclusion with *Platygonus* and/or *Mylohyus* was not an overriding factor in its Pleistocene distribution.

5:45 **Fox, D., Martin, R., James, H. and Pelaez-Campomanes, P.:** PALEOENVIRONMENTAL CONTEXT OF LATE CENOZOIC MAMMALIAN COMMUNITY EVOLUTION IN THE CENTRAL GREAT PLAINS, U.S.A., BASED ON THE STABLE ISOTOPE COMPOSITION OF PALEOSOL CARBONATES

FOX, David, Univ. of Minnesota, Minneapolis, MN; MARTIN, Robert, Murray State Univ., Murray, KY; HONEY, James, Univ. of Colorado, Boulder, CO; PELAEZ-CAMPOMANES, Pablo, Museo Nacional de Ciencias Naturales, Madrid, Spain

Fossiliferous strata in the Meade Basin (southwest Kansas) preserve numerous superposed mammalian faunas and calcareous paleosols that range in age from Hemphillian to Rancholabrean. The faunas are primarily derived from screen washing and document in detail the development of the small mammal community of the modern grassland ecosystem of the Great Plains. We use the stable carbon ( $\delta^{13}\text{C}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotope composition of more than 500 paleosol carbonates from 12 field areas

to reconstruct temporal and spatial variations in environmental conditions in the Meade Basin. The  $\delta^{13}\text{C}$  value of pedogenic carbonate reflects the proportion of C3 (trees, shrubs, cool-climate grasses) and C4 (warm-climate grasses) plants that grew in an ancient soil and provides a means to reconstruct past mammalian habitats. The  $\delta^{18}\text{O}$  value of paleosol carbonate is sensitive to temperature and aridity and provides a means to monitor climate change.

One Hemphillian section has intermediate  $\delta^{13}\text{C}$  values (-6.8 to -5.9 per mil), implying ca. 25% C4 biomass, as in Miocene paleosols elsewhere in the Great Plains. Blancan and Irvingtonian paleosols have higher mean  $\delta^{13}\text{C}$  values (-5.8 to -1.9 per mil), reflecting a general increase in abundance of C4 biomass and the establishment of C4-dominated grasslands in the region. The proportion of C4 biomass in Blancan and Irvingtonian paleosols varies somewhat both stratigraphically within sections and spatially across individual field areas and the basin as a whole, suggesting maintenance of a mosaic of habitats as open grasslands were becoming established. Paleosol carbonate  $\delta^{18}\text{O}$  values decrease by 3-4 permil from Hemphillian to Blancan sections, which is consistent with well-known global cooling during the onset of northern hemisphere glaciation. No general trend is evident in the Blancan and Irvingtonian  $\delta^{18}\text{O}$  values, and variability within sections probably reflects a combination of variations in both local climate and soil hydrology. These paleoenvironmental data will be used to interpret evolutionary and ecological changes in the small mammal fauna of the Meade Basin, allowing us to link these changes to paleoenvironmental change.

### TECHNICAL SESSION III GOVERNOR'S SQUARE 14

**MODERATORS: JASON HEAD AND JASON ANDERSON**

1:30 **Conrad, J.:** RE-ANALYSIS OF ANGUIMORPH (SQUAMATA: REPTILIA) PHYLOGENY WITH COMMENTS ON SOME PROBLEMATIC TAXA

CONRAD, Jack, Univ. of Chicago, Chicago, IL

Despite increased use of cladistics over the last two decades, the basic structure of the anguimorph phylogenetic tree remains uncertain. Fossil evidence from the major clades in the anguimorph radiation (Xenosauridae, Anguinae, and Platynota) are known by the Late Cretaceous, but how these clades and their constituent groups are interrelated remains unclear. The shinisaur clade adds further complications based on the paucity of fossils and morphological mischaracterization. Taxon sampling and “problematic” taxa also are important issues when reconstructing anguimorph phylogeny. Anguimorpha includes a rich fossil record of terrestrial and aquatic taxa, but usually only one of these categories appears in a given phylogenetic analysis. Mosasauroids rarely appear in analyses with more than two or three other fossil platynotans and Anguinae possesses a diverse but usually overlooked fossil history. The record also includes some “problematic” taxa, such as *Peltosaurus* and *Necrosaurus*, combining plesiomorphic and apomorphic character states. Often, these taxa are excluded from analyses or help to confound them.

With this in mind, I have undertaken a broad-scale phylogenetic analysis of Anguimorpha including 83 ingroup and seven outgroup taxa scored for 220 informative morphological characters. Of the 61 fossil taxa included, previously 26 have been suggested as possessing aquatic adaptations. Possibly due to inclusive taxon sampling, the new analysis yields a phylogenetic hypothesis with some novel topological results, including the placement of “problematic” taxa. *Carusia* and Xenosauridae represent basal anguimorph taxa. *Peltosaurus* is the outgroup to other anguins. *Shinisaurus* and an unnamed Eocene fossil from Wyoming form a clade at the base of Platynota. Inclusion of mosasauroids reveals

that some taxa previously believed to belong to Varanidae lineage are actually basal to the varanid-mosasauroid split. Necrosauridae represents a polyphyletic assemblage of taxa distributed throughout the Platynota.

1:45 **Evans, S., Raia, P. and Barbera, C.:** *CHOMETOKADMON* AND THE EARLY CRETACEOUS LIZARD ASSEMBLAGE OF PIETRAROIA, ITALY

EVANS, Susan, Univ. College London, London, United Kingdom; RAIA, Pasquale, BARBERA, Carmela, Universita di Napoli, Napoli, Italy

Lizards were originally recovered from the Early Cretaceous (Albian) locality of Pietraroia, Italy, more than 150 years ago, although the first find (later named *Costasaurus*) was misidentified as a salamander. The more complete *Chometokadmon* had a similarly confused history. Originally described as a lizard, it was referred to the Rhynchocephalia early last century with the addition of new specimens. This attribution persisted until 1988, when reexamination confirmed that the holotype was a lizard.

*Chometokadmon* has been reassessed as part of a review of the Pietraroia lepidosaurian assemblage. The specimen is well preserved and fully articulated, with procoelous vertebrae, normal body proportions, and elongate hind feet. The skull shows several interesting features, most notably sharp, recurved maxillary teeth; a narrow, elongate parietal; unconstricted upper temporal fenestrae; and a covering of small irregular osteoderms. These remain free of the skull bones and appear to be concentrated on the lateral surfaces, encircling the eyes and investing the temporal region.

Cladistic analysis places *Chometokadmon* firmly within Scleroglossa and, less securely, as the sister taxon of the Middle Jurassic-basal Cretaceous *Parviraptor*, a putative stem-varanoid. If correct, this hypothesis of relationship is consistent with the generally archaic nature of the Pietraroia assemblage. With Tepexi de Rodriguez in Mexico, Pietraroia provides the last record of Laurasian rhynchocephalians, while the squamates include taxa close to *Eichstaettisaurus* and *Ardeosaurus* from the Late Jurassic of Germany. At the time of deposition, the area around Pietraroia formed a small island on the southern edge of the European archipelago. This may explain the apparently relictual character of its fauna.

2:00 **Smith, K.:** THE MIDDLE EOCENE *GEISELTALIELLUS* FROM GEISELTAL AND MESSEL, GERMANY, AND THE EVOLUTION OF CORYTOPHANID LIZARDS (SQUAMATA: IGUANIA)

SMITH, Krister, Yale Univ., New Haven, CT

Iguanian lizards comprise a group notable for the opacity of its higher-level phylogeny and historical biogeography. The natural range of extant pleurodont iguanians currently excludes Europe—most taxa are indeed of the New World—although it includes Madagascar and Fiji, and fossil taxa have been described from the Eocene of Europe. Difficulties including character conflict and the paucity of well-known early Tertiary fossils have conspired to render the broad-scale history of Iguania so intractable. The well-preserved Eocene iguanian *Geiseltaliellus*, known for 60 years from Geiseltal and more recently from Messel (both in Germany), is thus of considerable interest.

*Geiseltaliellus* was originally ecologically compared to the extant *Basiliscus* and has been considered a close relative. Re-examination of known material and a cladistic approach were pursued in this study. Several small differences exist between Geiseltal and Messel specimens of *Geiseltaliellus*, though they share at least one apomorphy. Messel *Geiseltaliellus* is shown to share several derived features with the extant Corytophanidae, including a Y-shaped parietal table and dorsomedial expansion of the postorbital. It displays other features whose evolution in Corytophanidae has previously been ambiguous: an indentation of the orbital rim at the lacrimal-prefrontal junction and a fenestrated



clavicle. Messel *Geiseltaliellus* also possesses a tiny bone, interpreted as the postfrontal, wedged between a dorsally forked postorbital.

Because it retains several primitive features that had further been modified by the time of origin of (crown) Corytophanidae, *Geiseltaliellus* is suggested to lie on the stem that clade. *Geiseltaliellus* thus helps to clarify the morphology hypothesized for the most recent common ancestor of the clade. Its geographic location also strongly suggests that species on the corytophanid stem were once distributed far to the north of the total range of the crown. The support found in this study for its alliance with Corytophanidae, in combination with its early middle Eocene age, renders *Geiseltaliellus* an ideal candidate for the estimation of divergence times in Iguania.

2:15 **Head, J. and Polly, D.: THEY MIGHT BE GIANTS: MORPHOMETRIC METHODS FOR RECONSTRUCTING BODY SIZE IN THE WORLD'S LARGEST SNAKES**

HEAD, Jason, Smithsonian Institution/Queen Mary, Univ. of London, Washington, DC; POLLY, David, Queen Mary, Univ. of London, London, United Kingdom

Body size estimates for fossil snakes based on vertebral size have been previously hampered by intracolumnar variability in vertebral size and difficulty in referring isolated fossil vertebrae to specific regions of the vertebral column. We developed a morphometric method to find the best position of vertebral elements in order to reconstruct body size for the type collection of *Gigantophis garstini* from the late Eocene Fayum, Egypt. To determine the position of *Gigantophis* elements, we constructed a geometric morphometric model of a snake vertebral column based on representatives of alethinophidian higher order lineages. Probability-of-fit distributions were estimated for locations at 5% intervals along the column from extant taxa. Maximum likelihood and discriminate function analysis were used to find the most likely position for each of four *Gigantophis* vertebrae, three of which were located between the posterior 5 to 10 percent of the vertebral column, with the remaining one in the first 15 percent. Regression analysis of body length against vertebral size at these positions in extant taxa predicts a snout-vent length of 8.2 to 9.4 m and total length of 9.3-10.7 m for *Gigantophis*, indicating that it is the largest snake for which such an analysis can be performed. These results, combined with a diverse coeval mammalian fauna, suggest *Gigantophis* preyed on a wide range of large-bodied taxa, including artiodactyls, hyracoids, and basal proboscidiens.

2:30 **Bever, G.: VARIATION IN THE SKULL OF EXTANT TURTLES: IMPLICATIONS FOR THE FOSSIL RECORD**

BEVER, Gabe, Univ. of Texas at Austin, Austin, TX

Over the last ten years, the neontological literature has seen a marked increase in the number of studies that assess and incorporate data on the intraspecific variation in the discrete characters used for phylogenetic analysis. Not surprisingly, few of these studies apply these data to an analysis that includes fossil taxa or draw conclusions regarding how these variations may affect our interpretation of the fossil record. Our current understanding of the phylogenetic relationships and temporal distribution of turtles relies heavily on discrete characters from the cranium and lower jaw. I therefore estimated the implications that an expanded understanding of intraspecific variation in the skull of extant turtles has on phylogenetic hypotheses that include fossil taxa and our ability to identify fossil specimens using an apomorphy-based approach. The extant diversity, availability of adequate specimens in museum collections, and dense fossil record of emydid turtles provides a unique opportunity among turtles to establish patterns of individual, sexual, ontogenetic, and geographic variation. My results indicate that significant intraspecific variation is present in the skull of most extant emydid species and that this

variation places previously unrecognized limits on the phylogenetic and diagnostic resolution of cranial characters alone to the study of fossil turtles.

2:45 **Joyce, W.:** A PHYLOGENY OF TURTLES AND THE AGE OF THE TURTLE CROWN

JOYCE, Walter, Yale Univ., New Haven, CT

This study is the first morphological analysis of turtle relationships that attempts to test the monophyly of numerous groups of turtles by using only single species as terminals and by integrating a large number of primitive fossil taxa. The final data matrix consists of 136 osteological characters with 171 derived character states for 45 fossil and 22 living species of the clade Testudinata.

The results of this analysis corroborate the monophyly of a large number of previously hypothesized clades, but refute the accepted hypothesis regarding the basal split of living turtles. In particular, the primitive turtles *Proterochersis robusta*, *Kayentachelys aprix*, *Mongolochelys efremovi*, *Meiolania platyceps*, and *Kallokibotion bajazidi* are removed from their current position as crown turtles and placed along the phylogenetic stem of this clade. The age of the turtle crown must thus be adjusted from the Late Triassic to the Late Jurassic, a conclusion relevant when testing molecular clock hypotheses. This revised topology has important implications regarding the evolution of several character complexes, because it implies that the common ancestor of all living turtles must have possessed a partially braced brain case and a primitive trochlear mechanism. Other noteworthy results include the tentative exclusion of protostegids from *Chelonioidea*, the placement of *Platysternon megacephalum* outside of *Chelydridae*, and the tentative interpretation of *Sandownia harrisi* as a basal eucryptodire.

3:00 **Gaffney, E. and Tong, H.:** CHANGING VIEWS OF PLEURODIRE EVOLUTION: NEW DISCOVERIES FROM THE CRETACEOUS AND PALEOGENE OF AFRICA

GAFFNEY, Eugene, TONG, Haiyan, American Museum of Natural History, New York, NY

Early in their history, turtles split into two main groups, cryptodires and pleurodires. Although cryptodires are more diverse and better known, both in the recent biota and as fossils, recent work is showing that pleurodires had a more complex and extensive evolutionary history than had been realized. Previously unknown radiations, particularly in the near shore marine realm, are revealed by taxa with diverse cranial morphology, indicating many different feeding and sensory strategies. The pleurodire group that has changed most with new discoveries, is the largest group, the Pelomedusoides, particularly its most diverse family, the Bothremydidae. For example, a genus originally known only from New Jersey, *Taphrosphys*, now has more than ten near relatives based on skulls from the late Cretaceous to Eocene of North Africa. The near-shore marine phosphate sequence of Morocco has been particularly productive, but taxa are also known from Mali, Egypt, and Niger. The group including *Taphrosphys* and its near relatives, are united by a maxilla-quadrato contact, narrow jaws, and an open postorbital wall. They show a great diversity in jaw mechanisms, feeding adaptations, and sensory modifications. Jaw mechanisms involve the increased size of the pterygoideus musculature and the decreased size of the main adductor musculature. Extremes of nasal morphology, with an unknown function, vary from very long, narrow snouts, to wide, telescoped snouts. Skull characters form the core of this phylogenetic analysis, but there are enough associated skull-shell taxa to allow the addition of shell-only taxa into the cladogram, even with large amounts of missing data.

3:15 **BREAK**

3:30 **Anderson, J., Sumida, S., Berman, D., Henrici, A. and Martens, T.:** THE DISSOROPHOID TEMNOSPONDYLS FROM THE EARLY PERMIAN OF BROMACHER, GERMANY

ANDERSON, Jason, Western Univ. of Health Sciences, Pomona, CA; SUMIDA, Stuart, California State Univ. at San Bernardino, San Bernardino, CA; BERMAN, David, HENRICI, Amy, Carnegie Museum of Natural History, Pittsburgh, PA; MARTENS, Thomas, Museum der Natur Gotha, Gotha, Germany

The deposits of the Bromacher Quarry have been interpreted as an important window into terrestrial faunas of the Early Permian. Previously, a single temnospondyl, the trematopid dissorophoid *Tambachia*, has been described from this locality. Here we report on two additional dissorophoids recently discovered. One is a trematopid specimen, a complete skull and partial postcrania, sharing with *Tambachia* an identical premaxillary tooth count, a similar caniniform region at the position of the fourth maxillary tooth, and the unique morphologies of the supratympanic flange and deep furrow separating the basal plate of the parasphenoid from the basipterygoid articulation. The specimen differs from the holotype in having a distinct LEP, and a long subnarial process of the lacrimal, which forms the ventral margin of the external naris for the posterior half of its length. This area in the holotype is poorly preserved, so the unique short subnarial process could be a taphonomic artifact; however the new specimen is about half the size of the holotype so there might be a change in length through ontogeny.

The second dissorophoid is a complete skull of a new species of amphibamid, similar in morphology to *Eoscopus* and *Tersomius*. It has the characteristic amphibamid shortened postorbital area, median rostral fontanel, and LEP present suborbitally, although its complete extent is unknown. This specimen possesses a unique posterior extension of the external naris superficially similar to the trematopid morphology. In the new species this extension is formed by a posterior invagination of the external naris into the lacrimal, while in all trematopids, including juveniles, the posterior extension of the external naris is located along the suture between the nasal and lacrimal. This analogous structure speaks to a similar soft tissue structure, possibly a salt gland, present in both trematopids and amphibamids. This new information is used to produce a phylogenetic analysis of dissorophoid interrelationships and test recent comments on the transitional nature of *Ecolsonia*.

3:45 **Triche, N.: BIOGEOGRAPHY OF FOSSIL AND EXTANT PENGUINS (AVES: SPHENISCIDAE)**

TRICHE, Nina, Univ. of Texas at Austin, Austin, TX

Penguins have one of the longest fossil records of all extant birds (Neornithes), with occurrences ranging from the early Paleocene to recent sub-fossils. Their biogeographic history, therefore, should shed light on a number of interesting problems such as the center of origin of birds or how long-term avian biogeographic patterns change in relation to climatic and tectonic variables. Despite this promising record, there is no current hypothesis of fossil or extant penguin biogeography, owing mostly to the fact that no recent morphologic or systematic synthesis of fossil and extant spheniscids has been attempted. Although much work was done on fossil penguins in the previous century, no consensus was reached regarding the systematic or biogeographic history of the group. Recent fossil discoveries that have significantly extended the temporal and geographic range of penguins can now be combined with more modern cladistic methods into new, synthetic analyses. Despite numerous appeals for a morphological phylogeny in recent descriptive and ecological works, however, any biogeographic hypotheses relating to fossil penguins remain handicapped by the lack of such a study. Therefore, biogeographic work must be based on molecular cladistics until morphology is incorporated into penguin phylogeny; in this context, fossil data is restricted to dating first occurrences in an area and to examining biogeographic patterns not reliant on cladistic biogeography.

Cladistic analysis based on existing molecular phylogenies is applied here to test the origin and dispersal history of the Spheniscidae. This dispersal is related to the opening of southern seaways such as Drake's Passage and the Tasman Sea. The distributions of fossil taxa combined with tectonic data

indicative of the timing of the breakup of Gondwana are used to constrain the origin and dispersal history of the group. Biogeographic patterns of fossil penguins permit tests of Bergman's Rule over a large latitudinal gradient and support recent suggestions that Neornithes has a Gondwanan origin.

4:00 **Hill, R.:** MORPHOLOGICAL AND HISTOLOGICAL DIVERSITY IN THE INTEGUMENT OF EXTANT AND FOSSIL CINGULATES (MAMMALIA: XENARTHRA)

HILL, Robert, Philadelphia Univ., Philadelphia, PA

Because the integument (skin and its associated structures) consists primarily of soft tissues, it is frequently disregarded in morphological studies that include fossils. Osteoderms (skin bones) provide an exceptional opportunity to study the integument in both extant and extinct forms. Among mammals, osteoderms are known only in xenarthrans, being morphologically most elaborate in the large Pleistocene glyptodonts of South and North America, and in modern armadillos (*Dasypodidae*).

Osteoderms of modern armadillos are physically associated with a variety of soft tissues including nerve, muscle, epithelium, and connective tissue. Certain soft tissue complexes are consistently associated with definite osteological structures, and therefore represent a relatively robust foundation upon which to base soft-tissue reconstructions of extinct xenarthrans. For instance, large circular pits on the external surfaces of armadillo osteoderms house hair follicles with associated large apocrine glands. In most cases, a single, primary foramen transmits a neurovascular bundle through the base of each osteoderm. Fibrous connective tissue spans the region between adjacent osteoderms. Assignment of specific osteological correlates remains ambiguous in many cases, however, because bony features of osteoderms may be influenced by more than one soft tissue. Examples include secondary pits on the internal surfaces of osteoderms, which may be associated with lymphatics, blood vessels, or pressure-sensitive nerve endings (lamellated corpuscles).

The osteoderms of glyptodonts exhibit greater morphological diversity than do those of armadillos, rendering some soft tissue reconstructions problematic. Although hair follicles and fibrous joints may be inferred for the osteoderms of some glyptodonts, the origin and biological significance of other structures, such as reticulating sulci in *Panochthus* and perforating canals in *Doedicurus*, remains ambiguous and should be interpreted with caution. Inclusion of new anatomical data on the integument into morphology-based cladistic analyses increases resolution and reveals previously hidden phylogenetic signals.

4:15 **Kalthoff, D.:** DENTAL MICROSTRUCTURES IN FOSSIL AND RECENT XENARTHRA (MAMMALIA)

KALTHOFF, Daniela, Universitat Bonn, Bonn, Germany

The xenarthrans are a group of mainly South American mammals that first occurred in the fossil record in the late Paleocene. They include today the sloths (*Phyllophaga*), the armadillos (*Cingulata*) and the toothless anteaters (*Vermilingua*). Based on recent morphological and molecular data, the xenarthrans are phylogenetically distinct from any other known mammal group, living or fossil. The reason for their isolated position in mammal systematics is a number of enigmatic morphological features, one of which is the total loss of tooth enamel in all members but the earliest armadillos. To compensate for this 'disadvantage' the xenarthrans have developed ever-growing teeth with a layered composition of different dentine types and cementum. This enables them to have teeth with functionally structured wear facets like other mammals. This survey compares patterns of internal dental design of various representatives of xenarthrans including glyptodonts, megatheres and mylodontids. These microstructures are significant both for biomechanics and determining relationships among xenarthrans.

4:30 **Labs-Hochstein, J. and MacFadden, B.:** WHAT ARE EDENTATE (XENARTHRA) TEETH MADE OF ANYWAY? MINERALOGY AND CHEMICAL COMPOSITION OF EDENTATE TEETH AND IMPLICATIONS FOR DIET RECONSTRUCTION

LABS-HOCHSTEIN, Joann, MacFADDEN, Bruce, Florida Museum of Natural History, Gainesville, FL

Edentata (Xenarthra) are characterized by a lack of enamel. Using SEM and polarized light, previous studies have determined that most edentates have orthodontine with central modified-orthodontine and varying degrees of cementum. The only exceptions are glyptodonts, which have orthodontine but the central tissue is similar to osteodontine. Unlike most placental herbivores that mineralize their teeth by adulthood, edentates have ever growing teeth; therefore proxy archives of diet and habitat could potentially be determined for a longer growth period. Previous studies of isotopic archives of fossil mammal teeth have concentrated on enamel, which has been shown to be a closed system not prone to diagenesis. The problem is that Edentates do not have enamel, so the questions that we address are: (1) how do edentate teeth differ mineralogically and chemically from enamel and; (2) how does potential diagenesis affects the stable isotopes archived in fossil Edentate teeth? Fourier transform infrared spectroscopy (FT-IR) and laser ablation inductively couple mass spectroscopy (LA-ICPMS) allows for the quantification of the mineralogical and chemical differences between modern and fossil Edentate teeth, and modern and fossil enamel. Once this is accomplished, the degree of diagenesis in fossil Edentate teeth relative to enamel can be assessed. An understanding of the diagenetic changes that occur in fossil edentate teeth is a critical prerequisite to interpreting the stable isotopic signatures for diet and habitat reconstruction.

4:45 **Reynolds, R.:** MIOCENE CAT TRACKS IN THE MOJAVE DESERT OF CALIFORNIA

REYNOLDS, Robert, LSA Associates Inc, Redlands, CA

Feliform footprints (*Felipeda*) are distinguished from caniform (*Canipeda*) prints by the circular metacarpal/metatarsal pad and ovoid digital pads. Claw marks are often absent. The Barstow Formation contains two sizes of *Felipeda* tracks. One is the size of a bobcat; the other is puma sized and is attributed to *Pseudaelurus sinclairi*. Like modern bobcat and puma, they are slightly wider than long, but dimensions vary depending on the substrate and type of motion of the cat. A recently located *Felipeda* trackway panel from Owl Canyon in the Barstow Formation allows description of the pace and stride of the smaller cat. The small cat tracks are associated with tracks of the larger *Pseudaelurus* and with small (protolabine? and miolabine?) camel tracks. This trackway panel is a few meters above the Skyline Tuff (14.8 Ma) and skeletal remains of the small cat have been reported higher in the section.

Tracks from the Copper Canyon locality in Death Valley suggest that four *Felipeda* ichnogenera were present by late Miocene, mid-Hemphillian LMA (7 Ma) time. Two are smaller than the small cat from Barstow, and two are similar in size to the puma-size Barstow cat. Of the larger, only one has similar morphology to the Barstow *Pseudaelurus* track.

5:00 **Taylor, T., Liebig, P. and Flessa, K.:** DETERMINING THE BIASES IN THE MARINE MAMMAL FOSSIL RECORD: TAPHONOMY OF THE NORTHERN GULF OF CALIFORNIA, MEXICO

TAYLOR, Ta-Shana, LIEBIG, Pennie, FLESSA, Karl, University of Arizona, Tucson, AZ

What preservational biases are present in the marine mammal fossil record? In order to answer this question, I surveyed the marine mammal death assemblage of the northern Gulf of California to determine how well the death assemblage reflects the diversity, species composition, and proportion of bone types in the living fauna. I found 781 bones and 9 carcasses among 236 sites along 13.5km of shoreline. I found remains of 9 of the 18 species known in the northern Gulf of California: *Zalophus*

*californianus* (12 skulls), *Phocoena sinus* (11 skulls), *Tursiops truncatus* (9 skulls), *Delphinus capensis* (9 skulls), *Balaenoptera physalus* (two skulls), *Pseudorca crassidens* (one skull), *Kogia breviceps* (one skull), and a possible *Mesoplodon* sp. (one skull). Two *Physeter macrocephalus* were identified in two separate locations, one by skull fragments and one by its large vertebrae. Coastal species are better represented than open water species. The maximum skeletal ratio of skull:vertebrae:ribs:phalanges:girdle/limbs in a marine mammal is 1:74:30:68:16. I found 47 skulls and 734 post-cranial bones, and a skeletal ratio of 1:12:3:1:1. Although vertebrae are the most common bones in the assemblage, all post-cranial skeletal elements are under-represented. Therefore, skulls provide the best estimate of the minimum number of individuals. I observed nine carcasses of marine mammals in the northern Gulf of California, several of which were observed in consecutive years. I compared the decay patterns of Gulf of California marine mammal remains to the decay pattern of human and marine mammal remains and I identified six decay stages for the carcasses: 1) Fresh/Bloat; 2) Intact Mummy; 3) Skull/Tail Exposure; 4) Body Breach; 5) Disarticulated Bones; and 6) Scattered Bones. Based on published descriptions of whale and human decay, I estimate that carcasses may persist on the northern Gulf of California beaches for 6-22 years. Marine mammal remains are common within the 11% of the northern Gulf of California shoreline surveyed, and provide a remarkably good sample of the living fauna.

5:15 **Foss, S., Lucas, S., Fremd, T., Lander, E., Mihlbachler, M. and Hanson, C. B.:** REANALYSIS OF THE EOCENE HANCOCK MAMMAL QUARRY LOCAL FAUNA (CLARNO FORMATION, NORTH-CENTRAL OREGON)

FOSS, Scott, John Day Fossil Beds National Monument, Kimberly, OR; LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM; FREMD, Theodore, John Day Fossil Beds National Monument, Kimberly, OR; LANDER, E. Bruce, Paleo Environmental Associates, Altadena, CA; MIHLBACHLER, Matthew, American Museum of Natural History, New York, NY; HANSON, C. Bruce, Richmond, CA

The Hancock Mammal Quarry (Clarno Formation, Wheeler County, OR) has yielded a taxonomically diverse megafauna that includes: *Hemipsalodon*, *Haplohippus*, *Epihippus*, *Protapirus*, "*Procadurcodon*," *Telataceras*, *Protitanops*, *Achaenodon*, *Heptacodon*, *Agriochoerus*, Nimravidae n.sp., and Aligatoridae n.sp. Recent investigations into this local fauna (HMQ LF) have resulted in the recognition of new large mammal family, the reidentification of some taxa, and a reconsideration of the age of the HMQ LF. A morphologically unique bunodont artiodactyl is provisionally identified as *Achaenodon* n. sp., "*Procadurcodon*" n. sp. is probably a new genus (and thus its biochronological significance in the HMQ LF is uncertain), and specimens previously identified as *Diplobunops* are reassigned to *Agriochoerus*.

The HMQ LF is unusual because the fauna consists of North American endemic taxa (*Protapirus*, *Epihippus*, and *Achaenodon*) of Uintan age, and Asian immigrant taxa (*Hemipsalodon*, *Telataceras*, and *Heptacodon*) that do not appear elsewhere in North America until the Duchesnean. The HMQ local fauna has long been assigned either a Duchesnean or Chadronian age. The same species of *Agriochoerus* is also found in the Randlett LF of Utah, supporting an early Duchesnean age, whereas *Achaenodon* is only known from Uintan deposits. Radioisotopic ages from the welded tuff at the base of the overlying John Day Formation indicate the HMQ LF is older than ~ 39 Ma. The new identifications and a review of the temporal distribution of HMQ LF mammal taxa support an assignment for the HMQ LF that is near the Uintan/Duchesnean boundary, probably latest Uintan.

5:30 **Moore, J.:** WHAT IS THE TRUE BIODIVERSITY OF THE ORELLAN SADDLE PASS MARKER FAUNA? THE EFFECTS OF TAPHONOMY ON THE PRESERVATION OF ABUNDANCE IN AN OLIGOCENE MAMMALIAN DOMINATED FAUNA

MOORE, Jason, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom

The biodiversity of a fauna is calculated using both species richness (number of different species) and species evenness (how the total number of individuals in the fauna is distributed between those species). The determination of the species richness of a fossil fauna is relatively simple, but that of the species evenness is much more complex. In order to calculate this, the percentage abundances of each taxon within a fauna must be known. There are large numbers of taphonomic, taxonomic, sedimentological and geographical factors which affect the preserved abundances of taxa within a fossil assemblage and the magnitude of each of these biasing factors must be quantified and corrected for before species evenness can be determined. The Saddle Pass Marker horizon is found within the middle Scenic Member of the Brule Formation (White River Group). It is primarily fluvial in origin with a strong pedogenic overprint and contains an abundant mammalian fauna similar to that known from many of the famous studies of the Scenic Member. Compared with the more fossiliferous lower Scenic Member, the Saddle Pass Marker has been subject to little previous study. As this means that the abundances of fossils within this horizon have not been significantly affected by prior collection, it is possible to accurately calculate the biodiversity of the Saddle Pass Marker fauna.

Samples representing more than 500 individuals were taken from four exposures of the Saddle Pass Marker in Badlands National Park, South Dakota. Detailed taphonomic, sedimentological and geographical data were taken for each specimen. By using these data with multivariate statistical techniques the magnitudes of the different biasing factors on the percentage abundances of the Saddle Pass taxa were calculated. The most significant biases observed were those against the preservation of smaller and less dense elements, but several other factors, including the facies of preservation, were also important. Correcting for these biases makes accurate, detailed comparison with modern faunas by both biodiversity and trophic category possible.

5:45 **Fajardo, R., Müller, R., Ketcham, R. and Colbert, M.:** A 3D INVESTIGATION OF THE MUTUAL ASSOCIATIONS OF TRABECULAR ARCHITECTURE AMONG ANTHROPOID PRIMATES: DO STRUCTURAL CONSTRAINTS ON FEMORAL NECK TRABECULAR ARCHITECTURE EXIST?

FAJARDO, Roberto, Beth Israel Deaconess Medical Center / Harvard Medical School, Boston, MA; Müller, Ralph, Institute for Biomedical Engineering ETH and University Zurich, Zurich, Switzerland; KETCHAM, Richard, COLBERT, Matthew, Univ. of Texas at Austin, Austin, TX

It is unexpected, but unknown, if constraints exist on trabecular bone structure. Do species build a bony lattice with similar structural features (e.g., strut thickness, shape of trabeculae) given the same amount of bone? This study analyzed the mutual associations of cancellous bone architecture in anthropoid primates.

The proximal femora of *Macaca fascicularis*, *Alouatta seniculus*, *Colobus guereza*, *Symphalangus syndactylus*, and *Papio cynocephalus* specimens were scanned using a high-resolution CT scanner. Volumes of interest were defined within the proximal neck and equaled 15% of the femoral neck length. The variables calculated within each specimen's volumes of interest included the bone volume fraction (BV/TV), structural model index (SMI), degree of anisotropy (DA), trabecular thickness (Tb.Th), trabecular number (Tb.N), trabecular separation, and connectivity density. Correlations between BV/TV and the other variables were determined.

Intraspecific analyses consistently indicated that SMI (indicator of rod-like or plate-like shape of trabeculae) inversely correlated with BV/TV (range of  $r = -0.60$  to  $-0.88$ , for all species  $p < 0.05$ ). BV/TV

correlated with Tb.Th in *S. syndactylus* ( $\rho = 0.71$ ,  $p = 0.04$ ) but not Tb.N. BV/TV correlated with Tb.N in most other anthropoid species (*M. fascicularis*, *A. seniculus*, and *C. guereza*, range of  $r = 0.73$  to  $0.91$ , for these species  $p < 0.01$ ) but not Tb.Th. Intraspecific and interspecific results were not similar. PGLS correlation tests indicated that SMI inversely correlated with BV/TV in male anthropoids ( $r = -0.90$ ,  $p < 0.05$ ) but not in females. Unlike the intraspecific data, the DA correlated with BV/TV (males  $r = 0.83$ , females  $r = 0.83$ , for both groups  $p < 0.05$ ). These trends were not size-related.

This study suggests flexibility in the construction of anthropoid femoral neck trabecular architecture. Only one consistent intraspecific structural correlation obtains, and intraspecific patterns are generally not reflected interspecifically, implying that trabecular bone architecture in the femoral neck is species-specific. The trabecular bone lattice can be built in more than one way.





pattern of microwear. It is herein proposed that, in addition to the current interpretation of vertical slicing, ceratopsids also engaged in an anisognathous palinal power stroke.

8:30 **Makovicky, P., Norell, M. and Xu, X.:** BASAL CERATOPSIANS FROM CHINA AND MONGOLIA WITH A REAPPRAISAL OF BASAL CERATOPSIAN RELATIONSHIPS

MAKOVICKY, Peter, The Field Museum, Chicago, IL; NORELL, Mark, XU, Xing, American Museum of Natural History, New York, NY

After many decades of stasis, our knowledge of early ceratopsian diversity has increased dramatically over the last few years. Not unexpectedly, this development has resulted in a number of conflicting phylogenetic hypotheses for the basal part of the tree. One taxon with a contentious phylogenetic position is *Chaoyangsaurus*, from the Tuchengzhi Formation of Liaoning, which has been variously posited as a basal neoceratopsian or as basal to the neoceratopsian-psittacosaurid clade. Another recent debate relates to whether leptoceratopsids fall within or outside of Coronosauria. Although differences in the number and composition of characters account for some of the discord, much of it is due to disagreements on the definition and coding of a few select characters, as well as taxon sampling. In order to address the points of contention, pertinent anatomical details of important basal taxa including *Chaoyangsaurus*, *Liaoceratops* and two undescribed species from China and Mongolia will be presented. The two new taxa provide further insights regarding character state distributions and taxonomic diversity at the base of Ceratopsia and Neoceratopsia, respectively.

8:45 **Smith, J., Sampson, S., Roberts, E., Getty, M. and Loewen, M.:** A NEW CHASMOSAURINE CERATOPSIAN FROM THE UPPER CRETACEOUS KAIPAROWITS FORMATION, GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, UTAH

SMITH, Joshua, SAMPSON, Scott, ROBERTS, Eric, GETTY, Michael, LOEWEN, Mark, Univ. of Utah Utah Museum of Natural History, Salt Lake City, UT

Recent fieldwork in the Upper Cretaceous (Campanian) Kaiparowits Formation, Grand Staircase-Escalante National Monument, southern Utah, has produced well preserved remains of a new chasmosaurine ceratopsian dinosaur. Three partial specimens of this new taxon have thus far been recovered, including a nearly complete, fragmented skull associated with approximately 48% of the postcranial skeleton. Chasmosaurine synapomorphies include: elongate facial skeleton; preentary with subhorizontal cutting surface; and relatively elongate, triangular squamosal. This new taxon can be diagnosed by a suite of autapomorphies. Most distinctive are the supraorbital horncores, which project dorsolaterally, a conformation otherwise unknown among ceratopsids. These horncores are also abbreviated and rostrocaudally compressed, with an overall oblate morphology. Additional autapomorphic features include D-shaped epijugals and elliptical orbits with the long axis vertically inclined. Within Chasmosaurinae, the new Utah taxon is relatively basal, sharing the following characters with *Pentaceratops*: hypertrophied, caudally directed epijugal; subrectangular parietosquamosal frill; and rostradorsally curved P1 (medialmost) epoccipital.

Stratigraphically, multiple specimens of this new chasmosaurine occur in the lower to middle portion of the Kaiparowits Formation, between 75–400 m. New radiometric evidence, based on multiple ash layers, brackets these beds between about 76.0 and 75.0 Ma. *Pentaceratops*, in contrast, is restricted to the uppermost Fruitland Formation and the Kirtland Formation, from beds dated between approximately 74.5 and 74.1 Ma. These dates suggest that the Kaiparowits taxon immediately preceded *Pentaceratops* temporally.

9:00 **Meng, Q., Varricchio, D., Liu, J., Huang, T. and Gao, C.:** AN UNUSUAL *PSITTACOSAURUS* SPECIMEN FROM THE LOWER CRETACEOUS YIXIAN FORMATION (LIAONING PROVINCE, CHINA) AS EVIDENCE FOR PARENTAL CARE

MENG, QingJin, Dalian Natural History Museum, Dalian, China; VARRICCHIO, David, Montana State Univ., Bozeman, MT; LIU, JinYuan, Dalian Natural History Museum, Dalian, China; HUANG, Timothy, PaleoWorld Research Foundation, Taipai, China; GAO, ChunLing, Dalian Natural History Museum, Dalian, China

The Lower Cretaceous YiXian Formation of China has produced a now famous collection of vertebrate fossils. The most common mode of preservation consists of complete to near complete skeletons flattened on thin lacustrine laminae often with remnants of the integument or body outlines. A second preservational mode occurs within more massively bedded, muddy units. These specimens lack integumentary remains and consist of small dinosaur skeletons fully articulated in three-dimensional near life positions. Typically, the vertebral column rests dorsal-side up with the ribcage intact and limbs folded beneath the torso or to the side. A new specimen, Dalian Natural History Museum D2156, consists of a tight aggregation of one adult and 34 juvenile *Psittacosaurus* sp., all exhibiting this second preservational mode. These complete skeletons lie concentrated within an area of 0.25 m<sup>2</sup> and although individuals commonly overlap, skulls remain uncovered by other skeletons. More peripheral individuals sit higher in the substrate than those at the center suggesting an original bowl-shaped depression. The adult skull measures 115 mm long and those of juveniles roughly 40 mm; total body length of juveniles is 21 cm. The size and degree of ossification of juveniles indicate that they are significantly older than hatchlings. Absence of weathering, disarticulation, scavenging or other disturbance argues for minimum post-mortem exposure. Further, life positions rule out hydraulic concentration and may indicate entombment while alive. Sedimentologic and geochemical analyses may provide clues to this burial history. Both groups of living archosaurs, crocodylians and birds, exhibit post-hatching care of young, but their radically different physiology, behavior and ecology question a homology of parental care between the two groups. Nevertheless, the close association of adult and young in this *Psittacosaurus* specimen suggests post-hatching parental care and would support parental care as plesiomorphic for archosaurs.

9:15 **Sues, H.-D. and Averianov, A.:** DINOSAURS FROM THE UPPER CRETACEOUS (TURONIAN) OF DZHARAKUDUK, KYZYLKUM DESERT, UZBEKISTAN

SUES, Hans-Dieter, National Museum of Natural History, Washington, DC; AVERIANOV, Alexander, Russian Academy of Sciences, St. Petersburg, Russian Federation

Middle-late Turonian fluvial strata at Dzharakuduk in the Kyzylkum Desert of Uzbekistan have long been known as a source of remains representing a diverse assemblage of dinosaurs, primarily due to the collecting efforts of the late Lev A. Nessonov. Recent field-work has greatly augmented this fossil record in terms of taxonomic diversity and anatomical representation of known taxa. There are now thousands of isolated but typically excellently preserved bones and teeth. They include the remains of probably neonate individuals for a number of dinosaurian taxa. Non-avian theropod dinosaurs are represented by Dromaeosauridae, Ornithomimosauria, Oviraptorosauria, Therizinosauroida, Tyrannosauroida, and several forms of uncertain affinities. To date, there is no record of Troodontidae. The dromaeosaurid *Itemirus* is now known from several braincases, and we refer teeth and postcranial bones to this taxon. It reached a size similar to that of *Utahraptor*. A medium-sized tyrannosauroid is characterized by labiolingually distinctly flattened teeth. Therizinosauroida is documented by abundant remains. A braincase originally assigned to *Turanoceratops* is probably therizinosauroid. A diplodocoid sauropod is represented by numerous pencil-like teeth and some postcranial bones. Abundant cranial and postcranial

elements indicate the presence of at least one taxon of large iguanodontoid ornithomimid. Additional ornithomimid taxa include an ankylosaurid and the basal neoceratopsian *Turanoceratops*. The dinosaurs from Dzharakuduk are of great interest as they represent a lowland community that existed along the western margin of Asiamerica during the early Late Cretaceous. There are faunal similarities to the upper part of the Bain Shire Formation of Mongolia and Iren Dabasu Formation of Nei Mongol (China).

9:30 **Farke, A.:** NOT JUST FOR LOOKS: FENESTRATION IN THE CERATOPSIDAN DINOSAUR FRILL AND IMPLICATIONS FOR EVOLUTIONARY MORPHOLOGY

FARKE, Andrew, Stony Brook Univ., Stony Brook, NY

A bony frill composed of the parietal and squamosals contributes to over 50 percent of total skull length in many ceratopsid dinosaurs. Recent work has emphasized the probable role of the frill in visual display. However, it also served as an anatomical origin for jaw musculature. Given the extent of vascular impressions on the frill's dorsal surface, muscles did not extend far beyond the supratemporal fenestrae in ceratopsids such as *Triceratops* and *Chasmosaurus*. Stress created by jaw muscles within the bone of the frill may have influenced frill morphology. Specifically, variability in the parietal fenestrae may reflect a response to such stresses. I modeled stress distribution in the frill of *Chasmosaurus* using finite element analysis (FEA), approximating the relatively planar frill as a two-dimensional structure. Two computer models, one with parietal fenestrae and one without, were identically loaded at the supratemporal fenestrae to simulate the pull of the jaw adductor muscles. Stress distribution throughout the frill was calculated using FEA, assuming standard bone material properties and an estimate of muscle force. In the unfenestrated frill, stresses were concentrated at the frill's rostral end. Fenestrae substantially changed stress distribution; stress was decreased in the rostro-lateral part of the frill, but increased on the lateral and caudal margins of the parietal fenestrae. Thus, the fenestrae redistributed bone stresses from the anterior part of the frill to around the fenestral margins. If these mechanical effects occurred in vivo, they may have had an impact on the evolution of frill morphology. In addition to stress distribution, the parietal fenestrae may have significantly reduced skull mass in the largest ceratopsids. However, this probably wasn't a factor in smaller animals such as *Protoceratops*. Ceratopsid frill evolution likely reflects a balance between the distribution of masticatory stress, frill strength, skull weight, and display needs.

9:45 **Padian, K., Horner, J. and Dhaliwal, J.:** SPECIES RECOGNITION AS THE PRINCIPAL CAUSE OF BIZARRE STRUCTURES IN DINOSAURS

PADIAN, Kevin, Univ. of California Berkeley, Berkeley, CA; HORNER, John, Montana State Univ., Bozeman, MT; DHALIWAL, Jasmeet, Univ. of California, Berkeley, CA

The evolution of the bizarre cranial structures and postcranial dermal armor of Mesozoic dinosaurs has been explained in two general ways: function and display. Functional explanations (and some display explanations) relate to natural selection; most display explanations relate to sexual selection. Display hypotheses segregate into intraspecific (attracting mates, repelling rivals) and interspecific (warning potential predators, etc.). Using phylogenetic, histological, and functional evidence, we show that neither selective regime accounts very well for the known patterns. Variations in bizarre structures within a clade do not fit a pattern consistent with a single functional explanation; rather, individual dinosaurs have generally been interpreted in *ad hoc* terms that do not extend evolutionarily to related forms. Sexual dimorphism in dinosaurs has been demonstrated in some cases, but when it has, it seldom goes beyond the kind of size differences seen in living reptiles (such as crocodiles and monitor lizards) and mammals, in which the unusual structures in question are rarely used in agonistic combat or display.

We propose instead that the observed bizarre structures in dinosaurs can be explained more generally by species recognition, a phenomenon supported both by fossil and recent evidence. The expected morphological patterns of species diversification differ sharply between the causes of selection (whether natural or sexual) and species recognition. The first ordinarily results in linear trends; the second evinces no particular pattern except differentiation. This pattern is seen in guilds of living ungulates. Its inference is most strongly supported when several closely related species are sympatrically present, or can be shown to have been recently present as ghost taxa.

10:00 **BREAK**

10:15 **Salisbury, S. and Frey, E.:** THE EPAXIAL MUSCULATURE OF FOSSIL CROCODYLIANS

SALISBURY, Steven, The Univ. of Queensland, Brisbane, QLD., Australia; FREY, Eberhard, Staatliches Museum für Naturkunde Karlsruhe, Karlsruhe, Germany

All eusuchian crocodylians have a sagittally segmented dorsal osteodermal skeleton, comprising a tetraserial paravertebral shield and, in non-gavialoid forms, at least one sagittal row of accessory osteoderms. This tetraserial configuration is in contrast to the biserial condition seen in other crocodylians, except for *Bernissartia fagesii*, the Glen Rose crocodylian, the Las Hoyas crocodylian, dyrosaurids and possibly some notosuchids.

Material referable to the Early Cretaceous atoposaurid *Brillianceausuchus babouriensis* from northern Cameroon is shown to preserve the remnants of soft tissue. On the internal surface of osteoderms from the lumbosacral region of the paravertebral shield, a meshwork of decussating lineations is interpreted as fossilized collagen fibre bundles from the insertion aponeuroses of the lateral two subsystems of the epaxial musculature -- the m. latissimus dorsi and the m. tendinoarticularis. Similar fibres are also present on the paravertebral osteoderms of *Goniopholis crassidens*, a goniopholidid from the Early Cretaceous of western Europe. In *G. crassidens*, none of these lineations are present on or lateral to the groove for the reception of the articular process of the following osteoderm, indicating that the lateral portion of each osteoderm was not connected to the underlying musculature.

The attachment of the epaxial musculature to the paravertebral osteoderms of extant crocodylians is characteristic of a bracing system that can be considered analogous to a longitudinally cross-braced I-beam carrier. Evidence for the attachment of the epaxial musculature to the paravertebral osteoderms in *B. babouriensis* and *G. crassidens* indicates for the first time that the bracing system of fossil crocodylians with a biserial paravertebral shield can also be regarded in this context, and further enables the reconstruction of the topography of the axial trunk muscles. The operation of the bracing system under specified mechanical regimes and subsequent hypotheses concerning the locomotor capabilities of these fossil crocodylians can thus be assessed using direct evidence.

10:30 **Weinbaum, J.:** THE SKULL OF *POSTOSUCHUS KIRKPATRICKI* AND ITS SIGNIFICANCE FOR A RELATIONSHIP WITH CROCODYLOMORPHS

WEINBAUM, Jonathan, Texas Tech Univ., Lubbock, TX

*Postosuchus* was an apex predator in North American terrestrial ecosystems during the Late Triassic Period, when rauisuchids like *Postosuchus* represent the largest predators, reaching lengths of 9-10 meters. Recent phylogenetic analyses of extinct suchian archosaurs have used *Postosuchus kirkpatricki* as the outgroup to crocodylomorphs. However, since these analyses have been based on characters from previous descriptions of *Postosuchus*, they are dubious because many details of the holotype skull of *Postosuchus*, TTUP-9000, had been obscured by plaster, wire mesh, and paint.

Subsequent preparation of the type material by the author has revealed an almost complete, well-preserved skull that differs significantly from previous descriptions. For this study, all other known *Postosuchus* skull material was examined as well. The bifurcated infratemporal fenestra is confirmed. New or undescribed details of the skull include: the sutural articulations of the maxilla, nasal, frontal, lacrimal, prefrontal, and jugal/quadratojugal are significantly different than previously recognized, the presence of sculpture on numerous dermal skull elements, a complex and enlarged olfactory system, and the shape of the mandibular fenestra. Other characters are shared between *Postosuchus* and crocodylomorphs, including; a highly reduced prefrontal with a descending process, a squamosal with a broad lateral expansion over the temporal region, the contact of the quadratojugal with the postorbital, and the jugal excluded from the posterior margin of the antorbital fenestra. These synapomorphies and other characters, strongly indicate a sistergroup relationship of *Postosuchus* and related rauisuchid archosaurs with crocodylomorphs.

10:45 **Brochu, C.:** ALLIGATORINE PHYLOGENY, THE LAW OF THE UNSPECIALIZED, AND THE STATUS OF *ALLOGNATHOSUCHUS* MOOK, 1921

BROCHU, Christopher, Univ. of Iowa, Iowa City, IA

Many Late Cretaceous and Tertiary alligatorines were small in size and had comparatively short snouts and molariform dentition, suggesting specialized ecology compared with modern *Alligator*. That specialists evolve from generalists, but not the other way around, is frequently assumed; but in this case, phylogenetic analysis of living and fossil alligatoroids, including characters reflecting dental morphology, indicates that the 'specialized' condition found in early alligatorines is plesiomorphic for the clade. These results also reaffirm the nonmonophyletic status of the most common generic name given these fossils, *Allognathosuchus*. The type species (Bridgerian *A. polyodon*) is closer to *Alligator* than to "*Allognathosuchus*" from Europe or the North American Paleocene, and a close relationship with other fossils sometimes referred to *Allognathosuchus* (e.g. *Wannaganosuchus*, *Albertochampsia*, *Chrysochampsia*, *Arambourgia*) is not supported. The name *Allognathosuchus* should be applied in a restricted sense to *Allognathosuchus polyodon* and its closest relatives. These results support multiple dispersal events of alligatorines from North America to Eurasia and suggest that the generalized morphology characterizing extant *Alligator* is secondarily derived from a more specialized condition, possibly coincident with the disappearance of other generalized crocodylians from North America toward the end of the Eocene.

11:00 **Whatley, R. and Buckley, G.:** A HATCHLING CROCODYLIFORM FROM THE UPPER CRETACEOUS MAEVARANO FORMATION, MADAGASCAR

WHATLEY, Robin, Univ. of California, Santa Barbara, CA; BUCKLEY, Gregory, Roosevelt Univ., Schaumburg, IL

A complete articulated hatchling crocodyliform has been recovered from the Upper Cretaceous Maevarano Formation, Mahajanga Basin, northwestern Madagascar. This exceptionally preserved fossil represents the earliest known ontogenetic stage in the local crocodyliform fauna, which consists of at least 7 ecologically diverse taxa.

The hatchling skull is narrow in dorsal view and the snout shorter than the orbital and postorbital regions combined. All cranial external surfaces are smooth and devoid of any sculpturing except for a central dorsal ridge separating the frontals. Prominent, fused supraorbital bones hood laterally facing orbits. A relatively large external naris is anterodorsally placed, and a small, bony process, reminiscent of the egg tooth seen in modern hatchling crocodylians, is present on the extreme anterodorsal surface of the left premaxilla. The strongly festooned upper jaw bears at least ten moderately heterodont teeth,

which extend posteriorly under the orbit. Premaxillary teeth closely interlock with anterior dentary teeth, all of which are lingually curved. The third tooth posterior to the premaxilla-maxilla boundary is the largest tooth in the dentition and differs from anterior teeth in being broad at its base, labio-lingually compressed with longitudinal fluting, and bearing carinae on its anterior and posterior margins. Directly below the small antorbital fenestra, a distinct notch in the maxilla accepts a short, broad dentary tooth. Long, gracile limbs suggest a more terrestrial life habit; the hindlimb is notable in having proximal and distal elements approximately equaling the length of the pes. Distal forelimb elements are slightly longer than the humerus, and the manus has well-developed proximal carpals and short phalanges.

This specimen may represent a very young individual of what has preliminarily been identified as a peirosaurid, a poorly represented taxon (only known from two premaxillae and a partial maxilla) in a fauna distinguished by abundant material from other crocodyliforms. Remarkable preservation permits the examination of ontogenetic features rarely observed in fossils.

11:15 **Turner, A.:** A NEW SPECIES OF *ARARIPESUCHUS* (CROCODYLIFORMES) FROM THE LATE CRETACEOUS OF MADAGASCAR

TURNER, Alan, Univ. of Iowa, Iowa City, IA

The Late Cretaceous crocodyliform fauna from the Maevarano Fm, Mahajanga Basin, is noted for its extreme diversity, with at least seven taxa identified. The fauna includes the large-bodied *Mahajangasuchus*, the bizarre pug-nosed *Simosuchus*, a long-snouted form, as well as the small-bodied *Araripesuchus*.

Here I report a new species of *Araripesuchus* present in the Maevarano Fm. The taxon is known from at least five specimens, including a nearly complete individual, three partial skulls, and associated post-cranial remains. This large sample, coupled with CT-scans, allows a detailed description of its morphology. The new form shares a number of derived characters with *Araripesuchus gomesii* and *Araripesuchus patagonicus*, but is distinguished from them by the presence of four autapomorphic characters (e.g. hypertrophied 10th dentary tooth, nasals not contacting the lacrimal, premaxilla forms little of the internarial bar, retroarticular process projecting from the dorsal part of the mandible and attenuating). Additionally, the new form lacks a number of derived features present in *A. gomesii* and *A. patagonicus*, including a groove on the ventral surface of the choanal septum.

Phylogenetic relationships of *Araripesuchus* are evaluated using a parsimony analysis of 127 characters and 28 mesoeucrocodylian taxa. In all most parsimonious trees the new taxon is recovered as sister to *A. gomesii* + *A. patagonicus*. *Araripesuchus* is diagnosed by four unambiguous synapomorphies (e.g. frontals extend only slightly into the supratemporal fossae, posteroventrally positioned occipital condyle, laterally compressed posterior cheek teeth, a constricted crown base on the cheek teeth). This clade is positioned outside Neosuchia, but more closely related to neosuchians than to notosuchians. When *Araripesuchus wegneri* is included in the analysis it is depicted as a member of the *Araripesuchus* clade. Although its position in the clade is unresolved and character support is weak, this finding rejects claims that *A. wegneri* does not belong within *Araripesuchus*.

11:30 **Billon-Bruyat, J.-P., Mazin, J.-M. and Padian, K.:** HOW PTEROSAURS LANDED: THE FIRST EVIDENCE FROM FOOTPRINTS

BILLON-BRUYAT, Jean-Paul, Office de la culture, République et Canton du Jura, Porrentruy, Switzerland; MAZIN, Jean-Michel, Université Claude Bernard Lyon I, Villeurbanne, France; PADIAN, Kevin, Univ. of California, Berkeley, CA

The terrestrial progression of pterosaurs, the flying reptiles of the Mesozoic Era, has been debated for over two centuries. The discovery of undisputed quadrupedal pterosaur tracks in the Late Jurassic of

France leaves no doubt that pterosaurs could progress on four legs, even though their hindlimbs are organized much like those of birds and other dinosaurs. In these trackways the manus print generally occurs outside the pes and slightly behind it. So as not to interfere with the wing, the manus was raised before the ipsilateral pes proceeded. The trackway pattern was LF-LH-RF-RH, contrary to the common tetrapod pattern (LF-RH-RF-LH). This pattern and other features suggest that pterosaurs were only secondarily quadrupedal. Their forelimb morphology and kinematics differ substantially from those of other animals.

We report the first known trackway of a pterosaur landing, also from the Late Jurassic sediments of Craysac, France. In this sequence, the pterosaur, a small pterodactyloid (pes length = 5 cm), did not make a running landing. Rather, it apparently stalled before landing to slow its descent and speed, because the distance between successive footfalls is so short. It touched the ground lightly on its heels, dragged its toes slightly as it left the track, and landed again almost immediately on both feet in parallel. It then placed both manus on the ground. This was followed by a short step of adjustment by all the feet; then the animal began to walk normally. These functions are consistent with those of extant birds when landing. The trackway shows that pterosaurs stalled to land, a reflection of their highly developed capacity for flight and maneuverability.

11:45 **Unwin, D. and Deeming, C.:** BABES ON THE WING -- EVIDENCE FOR HYPER-PRECOICIAL FLIGHT ABILITY IN PTEROSAURS

UNWIN, David, Humboldt Univ., Berlin, Germany; DEEMING, Charles, Univ. of London, Birkbeck, London, United Kingdom

Typically, birds and bats must grow to adult or near adult size before they are capable of flight. Pterosaurs, by contrast, appear to have been able to fly at only twenty percent of adult body length and five percent of adult mass. The primary evidence for this is provided by several near-hatchling size fossils of *Pterodactylus kochi* from the Upper Jurassic Solnhofen Limestone of Germany. In these individuals all skeletal elements of the flight apparatus including the pteroid are ossified and, in addition to containing structural fibres, the flight membranes were approximately the same shape and proportions as those of adults. Moreover, critical components of the fore and hind limbs show isometric growth patterns while calculations of the aerodynamic performance of these individuals indicate that wing loading and other parameters were similar to those of adults and that, theoretically, they were capable of flight. This is further supported by the discovery of these fossils preserved in locations far from any likely nesting site. Near hatchling, or early juveniles are known for several other pterosaurs, including *Rhamphorhynchus*, *Ctenochasma*, *Pterodaustro*, a dsungaripterid and *Azhdarcho*, suggesting that hyper-precocial flight ability was widespread, perhaps even universal within Pterosauria. This has two important implications. First, and contrary to the popular image of pterosaurs feeding flightless young, it suggests that, post hatching at least, there may have been little or no requirement for parental care. Secondly, a hyper-precocial flight ability may have imposed a limit on minimum hatchling size and thus also on minimum adult size. This might explain why, unlike birds and bats, there are no species of pterosaur with an adult wingspan of less than approximately 0.4m.

12:00 **Jiang, D., Schmitz, L. and Hao, W.:** TWO SPECIES OF MIXOSAURIDAE (ICHTHYOSAURIA) FROM THE MIDDLE TRIASSIC OF SOUTH-WESTERN CHINA

JIANG, Da-yong, Institute of Paleontology and Stratigraphy, Beijing, China; SCHMITZ, Lars, Department of Geological Sciences, Eugene, OR; HAO, Wei-cheng, Institute of Paleontology and Stratigraphy, Beijing, China



Mixosaur remains were previously reported from China; however, their taxonomic status remained unclear. Abundant and completely preserved specimens of Triassic marine reptiles were recently excavated from the Guanling Formation (Anisian, Middle Triassic) in Panxian County (Guizhou Province), southwestern China. Besides placodonts and nothosaurs, two mixosaur species can be discerned.

A new taxon can be separated from other mixosaur species by both cranial and postcranial characters. The jugal has a small posteroventral flange. The postorbital separates supratemporal and postfrontal and forms the lateral border of the terrace of the upper temporal fenestra. Further diagnostic characters are the radius bearing two distinct notches anteriorly and the presence of a sacral rib. Characters shared with other mixosaurs are the heterodont dentition, a significant increase in the ratio of vertebral centra height to length in the mid-caudal region, and straight and high neural spines. In addition, the forelimb shows two pisiforms, which is rudimentary as in *Mixosaurus cornalianus*.

Another mixosaur species from the same locality and horizon is similar to *Phalarodon fraasi* Merriam, 1910. The posterior dentary comprises four very large mesio-distally elongated teeth; the maxilla carries elongated, dome-like, large teeth. One of the diagnostic features of *Phalarodon fraasi*, multiple rows of maxillary teeth, has not been observed. Being aware of the high variability of mixosaur dentitions, this species is temporarily referred to as *Phalarodon* cf. *P. fraasi*.

The new fauna from Panxian County underlines the taxonomic diversity and wide geographical distribution of the Mixosauridae. From each major mixosaur locality (Monte San Giorgio, Spitzbergen, British Columbia, Nevada) at least two different species are known. The genus *Phalarodon* has a cosmopolitan distribution, being present in every fauna. The new Chinese locality exhibits the same pattern.

## 12:15 **Schmitz, L:** POSSIBILITY OF A THICK SCLERA IN ICHTHYOSAURS AND ITS IMPLICATIONS FOR VISUAL CAPABILITY

SCHMITZ, Lars, Univ. of Oregon, Eugene, OR

Whales have the biggest eyes among mammals, reaching horizontal eyeball diameters of up to 13 cm. Their eyes are characterized by an enormously thickened sclera which is believed to prevent deformation. Analyses of various mammalian eyes show that the scleral thickness scales strongly positively with respect to the horizontal eyeball diameter. This allometry effectively reduces the potential retinal surface area relative to the eye size. Thus, one would expect to see a relatively smaller aperture size in bigger eyes, as the limited retinal surface area does not require an isometrically scaled aperture; a larger aperture would be inefficient. Ontogenetic studies of the fin whale *Balaenoptera physalus* support this assumption.

Ichthyosaurs are marine reptiles that existed from the Early Triassic to the Mid-Cretaceous. One of their appealing characteristic features is their enormously large eye size with maximal horizontal diameter of 25 cm. Does this imply that ichthyosaurs had a thickened sclera as well? To test this hypothesis, biometric studies of ichthyosaurian scleral rings were pursued. An ontogenetic series of *Stenopterygius quadriscissus* from the Toarcian of Germany was analyzed. The aperture size (internal diameter of scleral ring) scales negatively with respect to the horizontal eyeball diameter. The eyeball diameter corresponds to the external diameter of scleral ring, which covers more than a hemisphere. Interspecific analyses considering 12 ichthyosaur genera from Triassic (5), Jurassic (6), and Cretaceous (1) showed the same slope and correspond to the allometry observed in the fin whale.

Both ontogenetic and interspecific allometries support the hypothesis of a thickened sclera in ichthyosaurs which has important implications for their visual capabilities. Due to the thick sclera, the posterior nodal distance (PND) is significantly shorter than one would expect from the horizontal

eyeball diameter. Thus, the f-number is probably overestimated, so the sensitivity was even better than previously reported. In addition, by shortening the PND the sampling frequency is reduced, resulting in a lower resolution.

## TECHNICAL SESSION V PLAZA BALLROOM F

### MODERATORS: BLAIRE VAN VALKENBURGH AND STEVEN WALLACE

- 8:00 **Goswami, A.:** CRANIAL MODULARITY ACROSS MAMMALIA: MORPHOMETRIC ANALYSIS OF PHYLOGENETICALLY AND ECOLOGICALLY-RELATED VARIATION  
GOSWAMI, Anjali, Univ. of Chicago, Chicago, IL  
The correlated evolution of traits is a principal factor in morphological evolution, but it is typically studied in genetic or developmental systems. The concept of *modules* (genetically, developmentally, and morphologically integrated subsets of traits within more traditional units) is an ideal bridge between these disparate scales of evolutionary analysis and is applicable to fossil taxa. However, most studies examining phenotypic modularity, via analysis of morphological integration, consider only a few taxa, with limited ability to test hypotheses of modularity's influence on morphological variation and diversity. Analyses of cranial modularity are presented for ~100 Recent and fossil taxa, spanning the placental orders Carnivora and Primates and the marsupial superfamily Dasyuromorphia and encompassing a wide range of ecological and morphological diversity. 55+ cranial landmarks were captured through 3D digitization for 15-22 specimens of each taxon. UPGMA and Ward's method cluster analysis of trait covariance matrices were conducted for each taxon and revealed a high degree of variability in cranial modules across higher taxonomic levels. Modules of the facial region (particularly the anterior oral-nasal region) display strong within-group correlations and are highly conservative in trait associations, while modules of the neurocranial region, particularly the cranial vault and zygomatic regions, are weakly correlated and more variable in trait associations, even within families.  
Variation in these modules across taxa may reflect both phylogenetic and ecological factors. Matrix correlation analyses show that similarity in cranial integration is strongly correlated with phylogenetic relatedness and dietary similarity, though in different clades. For example, within Carnivora, phylogenetic relatedness is highly correlated with cranial integration in Feliformia and Canidae, while diet is highly correlated with cranial integration in Arctoidea. These results show the complexity of cranial modularity and the potential for morphometric analyses to test hypotheses of modularity and its significance in morphological evolution.
- 8:15 **Wroe, S. and McHenry, C.:** BITE CLUB: A COMPARISON OF BITE FORCES IN EXTANT AND FOSSIL MAMMALIAN CARNIVORES  
WROE, Stephen, Univ. of Sydney, Sydney, NSW, Australia; McHENRY, Colin, Univ. of Newcastle, Newcastle, Australia  
Bite force is an indicator of preferred prey size. As a means of predicting feeding behavior in extinct carnivores we produced and compared estimates of bite force in a sample of extant and fossil mammals. After allowing for allometry, we found that bite force was typically higher in marsupial than placental carnivores. Relative to body mass, the hyper-brachicephalic marsupial lion, *Thylacoleo*, had the most efficient and powerful bite of all taxa. Force at the canine analogue in this species approached that of *Panthera* more than twice its body mass. The jaw biomechanics of *Thylacoleo* may have allowed it to systematically prey on species much larger than itself.

Bite strength in *Thylacinus* was greater than that predicted in a grey wolf of similar size. This finding conflicts with prior findings of a coyote-like specialization on small prey in the thylacine. Although considerable in absolute terms, bite force in the bone-cracking *Crocota* was close to the mean value for Carnivora of its size. Similarly, relative to body mass, bite force in *Sarcophilus* was comparable to that of its closest relatives. We conclude that primary adaptations among bone-cracking species may not be greater jaw musculature, but structural features that allow them to process bone without incurring material failure in their teeth and skulls. In dolicephalic canids, the jaw lever is less efficient than in brachicephalic felids. However, canid skulls are proportionally larger than those of cats, resulting in similar bite forces relative to body mass.

For the only placental fossil taxon included, *Smilodon*, bite force was low for an animal of its size, but nonetheless considerable in absolute terms. Mechanically, it is plausible that the canine shear-bite model of killing in machairodonts required less bite force than the ‘clamp and hold’ bite typical of large *Panthera*. Thus, *Smilodon* may have had sufficient power in its jaws to achieve a killing bite, without using a downward thrust of the head powered by neck muscles.

8:30 **Zack, S.:** SKULL AND PARTIAL SKELETON OF THE RARE EARLY EOCENE MAMMAL *WYOLESTES* (MAMMALIA: EUTHERIA) FROM THE BIGHORN BASIN, WYOMING

ZACK, Shawn, Johns Hopkins Sch. of Medicine, Baltimore, MD

Despite more than a century of collecting mammal fossils in the North American early Eocene, only a handful of specimens of *Wyolestes*, a relatively large mammal of enigmatic affinities, have ever been recovered. In the two decades since its first description, relationships to several taxa, including mesonychids, didymoconids, and creodonts have been suggested. With the exception of a few postcranial fragments, knowledge of *Wyolestes* has remained limited to dental morphology, complicating reconstructions of its ecology and phylogenetic position. A newly discovered specimen of *Wyolestes*, which includes a complete skull and considerable additional postcranial material, is exceptional both in its relative completeness, and in its potential to shed light on this rare and problematic taxon.

The preserved postcranium, which includes portions of the vertebral column, girdles and most long bones, as well as much of the manus and pes, clarifies the locomotor habits of *Wyolestes*. The postcranium combines general robustness with evidence of mobile joints and powerful movements, a combination most consistent with scansorial locomotion. This interpretation largely corroborates the original interpretation of a *Nasua*-like habitus for *Wyolestes*. However, some elements suggest a more fossorial component to the locomotor repertoire of *Wyolestes*. Cranially, *Wyolestes* is characterized by a long, narrow rostrum and a generally gracile skull. There is no evidence of an ossified bullae. One particularly unusual feature is the presence of a strong, horizontal nuchal plate as in extant *Solenodon*. The supposed relationship of *Wyolestes* to didymoconids or mesonychids is weakened by the absence of diagnostic cranial features of either group. Skeletal morphology is more consistent with creodont affinities, but the distinctive combination of features present in *Wyolestes* suggests a relatively lengthy, presently undiscovered evolutionary history.

8:45 **Kawakami, A.:** USING ONTOGENETIC DATA TO TEST PHYLOGENETIC AND ENVIRONMENTAL HYPOTHESES OF BULLA SIZE IN CARNIVORANS

KAWAKAMI, Alana, Yale University, New Haven, CT

The auditory bulla, and the surrounding basicranial region, is an important source of phylogenetically informative characters. It is also an important source of information about the environment for the organism that possesses it. Changes in its structure due to evolutionary history may

affect the range of frequencies that an organism is sensitive to. Previous studies of desert dwelling rodents have shown that a larger auditory bulla is more effective in enabling an individual to hear low frequency sounds, and, therefore, avoid predation. Other studies have suggested that the enlarged auditory bulla, characteristic of some carnivoran clades, may have been a response to the need to hear low frequency sounds in an open environment, such as grasslands. Therefore, a correlation between an open habitat and an enlarged bulla should exist.

Changes in timing and rates of ontogenetic events, known as heterochrony, play a significant role in evolutionary biology. Here I present the preliminary results of a study examining the effects of heterochrony on the growth of the skull of a number of species of feliform carnivorans, focusing on the herpestids. I used seventeen different skull measurements, including a calculation of the bullar volume, and a head-body length measure, if one was available for the individual specimen. Both adults and juveniles were included in this study. Relative age of juveniles was determined using the tooth eruption sequence and suture closures. Results indicate that changes in the relative timing and rate of growth is responsible for some of the variation in middle ear size relative to body size in Carnivora. Although small species may possess a larger bulla relative to body size than large species, absolute bulla size may be similar in species of varying sizes and habitats. Other factors, such as the morphology and physiology of the inner ear, may be responsible for the full range of frequencies to which an organism is sensitive. This suggests that bulla size may be more of a reflection of phylogenetic history rather than environmental pressures.

9:00 **Wallace, S. C., Wang, X. and Schubert, B.: HYPO- AND HYPER-CARNIVORES FROM THE LATE MIOCENE/EARLY PLIOCENE GRAY FOSSIL SITE: INDICATIONS OF A CONNECTION BETWEEN THE FORESTED BIOMES OF NORTH AMERICA AND EURASIA**

WALLACE, Steven C., East Tennessee State Univ., Johnson City, TN; WANG, Xiaoming, Natural History Museum of Los Angeles County, Los Angeles, CA; SCHUBERT, Blaine, Univ. of Arkansas, Fayetteville, AR

To date, four carnivores (*Parailurus*, *Arctomeles*, *Plionarctos*, and cf. *Machairodus*) have been identified from the late Miocene/early Pliocene Gray Fossil Site, in eastern Tennessee. Each exhibits a unique diet.

The “woodland badger” (*Arctomeles*) exhibits a specialized dentition for eating tough/hard vegetation such as acorns (*Quercus*) and hickory (*Carya*) nuts (both abundant within the deposit), whereas the red (lesser) panda (*Parailurus*) was likely a bamboo eater. Although no direct evidence for bamboo exists at the site (yet), living red pandas are specialized for eating bamboo. Furthermore, the presence of a living species (river cane) in Tennessee suggests that bamboo (or a closely related taxon) may have sustained the extinct panda during the late Miocene. However, it is likely that the Gray panda was able to broaden its diet while passing through an arctic arboreal corridor prior to reaching the eastern deciduous forest of the southern Appalachians. Living short-faced bears (*Tremarctos*) eat mostly vegetation, so it seems likely that the Gray taxon (*Plionarctos*), which exhibits complex crenulations within the basins of the molars, may have exhibited a similar diet. The saber-toothed cat, cf. *Machairodus*, is easily considered a hypercarnivore.

Both *Parailurus*, which represents the most primitive member of its clade, and the highly derived species of Old World badger (*Arctomeles*), are new hypocarnivorous taxa. The presence of a single hypocarnivore is rare, making the occurrence of two (and perhaps three) at the Gray site very unique. Additionally, the age and distinctive morphology of the two new hypocarnivores strongly suggest distinct immigration events that indicate a long period of interchange between the forested biomes of eastern North America and those of the Old World during the late Miocene, and seem to reveal

previously hidden dispersal corridors. Lastly, it seems likely that the dense forest, which surrounded the Gray “pond,” may have acted as a refugium from the changing (more open) environment recorded at other late Miocene fossil deposits.

9:15 **Van Valkenburgh, B., Spencer, L., Harris, J., Samuels, J., Friscia, A. and Meachen, J.:**  
CHRONOLOGY AND SPATIAL DISTRIBUTION OF LARGE MAMMAL BONES IN PIT 91,  
RANCHO LA BREA

VAN VALKENBURGH, Blaire, Univ. of California, Los Angeles, CA; SPENCER, Lillian, Univ. of Colorado, Denver, CO; HARRIS, John, George C. Page Museum, Los Angeles, CA; SAMUELS, Josh, FRISCIA, Anthony, MEACHEN, Julie, Univ. of California, Los Angeles, CA

The late Pleistocene tar seep deposits of Rancho la Brea, California preserve an exceptional record of life during a period of significant climatic and faunal change between about 44,000 to 4000 years ago. Millions of specimens from 500+ species have been extracted from these deposits. Despite the wealth of material and the fact that the deposits span both a major global warming phase and extinction event, there have been few studies of microevolutionary change, largely because the stratigraphy of the deposits is unclear. Skeletons are almost always disarticulated and the presumed semi-liquid nature of the asphalt deposits is assumed to allow both vertical and horizontal mixing of elements. To investigate the extent of temporal mixing, we AMS 14C dated amino acids from 40–50 long bones of the dire wolf (*Canis dirus*) and sabertooth cat (*Smilodon fatalis*) from one recently excavated deposit, Pit 91. Results suggest two episodes of deposition: 25–30 ka and 35–45 ka. Over half of the dated bones were entombed within a single 2000 year period (25-27 ka). The expected correspondence between depth and age is not perfect, although the oldest bones are largely confined to the deepest sediments. A 3-D spatial analysis of the dated bones confirmed the lack of stratigraphic coherence, and was also used with a larger Pit 91 data set to explore further questions concerning the nature of the deposits. Data on element location (x,y,z) and orientation for over 18,000 specimens from a published taphonomic analysis were used to document the distribution of elements by size, type, taxon, and surface characteristics (such as presence of abrasion, weathering, tooth marks, pit wear). Results reveal some evidence of both pre- and post-depositional transport. There are few teeth marks and little abrasion, indicating that the bones were quickly buried. Pit wear appears to be concentrated in certain areas, although it is hard to determine if it is due to pre-depositional concentration (e.g. at a bend in a stream), or due to localized post-depositional movement within the pit due to tar circulation, seismic activity, or some other cause.

9:30 **Finarelli, J. and Flynn, J.:** BODY SIZE EVOLUTION IN THE ARCTOIDEA (CARNIVORA,  
MAMMALIA): THE IMPORTANCE OF FOSSIL DATA IN RECONSTRUCTING ANCESTRAL  
STATES

FINARELLI, John, Univ. of Chicago, Chicago, IL; FLYNN, John, Field Museum of Natural History, Chicago, IL

Body size in modern mammals correlates to many physiological and ecological characteristics of interest to paleobiologists. A recent molecular phylogeny of Carnivora provides a robust phylogenetic topology that implies a novel inference of the ancestral body size for arctoid carnivorans. In this analysis, large-bodied Pinnipedia and Ursidae form sequential outgroups to Musteloidea; hence, large body size may have been ancestral for Arctoidea. To test this hypothesis, body size data were collected for extant caniform taxa and ranked from low to high body size. Kendall Rank Correlation shows a highly significant negative correlation between rank body size and clade rank (body size decrease:  $t_b = -0.317$ ,  $p < 0.001$ ). However, a series of Mann-Whitey tests between successive sister-clades

demonstrates that while ursids and pinnipeds are significantly larger than their respective sister clades, among the musteloids only weasels differ significantly in body size (smaller) from their sister clade.

Extant taxa represent only a subset of the total carnivoran diversity through time. Drawing conclusions based solely on extant representatives therefore both ignores extinct clades (e.g. Amphicyonidae) and makes the implicit assumption that the extant taxa faithfully record patterns of body size evolution. Additionally, the temporal component of fossil data can contribute significantly to more accurate reconstruction of ancestral character states. To assess the value of fossil data, body size estimates for fossil caniforms were combined with those of extant taxa. Estimates of ancestral body size were made for Arctoidea using both the restrictive extant-only and inclusive all-caniform datasets, under parsimony and probabilistic models. Preliminary results indicate arctoids are large-bodied when only the extant taxa are surveyed, but that small body size probably is the ancestral state when data for all taxa are included. Differences in predicted body size for the arctoid node when fossils are included underscore the importance of incorporating both the anatomical and temporal data of fossil taxa for ancestral character state reconstruction.

9:45 **Garcia, N., Dominguez-Alonso, P., Arsuaga Ferreras, J. L. and Carretero, J. M.: FIRST SPOTTED HYAENA FROM THE EARLY PLEISTOCENE OF EUROPE: A CT STUDY OF THE CRANIUM**

GARCIA, Nuria, Museum of Vertebrate Zoology, Berkeley, CA; DOMINGUEZ-ALONSO, Patricio, Univ. Complutense de Madrid, Madrid, Spain; ARSUAGA FERRERAS, Juan Luis, Instituto de Salud Carlos III-UCM, Madrid, Spain; CARRETERO, Jose Miguel, Univ. de Burgos, Burgos, Spain

The Sierra de Atapuerca represents the most important complex of Pleistocene sites in Europe due to the continuous human presence from around 1.2 Ma to present, together with an abundant faunal record. One of the richest sites is Trinchera Dolina, an 18 m fossiliferous cave deposit, of well studied stratigraphy and chronology. In the lowermost levels (TD4-5, dated to around 900 Ka), a complete hyaena skull was recovered. This discovery represents the first European occurrence of spotted hyaena (*Crocuta crocuta*). The exceptional preservation together with the lack of deformation converts this specimen in a unique case for CT study. A new highly advanced technology—a combination of computer X-ray tomography and 3-D reconstruction—has been applied to investigate the detailed anatomy of the cranium. These have permitted a life-restoration of internal features such as brain and sinuses. The complex telencephalic structure is described, including sulci, circumvolutions, venous sinuses and large olfactory bulbs. The caudally elongated frontal sinus overlaps the brain, reaches the occipital bone and creates an internal vault. These structures allow the expansion of the masticatory muscular insertions from the temporal bone towards the highly modified occipital bone.

10:00 **BREAK**

10:15 **Sears, K., Behringer, R. and Niswander, L.: THE DEVELOPMENT OF POWERED FLIGHT IN CHIROPTERA: THE MORPHOLOGIC AND GENETIC EVOLUTION OF BAT WING DIGITS**

SEARS, Karen, Memorial Sloan Kettering Cancer Center, New York, NY; BEHRINGER, Richard, M.D. Anderson Cancer Center, Houston, TX; NISWANDER, Lee, Memorial Sloan Kettering Cancer Center, New York, NY

Bats suddenly appear in the fossil record roughly 50 million years ago. The earliest bats resemble their modern counterparts in possessing the anatomical hallmarks of powered flight (e.g., greatly elongated digits and interdigital membranes). To quantify these similarities, we performed a morphometric analysis of wing bones from several fossil bats and bats from all modern families. Results

indicate that the lengths of the third, fourth and fifth digits (the primary supportive elements of the wing) have remained constant relative to body size for the last fifty million years.

The absence of transitional forms in the fossil record forces us to look elsewhere to understand the evolution of the bat wing. With this in mind, we compared the embryological development of bat wing digits (*Carollia perspicillata*) with the more generalized digits of the mouse (*Mus musculus*) using histological and molecular techniques.

Histological results indicate that the initial cartilage condensations and segmentation patterns of bat digits are similar in size and position to those observed in mouse, suggesting that bat digit elongation is due to post-segmental developmental processes. Longitudinal growth of post-segmental digits is dependent upon the relative proliferation and differentiation of chondrocytes in the growth plate. The area in which chondrocytes undergo differentiation (hypertrophic zone) is expanded in the bat growth plate, relative to mouse.

Limb culture experiments reveal that application of the protein of a single gene, *BMP2*, can stimulate expansion of the hypertrophic zone in both bat and mouse digits. In addition, *in situ* hybridization results indicate that the expression area of *BMP2* is expanded in bat digits relative to mouse.

Taken together, these results suggest that a simple change in the spatial expression of a single key genetic regulator of limb development drove the rapid evolutionary elongation of bat wing digits. By linking small changes in molecular patterning to dramatically different phenotypes, we provide a potential explanation for the rapid evolution of bat flight.

10:30 **Samonds, K. and Burney, D.:** NEW LATE PLEISTOCENE BAT FOSSILS FROM ANJOHIBE CAVE, NORTHWESTERN MADAGASCAR

SAMONDS, Karen, Stony Brook University, Stony Brook, NY; BURNEY, David, Fordham University, Bronx, NY

Despite decades of research on Madagascar's extant fauna, one of the most unique and endemic on the planet, the evolutionary history of the island's bats remains poorly known. Thirty bat species (in seven families) are presently recognized, 60% of which are endemic. Their origin and evolution remains enigmatic due to the poor fossil record; the deepest glimpse comes from fossils at a mere ~26,000 BP. Numerous bat remains have been recovered from these fossil sites, but are rarely identified or described.

We report a diverse assemblage, represented by isolated teeth, jaws, and postcranial elements, of newly discovered fossil bats from Anjohibe Cave, northwestern Madagascar. Some of these fossils were extracted from breccia dated at ~90,000 BP, more than three times the age of the island's oldest known Cenozoic fossils. Fossiliferous breccia was collected from four horizons in Anjohibe Cave and dated using U-series dating techniques. Three of the seven extant Malagasy bat families are represented: Hipposideridae—*Hipposideros*, *Triaenops*; Pteropodidae—*Eidolon*, *Rousettus*; and Vespertilionidae—*Myotis*, *Scotophilus*. *Hipposideros* is the most well-represented genus, represented by multiple jaw elements, proximal limb elements, and wrist bones, including the fused scaphocentralolunate. Compared to extant *Hipposideros commersoni* collected at Anjohibe, fossil *Hipposideros* have larger molars and a more mesiodistally expanded P4. Since *Hipposideros* is the largest microchiropteran bat present on Madagascar today, this suggests that these fossils represent either a closely related but extinct species, or that this genus experienced molar reduction through time, a phenomenon previously documented in other bat faunas.

Some bats are sensitive to habitat destruction and hunting, and therefore may have experienced extinctions and range restrictions during the Holocene, as has been shown for many other groups in

Madagascar. A better understanding of the Malagasy fossil fauna has great potential to help reconstruct the historical changes in bat species richness and diversity during the late Pleistocene and Holocene.

10:45 **Heesy, C. and Ross, C.:** THE NOCTURNAL ORIGIN OF THE ORDER PRIMATES

HEESY, Christopher, New York College of Osteopathic Medicine, Old Westbury, NY; ROSS, Callum, Univ. of Chicago, Chicago, IL

Adaptive scenarios of primate origins implicitly or explicitly assume that a nocturnal activity pattern is primitive for the group. A recent description and analysis of a newly discovered and relatively complete skull of the basal omomyiform *Teilhardina asiatica* led Ni and colleagues to infer that this animal was diurnal based on the relative size of the orbital aperture. This result is striking because all other omomyiforms for which data are available are interpreted to be nocturnal using similar comparisons. A phylogenetically based character analysis led Ni and colleagues to suggest that diurnality was in fact the primitive activity pattern of primates based in part on their diurnal reconstruction for *Teilhardina*. One problem is that *Teilhardina* is notably small-sized, requiring extrapolation beyond the extant distribution of primates for orbit-to-body size allometry. However, the viability of this extrapolation has yet to be demonstrated.

In this study, we evaluate the utility of orbit dimensions for reconstructing activity pattern from mammals comparable in size to *Teilhardina*. In addition, we conduct a new analysis of activity pattern trait evolution wherein we recode several primate ingroup and outgroup taxa and add taxa that were excluded in the previous study. Our results show that among primates and across mammals, the allometry of eye and orbit size at small body sizes is not linear, thereby making difficult inferences of activity pattern of a mammal similar in size to *Teilhardina*. The phylogenetic analysis of trait evolution using parsimony reconstructs nocturnality at the basal primate node as well as several adjacent ingroup and outgroup nodes. We conclude that the available comparative evidence supports previous hypotheses for the nocturnal origin of primates.

11:00 **Boyer, D., Bloch, J., Silcox, M. and Gingerich, P.:** NEW OBSERVATIONS ON THE ANATOMY OF *NANNODECTES* (MAMMALIA, PRIMATES) FROM THE PALEOCENE OF MONTANA AND COLORADO

BOYER, Doug, SUNY Stony Brook, Stony Brook, NY; BLOCH, Jonathan, Univ. of Florida, Gainesville, FL; SILCOX, Mary, Univ. of Winnipeg, Winnipeg, MB, Canada; GINGERICH, Philip, Univ. of Michigan Museum of Paleontology, Ann Arbor, MI

Two relatively complete skeletons of the Tiffanian plesiadapid *Nannodectes* are among the oldest known for plesiadapiforms. Comparison of dentally associated postcrania of *N. intermedius* (Crazy Mountains Basin, Ti-1) to those of *N. gidleyi* (San Juan Basin, Ti-4) suggest that the humerus and vertebrae previously attributed to *N. gidleyi* are not those of a plesiadapiform. Further, previously undescribed aspects of the basicranium, limbs, and vertebral column of *N. intermedius* and *N. gidleyi* allow for reassessment of the primitive morphology and inferred positional behavior of Plesiadapidae.

UhrCT data suggest that the ear of *N. intermedius* is similar to that of *Plesiadapis* in having a petrosal bulla. Further similarities include a tubular EAM, an intrabullar ectotympanic ring with an annular bridge lacking a recessus dehiscense, and a broad (~0.34mm), shallow, laterally positioned groove on the promontorium in the same position as the groove interpreted to transmit the internal carotid artery in other plesiadapiforms.

*Nannodectes* differs from *Plesiadapis*, but is similar to other plesiadapiforms for which postcrania are known, in having: (1) humerus with a relatively broader entepicondyle, narrower capitulum, and more laterally flaring supinator and deltopectoral crests; (2) relatively more elongate intermediate



phalanges; (3) relatively shorter distal phalanges; (4) craniocaudally relatively narrower cervical vertebrae; and (5) lumbar vertebrae with relatively narrower spinous processes. Unlike *Plesiadapis*, *Nannodectes* is similar to carpolestid plesiadapoids in having: (1) first metapodials with greater torsion than those of other plesiadapiforms; (2) dorsopalmarly relatively shallow intermediate phalanges; and (3) a calcaneocuboid joint that lacks a plantar pit. We infer that *Nannodectes* was a slow arboreal quadruped capable of claw-climbing on large diameter supports and grasping small diameter branches. As such, it is more similar to carpolestid plesiadapoids than is *Plesiadapis*, which probably spent more time on large diameter vertical supports.

11:15 **Rossie, J. and Beard, K. C.:** INTRACRANIAL ANATOMY OF *SHOSHONIUS COOPERI* (PRIMATES, TARSIIFORMES) AS REVEALED BY HIGH-RESOLUTION COMPUTED TOMOGRAPHY

ROSSIE, James, BEARD, K. Christopher, Carnegie Museum of Natural History, Pittsburgh, PA

The traditional view of Eocene omomyids as either ancestors or sister-taxa of living tarsiers has been challenged repeatedly over the past three decades on the basis of perceived cranial synapomorphies of living tarsiers and anthropoids that are not found in omomyids. Cranial anatomy of omomyids has long been known only for microchoerines, *Tetonius*, and the enigmatic *Rooneyia*. More recently, multiple crania of *Shoshonius cooperi*, a North American washakiin omomyid, have been recovered, and preliminary study of these specimens has revealed several derived similarities to *Tarsius*.

Here we report on the intracranial anatomy of *Shoshonius* based on high-resolution computed tomography scanning of two skulls. Morphology of the interorbital, nasal, and paranasal regions of *Shoshonius* are described for the first time. *Shoshonius* resembles tarsiers in lacking a sphenoid sinus, and possessing a very small maxillary sinus, an apical interorbital septum, and a very crowded posterior nasal cavity, the posterior pole of which lies ventral to the closely approximated orbits. In addition, internal anatomy relating to the foramen ovale, postglenoid foramen, posterior carotid foramen, and sylvomastoid foramen have refined our knowledge of the position and course of these important basicranial structures. These new data are incorporated into a reevaluation of the phylogenetic position of *Shoshonius*, and of the relationships among omomyids, tarsiers, and anthropoids.

11:30 **Penkrot, T., Zack, S. and Strait, S.:** NEW POSTCRANIA OF *MACROCRANION* (EUTHERIA: AMPHILEMURIDAE) FROM THE EARLY EOCENE, BIGHORN BASIN, WY

PENKROT, Tonya, ZACK, Shawn, Johns Hopkins Univ. Sch. of Medicine, Baltimore, MD; STRAIT, Suzanne, Marshall Univ., Huntington, WV

The hazy morphologic boundary between small-bodied condylarths and erinaceomorph insectivores presents a persistent problem for studies of the early evolutionary histories of both groups of Paleocene and Eocene mammals. A major reason is that most taxa involved are known exclusively from dental remains, limiting the number of characters that can be applied to the problem. In particular, with the exception of articulated (but badly crushed) skeletons of the amphilemurid insectivores *Macrocranium* and *Pholidocercus* from Messel, Germany, the postcrania of early erinaceomorphs have remained virtually unknown. As a consequence, previous efforts to distinguish small-bodied condylarths from erinaceomorph insectivores have been based exclusively on dental characters. This has been problematic, because at small body sizes, morphologic differences between taxa in the dentition may be subtle, necessitating the reliance on arbitrary characters. An abundance of isolated postcranial elements of *Macrocranium* from early Eocene Bighorn Basin quarries and screen washing localities permits a reassessment of the affinities of *Macrocranium*, based on postcranial as well as dental data. Detailed comparisons reveal particularly striking similarities in tarsal morphology shared by *Macrocranium* and

apheliscid condylarths, most notably the presence of a well-developed cotylar fossa and large cuboid facet on the astragalus, an elongate calcaneum with a proximally-facing fibular facet, and an elongate cuboid with a large astragalar facet. While the precise phylogenetic position of *Macrocranium* among Paleogene taxa remains incompletely resolved, postcranial morphology argues against a close relationship to modern erinaceids. Postcranial morphology holds future promise of clarifying the interrelationships of these and other small-bodied, bunodont taxa.

11:45 **Semprebon, G., Godfrey, L., Jungers, W., Sutherland, M. and Solounias, N.:** ECOSPACE RECONSTRUCTION OF THE EXTINCT LEMURS OF MADAGASCAR: EVIDENCE OF DIET AND NICHE DIFFERENTIATION

SEMPREBON, Gina, Bay Path College, Longmeadow, MA; GODFREY, Laurie, Univ. of Massachusetts, Amherst, MA; JUNGERS, William, Stony Brook Univ., Stony Brook, NY; SUTHERLAND, Michael, Univ. of Massachusetts, Amherst, MA; SOLOUNIAS, Nikos, New York Institute of Technology, Old Westbury, NY

Stereoscopic microwear analysis is used to construct a large comparative database of extant primates. The method is then used to examine microwear of all 16 species of extinct lemurs of Madagascar with known molar dentitions. The method distinguishes among graminivores, folivores, and frugivores, diagnoses hard-object feeding, and provides an estimate of the intensity of seed predation. We explore the ecospace occupied by extinct and extant Malagasy lemurs and compare the apparent prevalence of folivory, seed predation, and hard-object feeding in the present and in the past. Our data corroborate some previous reconstructions of the diets of the extinct lemurs of Madagascar but not others.

We show that (1) there was a significant hard-object specialist guild among the extinct lemurs of Madagascar; (2) there is a strong phylogenetic signal to the microwear signatures; (3) there is no evidence that any of the extinct lemurs relied on grasses, roots, or tubers or other strictly open habitat foods; and (4) there is therefore no confirmation of open habitat exploitation. We conclude that the Archaeolemuridae were hard-object feeders, the Palaeopropithecidae were seed predators, consuming a mixed diet of foliage and fruit to varying degrees; *Pachylemur* was a fruit-dominated mixed feeder, but not a seed predator; and all *Megaladapis* were leaf browsers. Our data have possible implications for the role of the disappearance of wooded habitats in megafaunal extinction on the island of Madagascar.

12:00 **Cuozzo, F. and Sauter, M.:** PATTERNS OF TOOTH WEAR AND THEIR RELATION TO SPECIFIC FEEDING BEHAVIORS IN EXTANT *LEMUR CATTAL* (MAMMALIA, PRIMATES): IMPLICATIONS FOR PRIMATE PALEOBIOLOGY

CUOZZO, Frank, Front Range Community College, Fort Collins, CO; SAUTER, Michelle, Univ. of Colorado, Boulder, CO

The study of extant primate dental variation, wear, and use provides important information for understanding primate paleobiology. When combined with dental analyses, field studies of extant analogs can help us to interpret the feeding ecology of extinct primates. We collected dental wear information from a sample of 65 anesthetized adult ring-tailed lemurs (*Lemur catta*) at Beza Mahafaly Special Reserve, Madagascar. This population has been the focus of long-term behavioral and ecological study. Thus, details of specific feeding behaviors are available. We also studied 16 ring-tailed lemur crania housed in the Beza Mahafaly Osteology Collection. Here we discuss patterns of dental wear in this population and how they relate to specific feeding behaviors.

Among the dental wear we observed is a distinct area of interstitial attrition between m1 and m2. Although noticeable in living individuals, it is most obvious in the skeletal specimens, in which three of

the seven crania with associated mandibles in the BMOC sample display this pattern. In two individuals, this area of attrition extends into the tooth roots (and into the body of the mandible in BMOC 67), forming distinct wear facets. In each of these three specimens, the severe attrition of the mandibular molars corresponds with extreme wear in M1, on which the distal cusps occlude with the area of m1 and m2 contact. It appears that this pattern of severe wear is in part a result of stripping leaves from vines, a feeding behavior observed in this population. As the crowns of m1 and m2 begin to wear (which occurs early in life in ring-tailed lemurs), the vine is pulled across the teeth, likely through the resulting gap, causing the severe wear and distinct facets. As ring-tailed lemurs are similar to certain fossil primates, this pattern of dental wear and its correspondence to a specific feeding behavior provides an analog for interpreting tooth use and feeding ecology in the primate fossil record.

12:15 **DeSilva, J., Shoreman, E. and MacLatchy, L.:** A FOSSIL *PAN* PROXIMAL FEMUR FROM THE PLIO-PLEISTOCENE OF SOUTHWESTERN UGANDA

DESILVA, Jeremy, SHOREMAN, Elle, MacLATCHY, Laura, Boston Univ., Boston, MA

Much is known about the evolution of hominids following their divergence from the other African hominoids. However, the same cannot be said of the African great apes. The known African ape fossil assemblage from the late Miocene to the present is represented by a single gorilla tooth. The absence of African great ape fossils make hypotheses of chimpanzee and gorilla evolutionary histories challenging.

A right proximal femur from the Plio-Pleistocene of Southwestern Uganda described here and assigned to *Pan* may be the first postcranial fossil great ape element known. Discovered in the Kikorongo crater of Queen Elizabeth National Park in 1961, this specimen was originally assigned to *Homo sapiens*. However, the fossil lacks the suite of features associated with bipedal locomotion typically found in Plio-Pleistocene hominid proximal femora. Instead, the femoral neck architecture and inferred mobility at the hip joint align the Kikorongo femur with the African great apes, particularly *Pan*. The femoral neck is circular in cross section, and is not anteroposteriorly flattened like Plio-Pleistocene hominids and modern gorillas. Additionally, like the African apes, the Kikorongo specimen has a high neck-shaft angle, and a short femoral neck with a narrow and deep superior notch.

The Kikorongo region itself is interstratified with late Pleistocene volcanic beds, early Pleistocene Semliki strata, and Pliocene Kaiso sediments. Because the provenance of the Kikorongo femur has not been securely established, this highly mineralized fossil could be anywhere from 10,000 to 6 million years old. Despite the uncertainty in age, this fossil is an important contribution to understanding the evolution of our closest living relatives.

**TECHNICAL SESSION VI  
GOVERNOR'S SQUARE 14**

**MODERATORS: NORMAN MACLEOD AND JACQUELIN SUNDELL**

**8:00 MacLeod, N., Walsh, S. and O'Neill, M.: THE AUTOMATED RECOGNITION OF VERTEBRATE FOSSILS: METHODS, APPLICATIONS, AND IMPLICATIONS**

MACLEOD, N., WALSH, S., The Natural History Museum, London, United Kingdom; O'NEILL, M., Oxford Univ., Oxford, United Kingdom

As with all areas of systematics, vertebrate paleontology has significant problems with the taxonomic impediment and (likely) low levels of taxonomic result reproducibility. These can, in principal, be addressed through automated object-recognition methods. Two generalized approaches are considered relevant, morphometric systems based on linear discriminant analysis (LDA), and artificial neural networks (ANN). In this investigation, digital images of the proximal radial heads of 47 modern mammal species ( $n = 4-12$ ) were used to create two taxonomically partitioned multivariate shape spaces. The LDA space utilized 2D, plan view, radial head outlines while the ANN space was based on polar, 32x32, histogram-equalized, plan-view images. Cross-validation results suggest both methods achieved comparable levels of group-specification. In this test the ANN results were judged superior, however, based on the nominal amount of time required for data collection/analysis and the freedom from sample dependence gained through application of an n-tuple classifier combined with a plastic self-organizing map (PSOM). A similar study of 73 species partitioned into 6 locomotor groups was undertaken to evaluate the potential of the ANN approach in non-taxonomic applications. In this instance ANN results were markedly superior to the LDA approach while retaining the same time and generalizability advantages. Finally, the ANN dataset was used to assess the locomotor interpretation of 21 fossil mammal radial heads and compared to morphometric results. On the basis of these comparisons it is concluded that (1) both ANN and LDA approaches are useful within their own analytic domains, (2) both can benefit from various sorts of technology transfers, (3) fast and efficient, automated object-recognition systems suitable for VP applications can be constructed using available hardware and software technology, and (4) such systems would be sufficiently accurate to be of great practical value.

**8:15 Behrensmeyer, A., Bobe, R., Campisano, C. and Levin, N.: HIGH RESOLUTION TAPHONOMY AND PALEOECOLOGY OF THE PLIO-PLEISTOCENE KOOBI FORA FORMATION, NORTHERN KENYA, WITH COMPARISONS TO THE HADAR FORMATION, ETHIOPIA**

BEHRENSMEYER, Anna, Smithsonian Institution, Washington, DC; BOBE, Rene, Smithsonian Institution, Washington, DC; CAMPISANO, Christopher, Rutgers Univ., New Brunswick, NJ; LEVIN, Naomi, Univ. of Utah, Salt Lake City, UT

Faunal comparisons between paleontological localities are usually conducted at broad levels of temporal resolution that may obscure finer-scale taphonomic and paleoecological information. This study takes an alternative, high-resolution approach to examine the geology and paleontology of fossiliferous deposits of the 3.4 to 3.2 Ma Tulu Bor Mbr., Koobi Fora Fm., northern Kenya. We targeted specific fossiliferous intervals using controlled surface sampling of vertebrate fossils, microstratigraphy, and isotope geochemistry. The resulting paleoecological data are then used for inter-basin comparison with time-equivalent environments and faunas of the Sidi Hakoma Mbr., Hadar, Ethiopia.

Documentation of all fossil remains along continuous outcrops provides information on the vertebrate fauna at different taxonomic and ecomorphic levels within a 180 kyr time interval. Comparisons of the controlled surface sample with previous catalogued collections reveals biases

affecting some groups (e.g., large ungulates). The proportions of aquatic, semi-aquatic, and terrestrial animals as well as major mammalian groups and bovid tribes reveal different aspects of the paleoecology of the Tulu Bor fauna and also indicate local variation within the fluvial lower Tulu Bor Mb. Detailed stratigraphy shows that most of the fossils are derived from channel and associated overbank environments with paleosols that supported mixed C3-C4 vegetation, based on stable isotope data.

Comparisons of the Tulu Bor and Sidi Hakoma faunas are both consistent and inconsistent with inferred depositional environments. The proportions of major mammalian groups are remarkably similar in the Tulu Bor and the lower SH faunas, providing evidence for a widespread middle Pliocene East African fauna. Bovid tribes differ between the fluvial and lacustrine environments at Hadar and also between Hadar and East Turkana, indicating considerable paleoecological variability at this level of resolution both within and between basins. Hominins are abundant at Hadar but absent in the contemporaneous lower Tulu Bor sample, suggesting paleoecological differences affecting hominin distributions.

8:30 **Caldwell, M. and Keswani, A.:** LAMINATED MARINE CARBONATES AND FOSSIL LÄGERSTATTENS: A NEW MODEL INVOKING PALEOECOLOGICAL CONTROL

CALDWELL, Michael, KESWANI, Arjun, Univ. of Alberta, Edmonton, AB, Canada

Laminated carbonates deposited in marine environments are often host substrates for exceptionally preserved vertebrates. Development of such preservation is influenced by complex sedimentary and benthic paleoecological dynamics such as seasonal upwelling in low-energy pelagic environments, soupy substrates, rapid-burial, and oxygen-deficient conditions; the result is exclusion of generalist macro-invertebrates and scavengers. These physical and chemical conditions influence the virtual absence of benthic scavenger-corpse interactions and facilitate development of unique taphonomic regimes. Three periods of taphonomic development are recognized: fallout, impact, and incorporation. These periods represent stages of taphonomic dynamics, before and during rapid burial, when the integrity of the vertebrate remains may be compromised. Lack of modifying processes in taphonomy are evidenced in petrographic analysis of laminated carbonates and comparisons of host-rock specimens from Solnhofen, Ein Jabrud, Hakel, and Hvar. For example, carbonates from Hvar, Croatia, consist of alternating layers of fecal pellets and lime mud. These textural variations reflect complex relations between benthic invertebrate paleoecology and vertebrate taphonomy. Aspects of paleoecological dynamics are manifest in the characteristics of abundant cryptic bioturbate textures within the laminated carbonates (i.e., local textural heterogeneities defined by microfills, and concentrically- and tangentially-aligned burrow fabrics). Evidence of cryptic bioturbation in specimens from Hvar likely represents low-diversity/high biomass meiofaunal assemblages of trophically specialized coprophagic nematodes, adapted to dysaerobic conditions; macro-scavengers were excluded by a variety of abiotic factors, including temporary anoxia. The meiofauna within such a paleocommunity was physiologically incapable of benefiting directly from the vertebrate corpses. Exceptional preservation at Solnhofen, Ein Jabrud, Hakel, and Hvar is not exclusively due to low oxygen substrates, but rather results from a complex array of paleoecological factors.

8:45 **Scott, J. and Renaut, R.:** EXPERIMENTAL FOOTPRINT TAPHONOMY: A QUANTITATIVE, STATISTICAL APPROACH

SCOTT, Jennifer, RENAUT, Robin, Univ. of Saskatchewan, Saskatoon, SK, Canada

Although it has been widely recognized that substrate conditions partly determine the morphology of vertebrate footprints, it has proven difficult to quantify the effects of the factors involved. Researchers

have focused mainly on the sedimentological and ecological factors present prior to the making of impressions while generally neglecting a consideration of the taphonomical factors that affect footprint morphology. We are focusing on the factors that affect morphology after impression, prior to and after burial.

Field studies around saline, alkaline and freshwater lakes in the semi-arid Kenya Rift Valley have shown that many sedimentological and environmental factors influence footprint morphology and are involved in their taphonomy. In order to understand these factors and their interactions, it is essential to isolate them and study their measurable characteristics. Selected measured parameters of experimental impressions were used to statistically analyze the effects of three important taphonomical factors tested in a series of laboratory experiments.

1. The importance of clay mineralogy was tested by contrasting between swelling (bentonite) and non-swelling (kaolinite) clays. Clay type had a strongly significant effect on impression morphology. 2. The influence of surface and pore water salinity was shown to be an important factor: salt precipitation and dissolution contributes directly to the deterioration of impressions; salt crusts can also stabilize the substrate surface; and saline pore waters indirectly affect impressions because they strongly influence the behaviour of swelling clay minerals. 3. The method of substrate drying was also tested by comparing between impressions dried by heat lamp, fan, and ambient conditions. There were strongly significant interactions between each of these methods and both clay type and salinity.

This quantitative and statistical approach to footprint taphonomy has been successfully developed to isolate and understand interactions between some of the taphonomical factors observed around saline, alkaline Lake Bogoria, Kenya (60-90 g/L TDS).

9:00 **Crowley, B., Koch, P. and Davis, E.:** DATING SIERRA UPLIFT WITH ISOTOPIC RECORDS FROM TERTIARY MAMMALS

CROWLEY, Brooke, KOCH, Paul, Univ. of California Santa Cruz, Santa Cruz, CA; DAVIS, Edward, Univ. of California Berkeley, Berkeley, CA

The timing of tectonic uplift in the Sierra Nevada Mountains (western US) is currently debated. Prior research on Sierran uplift indicates two conflicting results: (1) Recent, late Cenozoic uplift with dates under 10 million years before present (my), and (2) An older age of 20-60 my. The methods that have produced these divergent results are diverse, including approaches from geomorphology, geophysics and geochemistry. Recently, isotope geochemists have attempted to date the development of the rain shadow to the east of the Sierras as a proxy for high mountains blocking the flow of moisture from the Pacific Ocean. Because heavier isotopes of oxygen and hydrogen are concentrated in rain as it forms from clouds, the rain shadow across the Sierra Nevada creates a strong isotopic gradient, with  $^{18}\text{O}$  and  $^2\text{H}$ -depleted to the east. Prior work using this method has focused exclusively on authigenic minerals from the east of Sierras, and has been complicated by concerns regarding the time of mineral formation and the confounding effects of global climate change and tectonically-driven shifts in sources of moisture other than mountain uplift.

We have addressed these concerns by analyzing oxygen isotopes in tooth enamel from mammals. Mammals ingest meteoric water, incorporating it into the bioapatite in their teeth. Bioapatite therefore provides a proxy for the isotopic composition of meteoric water, and one that has a well known time of formation determined by biostratigraphy. By sampling tooth enamel from contemporaneous mammalian fossils on either side of the present Sierra range, isotopic differences induced by a rain shadow can be isolated from other regional and global factors. Our preliminary results using this approach indicate that the Sierra rain shadow has existed for at least 15 my, and thus favors early uplift of this mountain chain.

9:15 **Fricke, H., Picard, P. and Echt, S.:** CORRELATION BETWEEN LARAMIDE BASIN SEDIMENTS AND FOSSIL LOCALITIES USING CARBON ISOTOPE CHEMOSTRATIGRAPHY: EXAMPLES FROM THE LATE CRETACEOUS

FRICKE, Henry, PICARD, Patrick, ECHT, Susan, Colorado College, Colorado Springs, CO

Different global reservoirs of carbon typically have different carbon isotope ratios so that changes in the flux of carbon between them can result in isotopic shifts that in turn propagate through the carbon cycle. Because such modifications of the carbon cycle occur rapidly, carbon isotope “shifts” recorded in sedimentary rocks can be used as markers for correlation between stratigraphic sections. Such carbon isotope records can be preserved in terrestrial sedimentary materials such as charcoal, bulk organic matter, paleosol carbonate and tooth enamel carbonate.

The goals of this project are to determine (1) whether shifts in carbon isotope ratios occurred during the Late Cretaceous and were recorded by different sedimentary materials and (2) whether any such shifts can be used to correlate between stratigraphic sections from different Laramide basins of western North America. Previous research on paleosols from the Big Bend, Texas, region (Aguja/Javelina Fms.) indicated that significant shifts in carbon isotope ratios are recorded in paleosol carbonates over the last ~4 million years of the Cretaceous. Our more continuous, high-resolution data from the Denver basin, Colorado, confirm that several of these same carbon isotope shifts are also found in bulk sedimentary organic matter to the north. Similarly, many of these same carbon isotope shifts are recorded in both charcoal and dinosaur tooth enamel from the Williston basin of North Dakota (Hell Creek Fm.).

Overall these results from the Late Cretaceous provide strong evidence that carbon isotope shifts can be used as stratigraphic markers for correlation between Laramide basin sediments, and between dinosaur fossil localities collected from these sediments. Furthermore, because both Denver and Williston basin sections are well dated, it is possible to determine the timing of some of the major carbon isotope shifts with some confidence. Thus isotope shifts may also be used as a means of dating Laramide basin sediments when other options are not available.

9:30 **Lloyd, G. and Benton, M.:** DIFFICULTY IN IDENTIFYING MASS EXTINCTIONS AMONG TETRAPODS (LATE PERMIAN - EARLY JURASSIC)

LLOYD, Graeme, BENTON, Michael, Univ. of Bristol, Bristol, United Kingdom

The Late Permian to Early Jurassic transition is the most important in tetrapod history, and incorporates two or three posited extinctions; at the end-Permian, end-Carnian (possibly) and end-Triassic. However, because of small sample sizes, these events are hard to establish when the data are inspected closely. Two datasets, one of 814 genera and the other of 208 families, were compiled from the literature and each taxon assigned to categories of body size, diet, habitat and geographic range. Traditional metrics of diversity, extinction and origination failed to produce convincing evidence of mass extinction. However, where stage-crossing taxa alone were considered the two major events (end-Permian and end-Triassic) became more prominent (the postulated Late Carnian event could not be delineated). Chi-square tests compared survivorship and pre- and post-extinction faunas, although the former were plagued by low sample sizes. The most significant ecological changes are associated with the end-Permian event. Jablonski’s model of alternating macroevolutionary regimes is weakly supported, but not contradicted. Similarly differences between extinction events seem to support their contingency.

Further analysis of the datasets included, 1) Pearson chi-square tests of variable independence, 2) measures of endemism using Jacquard’s coefficient of similarity, and 3) comparisons between the two datasets. These results suggest that, 1) the selected ‘characters’ are mostly redundant due to significant levels of association, 2) faunas became more endemic throughout the Triassic (prior to Pangean

breakup), and 3) neither genus- nor family-level data is the ideal taxonomic rank in tetrapod macroevolution. Although this study has mostly negative ramifications for future research some possibly rewarding lines of enquiry are suggested.

9:45 **Smith, N., Turner, A., Callery, J.:** SAMPLING SENSITIVITY AND VICARIANCE BIOGEOGRAPHY: TESTING THE ROBUSTNESS OF VICARIANT SIGNALS

SMITH, Nathan, TURNER, Alan, Univ. of Iowa, Iowa City, IA; CALLERY, John, The Ohio State Univ., Columbus, OH

Various methods are employed to recover patterns of area relationships in extinct and extant clades. Detection of such historical patterns in fossil clades relies implicitly upon these patterns being accurately depicted within the phylogenies of the fossil groups. The fidelity of these patterns can be adversely affected by sampling error in the form of missing data. Little work has been done to evaluate the sensitivity of vicariant patterns to this form of sampling failure.

In order to test the robustness of vicariant signals to missing data we applied sequential pruning protocols to a large number of artificial phylogenies displaying purely vicariant patterns. This procedure approximates varying degrees of taxonomic sampling failure within artificial clades varying greatly in size and topology. Three endemic areas were considered in the study. Trees varied in size from 18 to 90 taxa and the clade size at which the vicariant signal was depicted varied from a 'small clade' (3 taxa), to 'medium clade' (6 taxa), and 'large clade' (9 taxa). Initial trials were run assuming equal probability of sampling failure among all three areas. Additional trials assigned varying weighted probabilities to each of the three areas in order to explore the effects of uneven geographical sampling.

Preliminary data indicate a period of consistently accurate recovery followed by a non-linear decrease in signal recovery as more taxa are pruned, with a final stage where false signals are more likely to be recovered than the true signal. The inflection of the graph as well as steepness and shape of the slope of the decrease depend upon tree size and clade size, as well as the magnitude of missing data.

These simulations reiterate the importance of taxon sampling, and furthermore attest to the importance of considering overall, as well as geographical, sampling failure when interpreting the robustness of vicariant signals. Careful consideration of these details, the utilization of rigorous cladistic biogeographical methods, and the employment of a time-slicing approach, can lead to more explicit statements concerning biogeographical patterns of fossil taxa.

10:00 **BREAK**

10:15 **Pagnac, D.:** NEW CAMELS (ARTIODACTYLA: CAMELIDAE) FROM THE MID-MIOCENE BARSTOW FORMATION, MOJAVE DESERT, CALIFORNIA

PAGNAC, Darrin, Riverside, CA

*Paramiolabis "minutus"* is a "dwarfed" species of this late Hemingfordian/early Barstovian genus of miolabine camel. The UURL of adult *P. "minutus"* is ~ 58mm, whereas that of *P. singularis* is ~85mm. The skull of *P. "minutus"* exhibits neotenic features, including an enlarged orbit and a gracile rostrum. Additionally, areas of inflation on the frontals and maxillae distinguish this species. The lack of a P2 suggests *P. "minutus"* is most closely related to *P. singularis*.

The protolabine camelid *Michenia* n.sp. exhibits intermediate morphology between that of Hemingfordian *M. agatensis* and late Barstovian/early Clarendonian *Michenia yavapaiensis*. The I1-2 are present in *M. agatensis* and *M. n.sp.*, but absent in *M. yavapaiensis*. The m3 height of *M. agatensis* is ~23mm, that of *M. yavapaiensis* is ~34mm, and that of *M. n.sp.* is 30mm. The i3-p2 diastema of *M. agatensis* is ~50% the length of the p2-m3, that of *M. yavapaiensis* is ~69% of the p2-m3 length, and that



of *M. n.sp.* is ~64% of the length of the p2-m3. *M. agatensis* has a fully erupted c and m1, *M. n.sp.* exhibits an unerupted c and m1, and *M. yavapaiensis* retains an unerupted p1, but the lower canine is lost. Finally, the metacarpal of *M. agatensis* measures ~270mm, that of *M. yavapaiensis* ~180mm, whereas that of *M. n.sp.* has an intermediate length of 210mm.

Both species are limited to the southwestern United States. *P. "minutus"* is known from the Green Hills and Second Division Faunas (early Barstovian) of the Barstow Formation and the Skull Ridge Member (early Barstovian) of the Tesuque Formation, New Mexico. *M. n. sp.* is known from the Rak, Green Hills, and Second Division Faunas (late Hemingfordian-early Barstovian) of the Barstow Formation. The restriction of these species to the southwest suggests that this area was the site of relict populations of both *Paramiolabis* and *Michenia*, genera which previously had a widespread distribution throughout the Great Plains.

10:30 **Kraatz, B.:** *DESMATOLAGUS* FROM THE VALLEY OF THE LAKES AREA, MONGOLIA WITH COMMENTS ON ITS TAXONOMIC COMPOSITION

KRAATZ, Brian, University of California, Berkeley, CA

*Desmatolagus* was first described from the Hsanda Gol Formation based on specimens collected during the Central Asiatic Expeditions. Although most common in the Oligocene of Asia, *Desmatolagus* has also been described from North America. The taxonomic composition of this genus has varied significantly over time, due largely to incomplete material and limited understanding of variation within the group. This genus has been described as both a leporid and an ochotonid, leading to taxonomic debate. Regardless, it is clear that *Desmatolagus* is one of the earliest ochotonids, or closely related to their earliest representatives. New fossil material from the Valley of the Lakes Area, Mongolia is helping to clarify the taxonomic composition of this genus and its relationship to other Asian lagomorphs. This study describes new *Desmatolagus* remains from the Valley of the Lakes Area, Mongolia, and puts them into preliminary phylogenetic context. *D. gobiensis* is well known from Hsanda Gol deposits, and is found in large numbers in these new collections. This new material also includes a taxon that is near *D. vetustus*, which is much less well known from the Hsanda Gol Formation. Although biostratigraphic revision of these specimens is currently underway, Hsanda Gol localities will be discussed in regard to their stratigraphic relationships to one another and to other similarly aged deposits in Central Asia.

10:45 **Lukowski, S., Bloch, J. and Krause, D.:** SEVERAL NEW SPECIES OF *ECTOCION* FROM THE CRAZY MOUNTAINS BASIN OF MONTANA AND STRATOCLADISTIC ANALYSIS OF PALEOCENE PHENACODONTIDAE

LUKOWSKI, Stephanie, South Dakota Sch of Mines & Technology, Rapid City, SD; BLOCH, Jonathan, Univ. of Florida, Gainesville, FL; KRAUSE, David, Stony Brook Univ., Stony Brook, NY

Paleocene Phenacodontidae of the Crazy Mountains Basin (CMB) in south-central Montana are known from at least 784 dental specimens that span the late Torrejonian through the early Tiffanian. Previously documented phenacodontids from the CMB include *Tetraclaenodon septentrionalis* and *T. puercensis* (To-2 to To-3), *Ectocion collinus* (Ti-1 to Ti-3), and *Phenacodus bisonensis* (Ti-1 to Ti-3). Three new Tiffanian Ectocion species have been recently discovered from Bangtail Quarry (Q) (earliest Ti-1) in the western CMB, and Bingo Q (Ti-1) and Locality 13 (Ti-3) from the eastern CMB. The CMB collection, which includes specimens from quarries stratigraphically intermediate between Douglass Q (Ti-1) and Gidley Q (To-3) provides no evidence for co-occurrence of *Tetraclaenodon* and *Ectocion*.

Stratocladistic analysis of the 13 known North American Paleocene phenacodontid species, using 22 morphologic characters and stratigraphic order, produced one most-parsimonious tree associated with a

single cladogram that also formed the cladistic result of the same morphologic data. At the level of phylogenetic trees, the stratocladistic result suggests that the three earliest *Ectocion* species (Ti-1) form an ancestor descendant lineage that gave rise to the new Locality 13 species and *E. cedrus* by Ti-3. Body size and relative size of premolars changes in the evolution of early Tiffanian *Ectocion*. Earliest Tiffanian *Ectocion* has relatively large premolars as well as larger body size overall than later occurring Ti-1 species in which there is a reduction in body and relative size of premolars. A trend towards relatively larger premolars is observed again in Ti-3, possibly the result of a shift in diet coincident with a change towards a cooler climate.

*Phenacodus* forms a monophyletic clade that is a descendent from the ancestor-descendent *Tetraclaenodon puercensis*-*T. septentrionalis* lineage. Our result indicates that *Tetraclaenodon* did not give rise to *Ectocion* and that the mesostyle evolved at least twice in the evolution of Phenacodontidae.

11:00 **Davis, B.:** THE INTERRELATIONSHIPS OF “PEDIOMYID” MARSUPIALS (LATE CRETACEOUS, NORTH AMERICA): A SYSTEMATIC REVISION OF THE FAMILY “PEDIOMYIDAE”

DAVIS, Brian, Univ. of Oklahoma, OMNH, Norman, OK

“Pediomyids” are a diverse group of small- to medium-sized marsupials which comprise a significant portion of many Late Cretaceous, North American mammalian faunas. Known almost exclusively from isolated teeth and jaw fragments, “pediomyids” exhibit far more diversity than any other contemporaneous group of North American mammals. This has lead some to suggest that the Family “Pediomyidae” is an artificial, polyphyletic assemblage composed of multiple lineages that independently acquired various traditionally-recognized “pediomyid” molar characters, such as a reduction of the anterior styler shelf, reduction of the stylocone and a labial shift in the attachment of the cristid obliqua. The present study seeks to elucidate the interrelationships of “pediomyid” marsupials and test the monophyly of the group using cladistic methodology, including a broad sampling of Late Cretaceous, North American taxa and a thorough set of qualitative molar characters.

Results suggest the Family “Pediomyidae” and the genus “*Pediomys*” are both polyphyletic and in need of systematic revision. The early Campanian genus *Aquiladelphis* appears to be unrelated to “*Pediomys*,” with the exception of “*P.*” *exiguus* which itself is unrelated to the other species in the genus. Within the related species of “*Pediomys*,” there is one well-supported lineage containing the type, *P. elegans*, and four other species. This lineage is retained in the genus “*Pediomys*.” The two smaller “pediomyids” (“*P.*” *krejicii* and “*P.*” *prokrejicii*) are primitive and basal to the main lineage, and are removed from “*Pediomys*” and placed in a new genus. The important early Campanian “pediomyid”-like taxon *Iqualadelphis* likely represents the ancestral morphology for at least some “pediomyids” (though this is probably due to generally primitive morphology). Results carry implications for the role “pediomyids” might have played in the initial North American marsupial radiation at the beginning of the Campanian, and their relationships to various South American taxa that appear at the beginning of the Cenozoic.

11:15 **Sundell, C. and Martin, L.:** THE BEHAVIORAL IMPLICATIONS OF A MULTIPLE DEATH ASSEMBLAGE OF OLIGOCENE MARSUPIALS FROM NORTH AMERICA

SUNDELL, Craig, MARTIN, Larry, University of Kansas, Lawrence, KS

The discovery, preparation and study of an assemblage of at least 7 fossil marsupials (as well as several other individual marsupial specimens) from the Orellan burrowing mammal community near Douglas, WY yields a unique insight into the behavior and morphology of these extinct marsupials. A grouping of 7 within a burrow are homospecific while exhibiting differences in limb length, size and

other ontogenetic characters. This was probably a family group buried together during a local flood event. The presence of an age spectrum indicates sociality within this taxon. The occurrence in a burrow infilling indicates fossorial behavior, consistent with that reported for other small mammals from the Orellan. In combination with other specimens collected from the same locality and stratigraphic range, variations in tooth wear are observed, which supports ontogenetic differences.

Many additional articulated specimens provide valuable insights into the cranial and post cranial osteology of this taxon. The specimens discussed are younger in geologic age, taxonomically different, and more complete than the Chadronian *Peratherium* sp. described by Scott from the Florissant beds of Central Colorado.

11:30 **Wertheim, J., Flynn, J., Gans, P. and Wyss, A.:** NEW CHRONOLOGIC INFORMATION FOR THE LAGUNA DEL LAJA MAMMAL FAUNA(S): IMPLICATIONS FOR THE SALMA SEQUENCE

WERTHEIM, Jill, Univ. of California, Santa Barbara, Santa Barbara, CA ; FLYNN, John, The Field Museum, Chicago, IL; GANS, Phillip, WYSS, Andre, Univ. of California, Santa Barbara, Santa Barbara, CA

Recent prospecting in the central Main Range of Chile near Laguna del Laja (~37.5° S 71° W) has produced the first mammal fossils for the region. The fossils, locally abundant and well preserved, occur within a sequence of radioisotopically dateable volcanic and volcanoclastic deposits. Rich, fossil-bearing horizons occur sporadically throughout generally intensely folded exposures of the ~2 km thick early-middle Miocene Cura-Mallín Formation, in addition to less abundant levels in the younger Trapa Trapa Formation. Both formations are composed primarily of laterally discontinuous, 1-5 m thick volcanoclastic and fluvial units; intensive sampling in several localities has yielded diverse faunas, in addition to dateable horizons. Correlations between post-Neocomian formations have long been problematic in the central Andean Main Range due to geographic discontinuity, hydrothermal alteration, and structural complexity. Thus fossils, in conjunction with  $^{40}\text{Ar}/^{39}\text{Ar}$  radioisotopic data, are crucial for reconstructing the geological history and the record of mammal evolution of this area. Furthermore, the ability to radioisotopically constrain the age of this diverse fauna(s) with high precision (error  $\pm < 0.5$  Ma) presents a rare opportunity to calibrate related portions of the South American Land Mammal Age (SALMA) sequence.

11:45 **Ludvigson, G., Phillips, P., Joeckel, R., Gonzalez, L., Brenner, R. and Davis, J.:** TRACKING THE FOOTPRINTS OF ANCIENT GROUNDWATERS: A SEDIMENTOLOGIC VIEW OF DINOSAURIAN TRACK BEDS

LUDVIGSON, Greg, Univ. of Iowa, Iowa City, IA; PHILLIPS, Preston, Univ. of North Carolina-Pemberton, Pemberton, NC; JOECKEL, Robert, Univ. of Nebraska-Lincoln, Lincoln, NE; GONZALEZ, Luis, Univ. of Kansas, Lawrence, KS; BRENNER, Robert, DAVIS, Jeremy, Univ. of Iowa, Iowa City, IA

The role of early lithification as an important physical process leading to the preservation of dinosaur tracks has probably been overlooked in many cases. Are dinosaur tracksites the products of background sedimentation processes, or does their preservation sometimes depend on special circumstances? Our petrographic evaluation of several track-bearing horizons shows strong evidence for early cementation, prior to the onset of compactive deformation of the rock fabric by lithostatic loading with progressive burial. Criteria supporting this interpretation, present in both coarser-grained siliciclastic and carbonate host beds, includes: (1) the preservation of high intergranular volumes (30-50%) filled by early diagenetic cements; and (2) the development of fenestral fabric in peritidal lime mudstones. Rocks with high intergranular volumes  $> 30\%$  preserve the relict fabrics of unlithified

surficial sediments, and the stable isotopic geochemistry of the early diagenetic cements filling primary intergranular pore spaces preserves a paleoenvironmental record of synsedimentary pore fluid evolution. A collection of North American Late Jurassic and mid-Cretaceous dinosaur track sites subjected to our diagenetic studies shows that early cement precipitation occurred in (1) meteoric-phreatic pore fluids, (2) meteoric-vadose pore fluids, and (3) groundwaters influenced by meteoric-marine phreatic fluid mixing. In the first two cases, dinosaur track beds have proven to be important archives of terrestrial paleoclimatic data. In the latter case, dinosaur track beds in coastal plain successions are shown to occur as sheet-cemented zones at sequence and parasequence boundaries that are immediately overlain by marine flooding surfaces. We suggest that these strata can serve as geochemical archives of paleoenvironmental information while simultaneously documenting animal behavior.

12:00 **Burres-Jones, C.:** REPRECIPITATION OF CALCIUM PHOSPHATES WITHIN THE FOOD/FECAL BOLUS AS PART OF A SUITE OF CHARACTERS FOR RECOGNITION OF DISAGGREGATE SCAT IN THE FOSSIL RECORD

BURRES-JONES, Cara, Pasadena City College, Pasadena, CA

Examination of modern and fossil carnivore scat by SEM has yielded a suite of potential microtaphonomic characters for identification of digested bone fragments as coprocoenotic, even if a coherent bolus shape has not been maintained. In addition to the distinctive corrosive tissue modification and loss that characterizes digested microvertebrate skeletal materials, the recognition that the mineralization of scat can be successional is important. A distinction is made among 1) mineralization that could occur within the digestive tract of the carnivore (or shortly after defecation within the fecal material), 2) biomineralization that occurs due to the activities of colonizing microbes after scat deposition and 3) diagenetic mineralization after burial.

EDX data show a calcium phosphate matrix adhering to both fossil and modern bone fragments from carnivore scat. This presumed reprecipitate of dietary calcium phosphates liberated during the acidic phase of digestion has entrapped and cemented together other gut contents including hair and, in one instance what appears to be two *Bacillus*-like bacteria in a diplobacillus arrangement, essentially plastering them to the bone surface. Where the matrix has cracked open, hairs are revealed laying in natural hemi-cylindrical molds that often preserve the impressions of the hairs' cuticular scale patterns, thus providing a bio-structural marker that narrows the window of formation of this mineralized matrix. The hair entrapped in the modern scat samples appears little modified by digestion and retains good cuticular scale morphology, while the cuticle of hair entrapped in the fossil samples appears to have been partially digested by the actions of fungal hyphae and shows some degree of bio-mineralization. The fractured matrix also commonly displays small spherical spaces that are interpreted as possibly having been formed by gas bubbles.

Recognition of the presence of disaggregate scat in an assemblage could significantly affect taphonomic and paleoecologic interpretations if the taphonomic bias of accumulation by a predator had not previously been considered.

12:15 **Daniel, J. and Chin, K.:** THE ROLE OF BACTERIALLY MEDIATED PRECIPITATION IN THE PERMINERALIZATION OF BONE

DANIEL, Joseph, Univ. of Colorado at Boulder, Loveland, CO; CHIN, Karen, Univ. of Colorado at Boulder, Boulder, CO

Vertebrate taphonomy has been dominated by studies investigating bone destruction, but relatively little attention has been paid to how bone is preserved. This paper presents research on bone preservation, extending preservational taphonomic studies to vertebrates. The role of bacteria in mineral

precipitation was examined using an actualistic experimental approach. A saturated calcium carbonate solution was percolated through cubes of fresh, bleached cow bone placed in river sand for twelve weeks. Four different trials were run. The “natural” trial used unmodified sediment with a natural bacterial population. Two trials were run with bleach and sodium azide added to inhibit bacterial populations. The possible side effects of bleach on mineral precipitation were tested in a washed trial in which bacteria were re-introduced into the sand after bleach treatment. The extent of calcium carbonate precipitation was evaluated by assessing sand agglutination on bone cube surfaces and mineral deposition within the bone tissue. Spongy bone from both the natural and washed trials showed significant sand agglutination within two to six weeks, and mineral deposition was apparent throughout the cubes by twelve weeks. Spongy bone from the bleach and azide trials showed little sand agglutination after twelve weeks and little to no mineral deposition was seen within the cubes. These results support an important role for bacterially mediated precipitation in bone permineralization and help elucidate the mechanisms and potential timing of bone fossilization. This research provides experimental evidence that bacteria are important agents of fossilization for bone as well as soft tissue.

**THURSDAY AFTERNOON, NOVEMBER 4, 2004**

**TECHNICAL SESSION VII  
PLAZA BALLROOM A/B  
MODERATOR: JAMES CLARK**

1:30 **Alcober, O., Martinez, R., Heredia, G., Colombi, C., Olivares, I. and Trotteyn, M.:** NEW VERTEBRATE FINDINGS IN THE UPPER TRIASSIC LOS COLORADOS FORMATION, ISCHIGUALASTO BASIN, NORTHWESTERN ARGENTINA

ALCOBER, Oscar, MARTINEZ, Ricardo, HEREDIA, Guillermo, Instituto y Museo de Ciencias Naturales - UNSJ, San Juan, Argentina; COLOMBI, Carina, OLIVARES, Itati, CONICET- IMCN - UNSJ, San Juan, Argentina; TROTTEYN, Maria, Instituto y Museo de Ciencias Naturales - UNSJ, San Juan, Argentina

Four new vertebrate taxa have been recovered from the most upper section of the Los Colorados Formation (Upper Triassic - Norian). The first remain consists of an almost complete articulated skeleton, including skull and lower jaw, of a new plateosaurid prosauropod dinosaur. The new taxa shows unusual features never seen in other prosauropods like a high and very short skull and a thin maxilla with a robust vertically oriented dorsal process, among others. The second specimen includes a two inches skull with articulated lower jaw and most of the cervical vertebra with articulated dorsal scutes. These remains belong to a crocodylomorph more closely related to *Protosuchus* from the Upper Triassic of North America than *Hemiprotosuchus* from Los Colorados Formation. The new specimen has a flat skull with an elongated shape resembling more advanced crocodylomorphs, lacking the typical protosuchian square snout, laterally opened depression on premaxilla for the enlarged lower tooth, well developed antorbital fenestra and a short dentary symphysis.

The third specimen includes a complete skull with articulated lower jaw and an isolated portion of articulated distal caudal vertebra with a double row of dorsal scutes. The new taxa shows cranial features closely related to the sphenosuchian *Pseudohesperosuchus*, although *Pseudohesperosuchus* does not have any evidence of a dorsal dermal armour.

The last one consists in a rostral portion of an inch skull of an herbivorous cynodont. The affinities of this specimen are uncertain because of the poor preservation, but enough to document the first record of cynodonts in Los Colorados Formation and the survivance of this group in the southern portion of Gondwana very close to the Triassic-Jurassic boundary.

1:45 **Clark, J., Xu, X., Forster, C., Wang, Y. and Eberth, D.:** NEW DISCOVERIES FROM THE MIDDLE-TO-UPPER JURASSIC SHISHUGOU FORMATION, XINJIANG, CHINA

CLARK, James, George Washington Univ., Washington, DC; XU, Xing, Institute Vert. Paleo. and Paleoanth., Beijing, China; FORSTER, Catherine, Stony Brook Univ., Stony Brook, NY; WANG, Yuan, Institute Vert. Paleo. and Paleoanth., Beijing, China; EBERTH, David, Royal Tyrrell Museum, Drumheller, AB, Canada

Joint expeditions from the IVPP and GWU explored the Shishugou Formation in the Junggar Basin, Xinjiang, annually from 2001 to 2003. The 2003 expedition re-opened a quarry in the lower, Middle Jurassic, part of the formation from which the type specimen of the sauropod *Bellusaurus sui* was collected. We amassed a large collection of this taxon during one and one-half week of quarrying, as well as rare remains of theropods. All of the material is disarticulated elements of juvenile animals and the vast majority is from the vertebral column and limbs, but several cranial and mandibular bones were

collected. Among these are a parietal, a postorbital, and a dentary. The upper, Late Jurassic, part of the formation at Wucaiwan yielded many skeletons of tiny crocodyliforms, mostly of a basal neosuchian with a shorter rostrum than *Sunosuchus junggarensis*. One small area preserved a mass death of these crocodyliforms, with at least 10-15 skeletons.

Study of material collected in 2001 and 2002 from the upper part of the formation is clarifying the relationships of the dinosaurs, crocodyliforms, and tritylodonts. The neck and partial skull of a stegosaur from Jiangjunmiao is the first from this formation, and its dental morphology indicates it is a basal form. Abundant material of a medium sized theropod, including articulated specimens and a juvenile skull, belongs to a new basal tetanuran. The most common ornithomimid is represented by excellent cranial and postcranial material that is likely *Gongbusaurus wucaiwanensis*, previously known from a single fragmentary specimen. Excellent cranial and postcranial material of tritylodonts from Wucaiwan are the first from the upper part of the formation, and include at least two taxa. Crocodyliforms include a basal crocodyliform similar to *Shartegosuchus* from western Mongolia, suggesting a correlation between the upper Shishugou and the Upper Jurassic beds at Shar Teeg. Our collection reaffirms the faunal differences between the lower and upper part of the Shishugou Formation.

2:00 **Foster, J. and Trujilli, K.: THE SMALL-VERTEBRATE SAMPLE OF THE MORRISON FORMATION: HAS COLLECTING BIAS HIDDEN A SIGNIFICANT AQUATIC COMPONENT IN THE LATE JURASSIC?**

FOSTER, John, Museum of Western Colorado, Grand Junction, CO; TRUJILLO, Kelli, Univ. of Wyoming, Laramie, WY

The Upper Jurassic Morrison Formation of western North America has yielded one of the most diverse and well-represented small-vertebrate faunas in the Mesozoic of the western hemisphere. Counts of more than 2000 specimens in museum collections indicate that the most abundant small-vertebrate groups in the Morrison Formation are, in descending order of abundance: 1) turtles, 2) mammals, and 3) fish. In terms of numbers of localities at which they are found, three of the four most common groups are crocodylians, turtles, and fish. Overall, semi-aquatic and aquatic taxa clearly outnumber terrestrial taxa. This may not be surprising, given that most facies in the Morrison that preserve vertebrates represent freshwater paleoenvironments, but thus far such aquatic taxa, particularly fish, have been regarded as relatively rare, fitting the geologic evidence for xeric conditions in the region during the Late Jurassic. We show that at two screenwashed sites in the Morrison Formation of Wyoming, aquatic and semi-aquatic taxa are very common, indicating that, whatever the climatic conditions, abundant perennial surface water sources were present on the floodplain. The samples from the two individual sites contain 88%-89% combined aquatic and semi-aquatic taxa. In the formation as a whole, aquatic and semi-aquatic taxa account for 61% of the small-vertebrate sample and terrestrial and aerial taxa account for 39%. The two Wyoming sites yielded many teeth, jaws, palatal fragments, scales, and fragments of skull bones, all belonging to fish; most of these were only noticed under a microscope. Most small vertebrates in the Morrison Formation have been found as a result of quarrying for larger animals and from surface collecting of prospecting sites. Compared with the case in some other Mesozoic formations, few Morrison sites have been thoroughly screenwashed. If other Morrison localities yielding abundant surface material of crocodylians and turtles were screenwashed, we predict that some would be found to contain many more small-vertebrate remains and that many of these would be of fish and other aquatic and semi-aquatic taxa.

2:15 **Straight, W. and Eberth, D.: TAPHONOMY AND MODE OF FOSSIL ACCUMULATION IN THE UPPER CRETACEOUS HORSESHOE CANYON FORMATION, ALBERTA, CANADA**

STRAIGHT, William, Duke Univ., Durham, NC; EBERTH, David, Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada

A survey of taphonomic modes and facies associations for 521 discrete vertebrate fossil sites in the 210m thick lower Horseshoe Canyon Formation (IHCF), south-central Alberta, reveals that the vast majority (95%) occur in association with fine-grained, non-channel facies. Of these, 77% occur in mudrocks deposited in overbank settings and 23% in silty sandstones of splay origin. In these fine-grained facies, bones and teeth are believed to have accumulated through attrition on poorly drained proximal floodplains adjacent to anastomosing river channels. Fossils are fragmentary and exhibit minor wear and abrasion, modest evidence of fungal mottling, and abundant evidence of pedogenic corrosion and polish. Over half (54%) of the sites cluster in laterally extensive, facies-independent floodplain and floodbasin horizons. A high-resolution stratigraphic analysis of the IHCF suggests that this taphonomic mode resulted from the concentration of animal remains when accommodation was low and fine-grained sediment was abundant. Optimum bone-concentrating conditions developed during stillstands, which are preserved repeatedly and cyclically in the IHCF as subtle, laterally discontinuous erosional surfaces and occur as a result of high-order variations in regional base-level. Thus, these fossiliferous horizons are generally analogous to condensed sections in open marine settings.

2:30 **Folie, A., Sige, B. and Smith, T.:** THE EARLIEST TERTIARY HERPETOFAUNA OF EUROPE

FOLIE, Annelise, Royal Belgian Institute of Natural Sciences, Brussels, Belgium; SIGE, Bernard, Universite Claude Bernard-Lyon 1, Villeurbanne, France; SMITH, Thierry, Royal Belgian Institute of Natural Sciences, Brussels, Belgium

The Belgian vertebrate site of Hainin (Mons Basin) was discovered in the seventies, following the boreholes made by the Faculte Polytechnique de Mons to reach the marine Danian layers. The overlying "Montian" continental deposits (middle Paleocene), yielded the earliest Tertiary mammal fauna in Europe (reference-level MP1-5). Among the vertebrate remains, 80 disarticulated fragments from a first borehole were attributed to amphibians and lacertilians. Previous studies determined that amphibians are represented by Anura of the family Discoglossidae and maybe Palaeobatrachidae, and by Caudata mainly belonging to the family Salamandridae. Lacertilians were mainly represented by Lacertidae and Anguinae, while cf. *Dunnophis* attested the presence of ophidians. Because of poorly preserved and non diagnostic material, the systematic identification was mostly restricted to the familial level. After years of discontinued technical work to treat the sediment and to pick up the specimens from the residue, all of them have been recently isolated. The material is exceptional as it contains around 1300 diversified and well-preserved herpetological fragments, including around 600 nearly complete vertebrae. The study of this new material just begins but the preliminary results already provide new data. The mostly represented amphibian group is that of the Caudata, which displays at least 10 vertebrae morphotypes. Well-preserved ilia and complete surangular, humerus distal ends and urostyle attest the presence of several anuran taxa. One abundant osteoscuter type probably represents a glyptosaurine Anguinae similar to the genus *Proxestops*, well known from the Paleocene of western interior North America. Well-preserved jaw fragments (premaxillae, maxillae and dentaries) and skull bones (frontals and parietal) of a new taxon present characters shared by Cordylidae, Scincidae and Paramacellodidae. Finally, the biogeographic and environmental conditions that occurred in Hainin during the middle Paleocene will also be completed.

2:45 **Stanton, K. and Carlson, S.:** CARBON AND OXYGEN ISOTOPES IN EXTANT ARCHOSAURS (RATITES AND CROCODYLIANS): THE HOOK ON WHICH TO HANG THE HAT OF FOSSIL NON-AVIAN DINOSAUR ISOTOPIC DATA



STANTON, Kathryn, CARLSON, Sandra, Univ. of California Davis, Davis, CA

Extant avians and crocodylians are the best candidates for isotopic comparisons in dinosaurian biogeochemical studies because they are the closest extant relatives of non-avian dinosaurs, and because they represent more basal and more derived lineages (respectively) relative to terrestrial dinosaurs. In this study we develop a baseline of  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  isotopic data from biominerals (bones and teeth) in extant crocodylians and ratite birds; none currently exists. Specific questions that we address are: Do extant ratites and crocodylians display a latitudinal (i.e. climatic)  $\delta^{18}\text{O}$  gradient? Can isotopes be used to segregate dietary ( $\delta^{13}\text{C}$ ) and habitat ( $\delta^{18}\text{O}$ ) preferences, e.g. diet and trophic partitioning, closed vs. open-canopy dwellers, or drinkers vs. non-drinkers, in these groups? Are body size effects apparent in  $\delta^{18}\text{O}$  data?

$\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  data were collected from bones, enamel, and dentine from a latitudinal gradient (~34' N to 53' S) of ~10 species in 4 genera of extant crocodylians and ~5 species in 5 genera of extant ratites. Results suggest that 1) a  $\delta^{18}\text{O}$  latitudinal gradient is apparent, although it can be overprinted by both dietary and physiological effects. 2) Ratites display lower  $\delta^{13}\text{C}$  variability than do crocodylians. 3) Dietary effects are apparent, e.g. non-drinking ostriches display more enriched  $\delta^{18}\text{O}$  relative to drinking ratites. Isotopic data from this study establishes patterns of variation in modern archosaurs from which predictions of isotopic variation in dinosaur specimens can then be tested. These results will provide a dataset for interpretations of isotopes from two Maastrichtian non-avian dinosaur faunas: the Royal Tyrrell Museum of Paleontology *Albertosaurus* bonebed (Upper Horseshoe Canyon Formation, Alberta) and the Concordia College *Edmontosaurus* bonebed (Lower Hell Creek Formation, South Dakota), and can serve as a similar foundation for other archosaurian biogeochemical studies.

3:00 **Wheatley, P.:** CALCIUM ISOTOPE SIGNATURES IN BONE AS A POTENTIAL BIOMARKER FOR OVIPARITY

WHEATLEY, Patrick, Jackson School of Geological Sciences, The Univ. of Texas at Austin, Austin, TX

In order to make inferences about extinct and fossil animal physiology and behavior, paleontologists are increasingly utilizing stable isotopes. Using bones from animals that minimally remodel their hard tissues, it may be possible to infer processes that occurred during the early ontogeny of an animal's life. To examine potential isotope fractionating processes in early development, I constructed an isotopic growth series utilizing Ca isotopes for extant domestic chicken embryos. Fertilized domestic chicken (*Gallus gallus*) eggs were obtained and the albumen, yolk, eggshell, and embryonic bone analyzed in order to determine Ca isotopic composition. The eggs ranged in ontogenetic age from 10-20 days after oviposition.

Yolk and shell components contained  $\delta^{44}\text{Ca}$  values roughly consistent with that of work done by other researchers on unfertilized eggs. Prior studies of the Ca isotope composition of vertebrates show that the  $\delta^{44}\text{Ca}$  value of bone is lower than that of its diet, which is approximately the same as soft tissue. The embryonic bone measured in this study was characterized by a  $\delta^{44}\text{Ca}$  value that was higher than the primary source of Ca (shell) and about the same as the secondary source of Ca (yolk). Moreover, the embryonic chicken bone has substantially higher  $\delta^{44}\text{Ca}$  than previously measured values in adult chicken bone. Prior research done on viviparous mammal bone showed  $\delta^{44}\text{Ca}$  values of juvenile bone were indistinguishable from adult bone at the same trophic level. These data taken together indicate that high  $\delta^{44}\text{Ca}$  values in neonate animals may be a biomarker of oviparity. In species with little or no bone remodeling, this unique isotopic signature could persist into later stages of ontogeny. This information could be useful for studying temporal and geographic patterns of viviparity and oviparity in the fossil

record. Further research on squamate reptile clades that exhibit both viviparity and oviparity may provide evidence to support or refute this hypothesis.

**TECHNICAL SESSION VIII**  
**PLAZA BALLROOM F**  
**MODERATOR: LAWRENCE FLYNN**

**1:30 Stevens, N., Gottfried, M., O'Connor, P., Roberts, E. and Kapilima, S.: A NEW PALEOGENE FAUNA FROM THE EAST AFRICAN RIFT, SOUTHWESTERN TANZANIA**

STEVENS, Nancy, Ohio Univ., Athens, OH; GOTTFRIED, Michael, Michigan State Univ., East Lansing, MI; O'CONNOR, Patrick, Ohio Univ., Athens, OH; ROBERTS, Eric, Univ. of Utah, Salt Lake City, UT; KAPILIMA, Saidi, Univ. of Dar es Salaam, Dar es Salaam, Tanzania

Paleogene vertebrate fossils are well-documented in northern Africa (e.g., the early Oligocene Jebel el Qatrani formation of Egypt), yet relatively fewer specimens have been recovered from the sub-Saharan portion of the continent. We announce the discovery of a new Paleogene fauna from the Mbeya region of southwestern Tanzania. Fossil material comes from a laterally extensive microsite located in sandstone deposits that are interpreted as either channel lag or flood deposit. The locality has produced numerous small (< 2 cm) isolated fish, anuran, crocodylian, bird and mammal specimens, in addition to an articulated anuran distal hindlimb. Mammalian specimens prepared thus far include teeth, jaws and postcrania of multiple phiomorph rodent taxa (e.g., *Metaphiomys beadnelli*), suggesting a late Paleogene age for the site. In addition, well-preserved gastropods, crustaceans and trace amounts of plant pollen have been identified. The recovery of such a diverse vertebrate and invertebrate assemblage is crucial for understanding the evolutionary history of rodent and other vertebrate taxa from continental Africa. Work is underway to further clarify the geological and paleontological significance of this region.

**1:45 Campbell, K. and Frailey, C.: REVIEWING THE PALEOGENE SANTA ROSA LOCAL FAUNA OF AMAZONIAN PERU**

CAMPBELL, Kenneth, Natural History Museum, Los Angeles, CA; FRAILEY, Carl, Johnson County Community College, Overland Park, KS

It has long been recognized that the Tertiary record of vertebrates in South America is largely restricted to the southern part of the continent, a fact that has biased our understanding of faunal evolution on that continent. Although efforts over the last decade have improved our knowledge of the Neogene of northern South America, there remains little information on low latitude paleofaunas of the Paleogene. Here we report on progress in interpreting the abundant fossil assemblage from the Santa Rosa local fauna of eastern Peru, the first Paleogene vertebrate fauna known from tropical, lowland Amazonia, an area encompassing approximately 40 percent of the continent.

The Santa Rosa local fauna comprises a diverse array of vertebrate species, most notably including South America's oldest known rodent fauna. The most common vertebrates in the paleofauna are fish, followed by reptiles, mammals, amphibians, and birds. Thus, aquatic, terrestrial, arboreal, and flying components of the paleofauna are all represented. Nearly 40 species of mammals are represented, the most numerous and diverse being marsupials and rodents. Microvertebrates dominate the paleofauna, whereas fragmentary specimens hint at the presence of a diverse macrofauna. The mammals of the Santa Rosa local fauna present an array of new genera and species unexpected in light of the well-known Eocene faunas of southern South America, with some species so unique as to be unassignable to known mammalian orders.

The Santa Rosa local fauna is considered to be mid- to late Eocene in age based on the stage of evolution of the marsupials and rodents. Paleoecological interpretations are suggestive of riparian forests bordering shallow, slow moving streams, with open canopy woodlands nearby.

2:00 **Vucetich, G., Carlini, A., Madden, R. and Kay, R.:** NEW DISCOVERIES AMONG THE OLDEST RODENTS IN SOUTH AMERICA: HOW OLD AND HOW PRIMITIVE?

VUCETICH, Guiomar, CARLINI, Alfredo, Univ. Nacional de La Plata y Museo, La Plata, Argentina; MADDEN, Richard, KAY, Richard, Duke Univ., Durham, NC

It is well known that South America was an island continent during much of the Cenozoic and this isolation broke down sometime during the Paleogene when two new mammalian groups, the rodents and primates arrived. The phyletic origin, geographic source area, and antiquity of the immigration events of these two groups has inspired much controversy. Recently, various authorities have provided new information about the oldest rodents of South America, generating new problems and discussion, especially with respect to the age of their arrival.

New fossil rodents, the oldest known from Patagonia, have been recovered from a pre-Deseadan level at Gran Barranca (Chubut Province) in association with a volcanic tuff whose  $^{40}\text{Ar}/^{39}\text{Ar}$  age results present problems of interpretation, but constrain its age to between 34 and 30 Ma. The associated fauna is rich and diverse, and includes some typical Deseadan taxa (*Rhynchippus*), some typical Tinguirirican taxa (*Protarchaeohyrax*, *Archaeotypotherium*), some Mustersan-Deseadan taxa (*Palaeopeltis*) and lacks typical Deseadan rodents. The material includes at least three taxa. The most abundant is a new taxon more primitive than *Sallamys* because of its moderately developed mesolophid. This new taxon is related to the octodontoid lineage *Sallamys? minutus* (Deseadan age from Taubate, Brazil) ?*Sallamys* (Deseadan of Salla, Bolivia) *Willidewu* (Colhuehuapian of Patagonia) *Protadelphomys* (Colhuehuapian of Patagonia). A second taxon, represented by an m1 or m2, is larger and more hypsodont than the first and has a fully developed mesolophid. The third taxon is a novel small and very brachydont species of as yet uncertain affinity. Comparison of this new material with known early Oligocene rodents from South America, and the absence of any trace of rodents from the immediately subjacent level at Gran Barranca (33.4 Ma), suggests that the initial rodent diversification in South America was rapid and geographically diverse.

2:15 **Flynn, L. and Morgan, M.:** AN UNUSUAL RODENT FROM AN INFREQUENTLY SAMPLED INTERVAL IN THE SIWALIKS OF PAKISTAN

FLYNN, Lawrence, MORGAN, Michele, Harvard Univ., Cambridge, MA

The Siwalik deposits of Pakistan yield numerous superposed assemblages that record stability and change in the small mammal fauna throughout middle and late Miocene time on the Indian subcontinent. Nonetheless, there are some intervals that are poorly represented by microfaunas. One such stratigraphic interval is the thick sandstones of the Nagri Formation, which span one to two million years. There are exceptions to the Nagri dearth of fossils. Sethi Nagri, locality Y311, is a remarkable example occurring near the top of the Nagri Formation. Between the older, rich Chinji Formation assemblages and Y311, few fossil localities have been found to yield rodents. In 1989 our group discovered the rich small mammal locality Y797 dating to about 11 Ma just prior to the first appearance of hipparionine equids.

Y797 is notable for presence of a new large diatomyid rodent recorded nowhere else in the Siwaliks. Diatomyidae are a small group of enigmatic origin. The new genus has affinity with *Diatomys* from China and Thailand and with predecessors such as *Fallomus* from the pre-Siwalik formations of Bugti and the Zinda Pir Dome, Pakistan. It is derived in large size, absence of accessory cusps, and extreme bilophodonty. It is by far the latest member of its group. This taxon is rare by any standard: both rare in its unique occurrence and its representation at Y797 (only two teeth among 340 specimens). Older members of the family are generally abundant in the faunas that produce them.

Does Y797 preserve a unique rodent fauna derived from an unusual ecological setting? We suspect not because faunal similarity is quite high at the species level with respect to older Chinji and younger Nagri assemblages. Possibly Y797 preserves this new diatomyine by chance sampling. Also possible is that the new form occupied a niche differing from that of its predecessors, one that permitted survival (perhaps peripheral to the Siwaliks), yet one that did not contribute to preservation in abundance.

2:30 **Hopkins, S.:** THE MECHANICS AND EVOLUTION OF FOSSORIALITY IN MYLAGAULID RODENTS: FUNCTIONAL AND ECOLOGICAL DIVERSITY IN A CLADE OF FOSSORIAL MAMMALS

HOPKINS, Samantha, Univ. of California Berkeley, Berkeley, CA

Rodents of the family Mylagaulidae have long been recognized as fossorial, based on their cranial and postcranial adaptations. However, ecological classification of this clade has been hampered by a number of problematic morphological features that are inconsistent with modern fossorial rodents. In particular, the presence of prominent nasal horns in at least one genus (*Ceratogaulus*) and possibly several genera of this family, presents difficulties in reconstructing the ecology of this group. No other fossorial mammals, extant or extinct, possess this characteristic; hence the nasal horns represent a unique morphology and, given the importance of the head in fossoriality, probably a unique ecology. Any statement about the ecology of this clade needs to take this feature into account.

An examination of the functional morphology of the head and neck indicates that most mylagaulids differed from all extant North American fossorial mammals in that they used the snout extensively in digging, as do modern golden moles (family Chrysochloridae), blind mole rats (genus *Nannospalax*), and the extinct proscalopid moles (family Proscalopidae). Most mammals employing this behavior are subterranean (spending very little time above ground), rather than simply fossorial. Fossorial mammals, which spend a significant amount of their time above the ground, are usually limited to scratch digging. Almost all mylagaulids have morphology consistent with head-digging; however, the horned mylagaulids (genus *Ceratogaulus*) may be an exception. *Ceratogaulus* species appear to be more strongly adapted for scratch digging and less able to use the head in digging. A pattern of co-occurring species of horned and hornless mylagaulids through the mid- to late Miocene in the Great Plains may have resulted from the diversification of this clade to occupy fossorial as well as subterranean niches. It is possible that this ecological change played some role in the biogeographic patterns of mylagaulids and aplodontine aplodontids in the middle and late Miocene.

2:45 **Moers, T. and Stefan, C.:** THE BEAVER *ANCHITHERIOMYS* FROM THE MIOCENE OF CENTRAL EUROPE

MOERS, Thomas, Swedish Museum of Natural History, Stockholm, Sweden; STEFEN, Clara, Museum fuer Tierkunde, Dresden, Germany

*Anchitheriomys* is a rare beaver genus from the Miocene of Europe, North America and Asia. It is characterized by hypertrophic incisors with convex and strongly striated enamel, and a complex pattern of enamel islands on the occlusal surface of the cheek teeth. Several species of *Anchitheriomys* have been described: *A. suevicus* from Europe, *A. fluminis* and *A. stouti* from North America, and *A. tungurensis* and *A. caucasicus* from Asia.

New finds of *Anchitheriomys* have been recently discovered in the middle Miocene deposits of the Hambach open cast lignite mine near Cologne in northwest Germany. The site Hambach 6C produced 2 mandibular fragments and 10 isolated teeth and teeth fragments, which add substantially to the known material of this rare genus.

The new material from northwest Germany and the first detailed descriptions of other mandibles from south Germany and Switzerland allow a review of this rare castorid genus from Central Europe. Based on this material, together with (partly) new isolated teeth, the metric variation of cheek teeth, and especially the great differences in dimensions of incisors, can be much better assessed.

The observed range in size can be attributed to ontogenetic changes (e.g. increasing occlusal surfaces in the cheek teeth), therefore all material is assigned to *Anchitheriomys suevicus*. Stratigraphically this species is restricted to the early middle Miocene, European Mammalian Neogene biozones MN 5-6. The comparison of *Anchitheriomys suevicus* with the North American *A. fluminis* and *A. stouti* and the Asian *A. tungurensis* indicates that there are at least two lineages within *Anchitheriomys* and that *A. fluminis* might be synonymous with *A. suevicus*.

3:00 **Steppan, S., Adkins, R., Anderson, J., Hale, C. and Spinks, P.: PHYLOGENY AND DIVERGENCE-DATES IN MUROID RODENTS BASED ON MULTIPLE NUCLEAR GENES: COMPARISONS AND CONTRASTS TO MORPHOLOGICAL HYPOTHESES**

STEPPAN, Scott, Florida State Univ., Tallahassee, FL; ADKINS, Ronald, Univ. Tennessee, Memphis, TN; ANDERSON, Joel, SW Foundation for Biomedical Research, San Antonio, TX; HALE, Christopher, Florida State Univ., Tallahassee, FL; SPINKS, Phillip, Univ. of Calif., Davis, CA

The muroid rodents are the largest superfamily of mammals, containing nearly 1/3 of all mammal species, and have been particularly problematic for morphological systematics. We report on our largescale phylogenetic studies comprising over 100 genera sequenced using four slowly evolving nuclear genes, GHR, BRCA1, RAG1, and c-myc, totaling 6,400 nucleotides (2,500 parsimony-informative). Most relationships among subfamilies are resolved. All four genes yield nearly identical phylogenies. There is a fundamental division of the fossorial rats (Spalacinae and Rhizomyinae) from all other muroids. Among the “core” muroids, a rapid radiation led to at least four distinct lineages: Asian *Calomyscus*, an African clade of at least four endemic subfamilies, a hamster clade with maximum diversity in the New World, and an Old World clade including gerbils and the diverse Old World mice and rats (Murinae). Within the latter, triserial *Acomys* is confidently removed from Murinae to Deomyinae, a clade well supported as the sister group to the gerbils (Gerbillinae). Four key regions appear to represent rapid radiations and, despite a large amount of sequence data, remain poorly resolved: the “core” muroids, the five cricetid (hamster) subfamilies, a large clade of South American Sigmodontinae, and major geographic lineages of Old World Murinae. Because of the detailed taxon sampling within Murinae, we are able to refine the critical *Mus-Rattus* fossil calibration and apply a rate-smoothed molecular clock to date key events in muroid evolution. Our divergence date estimates are more congruent with the fossil record than many recent molecular studies that use outgroup calibrations or fail to correct for elevated evolutionary rates in Myodonta. We discuss the implications of this robust phylogeny for the interpretation of molar evolution, particularly the triserial cusp pattern, and the utility of dental characters for systematics. The results suggest that morphological data have generally been successful at identifying subfamily-level clades but have failed to correctly recover groups at higher (family) or lower (tribal) levels with any confidence.

**TECHNICAL SESSION IX  
GOVERNOR'S SQUARE 14  
MODERATOR: DAVID ELLIOTT**

1:30 **Gonzalez-Barba, G.:** YPRESIAN SHARKS, BATOIDS, AND TELEOST FISHES FROM THE TEPETATE AND BATEQUE FORMATIONS, BAJA CALIFORNIA SUR, MEXICO

GONZALEZ-BARBA, Gerardo, Universidad Autonoma de Baja California Sur, La Paz, Baja California Sur., Mexico

Ypresian fossil fish faunas from the Bateque and Tepetate Formations are reported. Although Lutetian-Priabonian elasmobranch faunas have previously been described from each of these units, the Ypresian faunas represents a different assemblage from Baja California Sur, Mexico. The recorded taxa include: *Hexanchus microdon*, *Ginglymostoma angolense*, *G. maghrebianum*, *Nebrius obliquus*, *Carcharias hopei*, *Anomotodon novus*, *Isurolamna inflata*, *Serratolamna lerichei*, *Xiphodolamia ensis*, *Cretolamna appendiculata*, *Carcharocles disauris*, *Paleogaleus sublaevis*, *Galeorhinus ypresiensis*, *Physogaleus secundus*, *Abdounia recticonia*, *Leidybatis granulatus*, *Dasyatis* sp., *Aetobatus* sp., *Myliobatis* sp., *Rhinoptera* sp., *Eotrigonodon* sp., *Eutrachiurides* sp., *Trichiurus* sp., and *Phyllodus* sp. Of the two faunas, that of the Tepetate is more diverse and abundant, but this is generally the result of intensity of collection. Paleocene elasmobranchs and fishes are almost totally absent in the referred formations. The associated fauna includes abundant Capay Stage invertebrates, and new decapods have been described. These marine assemblages are the most diverse for the entire Pacific Basin during the Ypresian, and the implications for paleoclimatology, and paleobiogeography are interesting because they document strong associations with the Caribbean, eastern North American, African, European, Middle Eastern, and Asian Tethyan fish faunas. Paleocene and Eocene selachians and fishes are poorly known for the Pacific Basin. From a global perspective the changes in the fish fauna across this boundary are difficult to evaluate because of insufficient record. In this sense this Ypresian fauna will enhance our understanding of the dispersal of pelagic and benthonic animals that represent a mixture of temperate and tropical selachians and fishes into the Pacific Basin.

1:45 **Kriwet, J. and Benton, M.:** NEOSELACHIAN (CHONDRICHTHYES, ELASMOBRANCHII) DIVERSITY ACROSS THE K/T BOUNDARY

KRIWET, Jürgen, Faculty of Geosciences, Munich, Germany; BENTON, Michael, Univ. of Bristol, Bristol, United Kingdom

Fishes are often thought to have passed through mass extinctions, including the Cretaceous-Tertiary (KT) event, relatively unscathed. We show that neoselachian sharks suffered a major extinction at the K/T boundary. Seven out of 39 families ( $18 \pm 12\%$ ) became extinct. The proportional measure increases at lower taxic levels:  $61 \pm 9.6\%$  loss of genera (loss of 60 out of 98) and  $85 \pm 4.8\%$  loss of species (loss of 180 out of 211). However, the Maastrichtian and Danian are characterized by a high number of singleton taxa. Excluding these results in  $33.7 \pm 11.1\%$  lost genera and  $44.6 \pm 8.7\%$  lost species. The SCM for genera displays a decrease from the Maastrichtian (94.2%) to the Danian (85.0%) indicating a rather complete fossil record of neoselachian genera.

The extinctions were heavy among both sharks and batoids (skates and rays), but most severe among batoids, which lost almost all identifiable species. There were equal losses among open marine apex predators (loss of Anacoracidae, Cretoxyrhinidae, and Scapanorhynchidae) and durophagous demersal forms from the continental shelf and shallow seas (Hypsobatidae, Parapaleobatidae, Sclerorhynchidae, Rhombodontidae). Benthopelagic and deep-sea forms were apparently little affected. New families with

similar ecological roles (Carcharhinidae, Isuridae, Torpedinidae) replaced these families in the Danian, and full diversity of the different shark and batoid groups had been recovered by the end of the Paleocene or early Eocene. Sharks and rays suffered levels of extinction entirely in line with other groups of organisms at the KT extinction event.

2:00 **Gottfried, M., Fordyce, E. and Rust, S.:** A GIANT LATE OLIGOCENE MOONFISH FROM NEW ZEALAND

GOTTFRIED, Michael, Michigan State Univ., East Lansing, MI; FORDYCE, Ewan, RUST, Seabourne, Univ. of Otago, Dunedin, New Zealand

The Order Lampridiformes (Teleostei) includes seven extant families with 12 genera and 21 species, among them a number of spectacular and unusual fishes. Recent phylogenetic analyses (based on both morphological and molecular data) place the clade at or near the base of the acanthomorph teleost radiation. Lampridiforms are, however, poorly known in the fossil record, on the basis of only a few widely scattered Late Cretaceous to Tertiary occurrences in Eurasia and California. We report an extremely large new species of lampridiform, based on an articulated specimen recovered from the upper Oligocene (NZ Stage Duntroonian = middle Chattian, ~ 26Ma) Otekaike Limestone of North Otago, South Island of New Zealand. This new taxon is assigned to the Family Lamprididae (moonfish and opah) on the basis of its deep-bodied shape, distinctive caudal skeleton, and greatly enlarged cleithrum (which relates to the unique pectoral locomotory mode of moonfish). These features indicate that the fossil is probably a stem species in *Lampris*. The specimen has an estimated total length of ca. four meters, approximately twice the reported maximum for the extant moonfish *Lampris guttatus*. This new taxon is the only Southern Hemisphere fossil report of lampridiforms, the second fossil record for Lamprididae (along with *Lampris zatima* from the Miocene of California), and among the most complete fossil teleosts recovered from New Zealand.

The fossil moonfish adds a distinctive new element to the diverse late Oligocene marine vertebrate record from Otago, which also includes sharks, other bony fishes, penguins, and cetaceans. These records continue to elucidate mid-Cenozoic marine vertebrate evolution and biogeography in higher-latitude southern seas.

2:15 **Friedman, M. and Coates, M.:** A PREVIOUSLY UNRECOGNIZED DEVONIAN COELACANTH SHEDS LIGHT ON THE EARLY MORPHOLOGICAL DIVERSIFICATION OF THE CLADE

FRIEDMAN, Matt, Committee on Evolutionary Biology, Chicago, IL; COATES, Michael, Univ. of Chicago, Chicago, IL

Although coelacanths are often resolved as the most basal of the major sarcopterygian radiations, surprisingly little is known about their early evolutionary history. The systematic affinities of *Holopterygius*, from the latest Givetian-earliest Frasnian of Bergisch-Gladbach, Germany, have been enigmatic since its description. Known from a single specimen, this taxon is immediately distinguished by its greatly elongated diphyccercal caudal fin, a peculiar morphology that has elicited comparisons with tarrasiid actinopterygians. *Holopterygius* in fact shares several derived features with coelacanths, including a gracile pectoral girdle with an additional dermal element (extracleithrum) and a modified lower jaw with an abbreviated dentary. The reinterpretation of *Holopterygius* carries considerable implications for the early evolutionary history of coelacanths. Although *Holopterygius* represents a departure from the “typical” coelacanth body plan, it strongly resembles *Allenkypterus*, an equally peculiar Carboniferous genus. *Allenkypterus* is distinguished by an unusual teardrop-shaped body and, like *Holopterygius*, has a distinctive and greatly elongated tail. The diphyccercal caudal fin in both genera is strongly asymmetric, with a dominant dorsal lobe. Apart from these similarities of the caudal skeleton,



*Holopterygius* and *Allenkypterus* share a series of well-developed ventral ridge scales, which are otherwise unknown in coelacanths. Placement of *Allenkypterus* and *Holopterygius* as sister taxa draws at least three lineages known only from the Carboniferous or later into the Middle Devonian, only shortly after the first appearance of coelacanths in the fossil record. This validates the suspicion that much of the taxonomic (and presumably morphological) diversity of Devonian coelacanths remains to be sampled. Coelacanths have long had an iconic place in the study of vertebrate evolution for their apparent morphological conservatism over geological time; *Holopterygius* and its disparate Devonian contemporaries highlight the early exploration of morphospace by coelacanths.

2:30 **Elliott, D.:** COMMENTS ON PTERASPIDIFORM RELATIONSHIPS (AGNATHA, HETEROSTRACI)

ELLIOTT, David, Northern Arizona Univ., Flagstaff, AZ

The heterostracans are extinct armored agnathans, common in marginal marine deposits through the Silurian and Devonian, which are characterized by a pair of external branchial openings on either side of the head. In most phylogenetic analyses they are placed between the modern hagfishes and lampreys and the fossil osteostracans. However, the relationship between taxa within the heterostracans is still controversial in many cases due to the fact that many of the major taxa are still poorly known. One area that has been considered fairly well understood is the relationships within the Pteraspidiformes, a taxon that contains the Pteraspidida (including the Psammosteidae) as well as their sister group the Anchipteraspididae. The description of the anchipteraspidids from the Late Silurian of the Canadian Arctic also enabled a sister-group relationship to be shown with the Cyathaspidida with which they share a number of features. This relationship has been generally accepted and the unusual cyathaspidids *Listraspis* and *Ariaspis* have been considered as advanced species closely related to the anchipteraspidids. New material from the Canadian arctic, however, greatly enlarges the number of species related to *Listraspis* and shows that this taxon is not related to the Cyathaspidida but more directly to early heterostracans. Based on this it now appears that the Pteraspidiformes may be more closely related to early heterostracans, with which they share features such as the presence of numerous small body scales, than with their traditional sister group the Cyathaspidida.

2:45 **Brazeau, M. and Parker, K.:** A PRIMITIVE RHIZODONTID (SARCOPTERYGII, TETRAPODOMORPHA) FROM THE LOWER CARBONIFEROUS OF NOVA SCOTIA

BRAZEAU, Martin, McGill Univ., Montreal, QC, Canada; PARKER, Kate, La Trobe Univ., Melbourne, Australia

Rhizodontids are enigmatic tetrapodomorphs from the Devonian and Carboniferous. Their remains are poorly known making them difficult to place in phylogenetic analyses. New specimens from the Tournaisian (Lower Carboniferous) Horton Bluff Formation, Nova Scotia are described. These provide extensive phylogenetically useful information about rhizodontid lower jaws, pectoral girdles and appendages. The jaws exhibit a number of primitive osteolepiform characters such as parasymphysial-coronoid contact, a coronoid tooth row, and partial Meckelian ossification making them distinct from other known rhizodontids. The humerus also differs from other rhizodontids, as evidenced by a wide groove along the ventral margin of the entepicondyle, a robust pectoral process with associated deeply set foramina, and the aligned radial and ulnar condyles. These data suggest that the Horton Bluff rhizodontid material represents a new taxon.

Phylogenetic analysis of rhizodontid jaw characters suggests that the Horton Bluff form is more primitive than the more well-known genera from the United Kingdom. The lower jaws also resemble those of Devonian tetrapods in the presence of a weak dentary-infradentary overlap, dentary not

extending distally to the articular, and complex infradentary sutures. These characters suggest similar lower jaw functional anatomy and possibly closer phylogenetic relationships between early tetrapods and rhizodontids than currently believed.

3:00 **Daeschler, T., Shubin, N. and Jenkins, Jr., F.:** A NEW MEMBER OF THE SISTER GROUP OF TETRAPODA: AN ELPISTOSTEGID FISH (SARCOPTERYGII, ELPISTOSTEGALIA) FROM THE FRAM FORMATION, ELLESMERE ISLAND, NUNAVUT TERRITORY, CANADA

DAESCHLER, Ted, Academy of Natural Sciences, Philadelphia, PA; SHUBIN, Neil, Univ. of Chicago, Chicago, IL; JENKINS, Farish, Harvard Univ., Cambridge, MA

The Fram Formation (Upper Devonian, early to middle Frasnian) on southern Ellesmere Island has recently produced a diverse vertebrate fauna including an elpistostegid fish, a representative of the poorly-known sister group of the tetrapod clade. Skull and jaw material of the elpistostegid are associated with placoderm, dipnoan, porolepiform, and tristichopterid remains in a densely fossiliferous, sandy siltstone horizon.

Elpistostegids are the only fish known to possess three pairs of median skull roof bones. They also are characterized by a large median gular, a long snout incorporating an elongate prefrontal element, and dorsally-placed eyes. Only two elpistostegid genera have been described: *Elpistostege* from the Escuminac Formation (middle Frasnian), Miguasha, Canada, and *Panderichthyes* from early Frasnian deposits of the East European Platform. The elpistostegid from the Fram Formation has an exceptionally elongate lower jaw and snout. The large prefrontal flares caudally to form a significant part of the rostral margin of the orbit. The orbits are closely-spaced near the dorsal midline. Uniquely, dermal ornament is absent from the central portion of the snout. The anterior palatal fossa seems to be partially bisected by anteromedial processes of the vomers.

Elpistostegids are of great phylogenetic interest because of their sister-group relationship to tetrapods. The discovery of the new elpistostegid taxon strengthens biogeographic links between the Ellesmere Island, Miguasha, and East European Platform faunas.

## POSTER SESSION A

**Authors must be present from 3:30-5:45 p.m.**

**Posters must be removed by 6:00 p.m.**

1. **Ekdale, E. and Rowe, T.:** INTERNAL EAR STRUCTURE OF ZHELESTID MAMMALS

EKDALE, Eric, ROWE, Timothy, The Univ. of Texas, Austin, TX

“Zhelestidae” is a paraphyletic group containing eutherian mammals best known from the Cretaceous Bissekty Formation (Turonian-Coniacian) of Uzbekistan, as well as Cretaceous deposits in Europe and North America. Recent phylogenetic analyses support a close relationship between specimens referred to as “zhelestids” and certain archaic ungulate taxa. Characters that support such a relationship currently are taken only from the dentition because the majority of known specimens are isolated teeth, but petrosal bones allocated to species named from teeth are now known from Uzbekistan. An external description of the specimens was published, but the internal anatomy of the petrosals remains largely unknown. Our knowledge of the inner ear of these taxa is limited because it relies on damaged specimens; however the use of high resolution X-ray computed tomography (CT) permits non-destructive observation of the osseous labyrinth.

The inner ear of mammals is involved with hearing (cochlea), balance, and equilibrium (vestibule and semicircular canals). Although the function of the inner ear receives a great deal of attention, the

phylogenetic value of inner ear structures, especially the vestibule, is not fully known. In order to investigate the potential phylogenetic utility of the inner ear, we scanned petrosals and extracted endocasts of the inner ear from the digital CT slices. We described the anatomy of this region and measured certain aspects of the inner ear, including the degree to which the cochlea coils. This measure was previously approximated by using broken specimens, but we obtained a more accurate measurement from CT data. Additionally, we measured the angles between the semicircular canals and other portions of the osseous labyrinth which could only be determined through the use of CT. When viewed in a phylogenetic context, these features of the inner ear may shed light on the relationships between species referred to as “zhelestids” and other eutherians.

2. **Cuenca-Bescós, G., Canudo, J., Ruiz-Omeñaca, J., Rofes, J. and Barco, J.:** MAMMALS FROM THE EARLY CRETACEOUS OF SPAIN

CUENCA-BESCÓS, Gloria, CANUDO, José, RUIZ-OMEÑACA, José, ROFES, Juan, BARCO, José, Univ. de Zaragoza, Zaragoza, Spain

Isolated teeth of mammals are recorded in several Lower Cretaceous Spanish localities of the Iberian Range, such as La Cantalera (Blesa Fm., upper Hauterivian-lowermost Barremian), Galve (Colladico Blanco, Pelejón-2, Piélago-0 in the El Castellar Fm., upper Hauterivian-lowermost Barremian; Cerrada Roya, Poca and Yacimiento Herrero in the Camarillas Fm., lower Barremian) and Vallipón (Artoles Fm., upper Barremian) in Teruel Province, and Uña and Pie Pajarón (El Collado Fm., upper Barremian) in Cuenca Province.

Multituberculates, small rodent-like herbivorous mammals, dominate the mammal assemblages, where Jurassic survivors lived together with probably Cretaceous Asian immigrants. There were also insectivorous such as dryolestids, spalacotheriids, peramurids, gobiconodontids and docodonts. Modern mammals are almost absent from Early Cretaceous assemblages of Spain except for one possible, but very bad preserved, therian form Vallipón.

The rareness of mammals at the Cretaceous localities may be related, at least, to three factors, two related with the ecology of the terrestrial ecosystems, and one to the paleogeography during the Cretaceous. Mammals were not so abundant as shrews and rodents are today; probably other small vertebrates, as crocodiles and theropods, dominated the terrestrial ecosystems. The predators of mammals (such as the nocturnal birds of prey) were probably less important as a factor of accumulation as they are today. The paleogeographical factor is related with the large size of the Early Cretaceous basins, too wide to favour the concentration of animal carcasses in general, both its accumulation and its preservation.

3. **Smith, N., Sang, B. and Strait, S.:** DIVERSITY AND SPECIES ABUNDANCE OF EARLIEST EOCENE (WA-0) MARSUPIALS

SMITH, Nicholas, SANG, Brian, STRAIT, Suzanne, Marshall Univ., Huntington, WV

The earliest Wasatchian (Wa-0) was a time of great evolutionary and climatic change. Substantial faunal change, due to both dispersal and evolution, coincides with the Paleocene-Eocene thermal maximum (PETM), a time of global warming. Due to intensive collecting efforts at Castle Gardens, a Wa-0 locality in the southeastern Bighorn Basin, Wyoming, this locality now includes the largest collection of fossil Wa-0 mammals (>1,000). The objective of this study was to identify the marsupial species from Castle Gardens and analyze their relative diversity and abundance.

Three marsupial species were identified, including *Mimoperadectes labrus*, *Peratherium innominatum*, and *Peradectes protinnominatus*. *M. labrus* was the largest Wa-0 marsupial (120 grams). Seventeen specimens have been recovered, almost doubling the number previously described. Both *P.*

*innominatum* and *P. protinnominatus* were very small (10-15 grams). The majority of smaller marsupials at Castle Gardens were *P. innominatum* (n=58), while few (n=7) *P. protinnominatus* were found. The relative frequency of *Peratherium* is somewhat surprising since *Peradectes* is an established form previously known from the Clarkforkian, while *Peratherium* makes its first appearance in North America during Wa-0.

Slightly over 10% of the total number of mammalian specimens from Castle Gardens are marsupials; this percentage is substantially higher than other localities in the Bighorn Basin during the Clarkforkian and Wasatchian (which range from 0-4.6%). A marsupial abundance of 10.2% is much more similar to Washakie Basin faunas (which range from 11-14%). It is possible that temperature played a key role in marsupial abundance. With the exception of the large *Didelphis virginiana*, extant marsupials are restricted to warm climatic zones. Given the drastic warming during Wa-0 and recent studies demonstrating that the Washakie Basin was much warmer during the later Wasatchian than the Bighorn Basin, perhaps the higher relative abundance of marsupials at Castle Gardens can be attributed to the PETM.

4. **Guthrie, R. and Maddox, A.: OCHOTONA (LAGOMORPHA, OCHOTONIDAE) FROM THE PLIOCENE RICHMOND HILL FISSURE FILLS, BLACK HILLS, SOUTH DAKOTA**

GUTHRIE, Rebecca, MADDOX, Ashli, South Dakota School of Mines and Technology, Rapid City, SD

*Ochotona* remains recovered from the Pliocene (Blancan) Richmond Hill Fissure Fills in the Black Hills of South Dakota are plentiful and indicate that the fissure and cave environment was inhabited by a modest population of pikas. Specimens collected from the silty infilling sediments of four fissures/caves include dental, cranial, and postcranial material from a minimum of 10 individuals. The Richmond Hill pikas likely represent the latest occurrence of Hemphillian Ochotonid holdovers, and are the only reported North American occurrence of *Ochotona* in the Blancan.

As in modern forms, the presence of pikas in these deposits implies a mountain or steppe biome, dependent on species. Specific affinities of these specimens are tentative but favor Hemphillian forms, possibly extending their species' temporal range by surviving in the protected caves and fissures bordering a mountain meadow.

5. **Tomida, Y. and Jin, C.: AZTLANOLAGUS (LAGOMORPHA, MAMMALIA) REVISITED: ORIGIN, MIGRATION, EVOLUTION, AND TAXONOMY**

TOMIDA, Yukimitsu, National Science Museum Dept of Geology, Tokyo, Japan; JIN, Changzhu, Institute of Vertebrate Paleontology and Paleoanth, Beijing, China

*Azlanolagus agilis* was originally described based on the fossil material from the cave deposits from New Mexico, western Texas, and northern Mexico of Wisconsinan age. Additional material was later described from the Irvingtonian of central Texas and Blancan of southeastern Arizona. All the specimens above were re-examined in order to review its origin and evolution.

The comparisons of *Azlanolagus* material with the specimens of the series of *Pliopentalagus* species from the latest Miocene through late Pliocene known from Anhui, China show the following characters: (1) although smaller, general morphology of p3 in *Azlanolagus* is most similar to *Pliopentalagus* sp. A from the latest Miocene of China; (2) ratio of the enamel lake at the position of the posterointernal reentrant angle is 100% in both *Azlanolagus* and *Pliopentalagus* sp. A, while it becomes smaller in later forms in Asian lineage; (3) small but distinct reentrant angles are present on the trigonid of some of p4-m2 on both *Azlanolagus* and Chinese *Pliopentalagus* spp. series; (4) these angles are observed only on *Azlanolagus* and Chinese *Pliopentalagus* spp., and the ratio of presence reduces from 80 % in the latest

Miocene to 0 % in present in *Pliopentalagus* ' *Pentalagus* lineage in Asia, while 14% in Wisconsinan *Aztlanolagus*.

These observations strongly suggest that (1) *Aztlanolagus* is a direct descendant of Asian *Pliopentalagus* stock, and not a descendant of *Nekrolagus* as suggested before; (2) it probably migrated around 5 - 6 Ma, at the time of *Pliopentalagus* sp. A; (3) P/3 pattern did not change in North America, while it changed a lot in Asia (*Pliopentalagus* sp. A to *Pentalagus*); (4) *Aztlanolagus agilis* is so similar to *Pliopentalagus* spp. of China that its generic assignment should be changed to *Pliopentalagus agilis*.

6. **Lopez-Antonanzas, R.:** BIOGEOGRAPHICAL HISTORY OF THE CTENODACTYLID, THRYONOMYID, AND ZAPODID RODENTS FROM THE MIOCENE OF THE ARABIAN PENINSULA

LOPEZ-ANTONANZAS, Raquel, Museum National d'Histoire Naturelle, Paris, France

The early Miocene ctenodactylid, thryonomyid, and zapodid remains from the Arabic Peninsula and adjacent areas well shows that by the beginning of the Miocene the emerged lands of the Arabic plate experienced the arrival of rodents of various origin. These three families provide a fine example of long distance dispersal of rodents consistent with geological evidence indicating the establishment of an early Miocene land-bridge between Afro-Arabia and Eurasia as a result of the collision of the Arabian Peninsula with the Anatolian plate. The Arabic plate acted as a two-way turning point as the "travellers" of African origin continued their Miocene progression as to reach easternmost Middle East (*Paraphiomys*) while eastern taxa rapidly attained northern Africa (*Sayimys*, *Arabosminthus*).

This scheme is confirmed by the vertical and horizontal distribution of other components of the Miocene Arabian fauna. Thus, in the lower Miocene of the Arabic plate, taxa such as *Megapedetes*, *Dorcatherium*, *Prodeinotherium/Deinotherium*, and *Gomphotherium* have clear African roots. They all went through the Arabic plate to Turkey and then abroad. On the other hand, the Arabian lower Miocene has yielded taxa such as *Viverra*, *Pseudaehurus*, *Aceratherium*, *Dicerorhinus*, *Listriodon*, and *Oioceros* that are unambiguously or probably Eurasian in origin despite being known in the Miocene in Africa.

The early Miocene faunal exchange between Africa and its neighbouring vast continent through the Arabic plate was not the first of the tertiary history of mammals. It was not, of course, the last either. In fact, as shown by the Arabian middle Miocene fossil record, a slightly later wave of mammals of western and eastern origins crossed on the Arabic plate. The African squads included *Caprotragoides* while their Eurasian counterparts comprised taxa such as *Pachytragus*. Definitely, the Arabian area has acted a leading part in the early neogene history of mammals.

7. **Frailey, C. and Campbell, K.:** EOCENE RODENTS OF SOUTH AMERICA AND THE EVOLUTION OF THE CAVIIDAE

FRAILEY, Carl, JCCC-Science, Overland Park, KS; CAMPBELL, Kenneth, Natural History Museum of Los Angeles County, Los Angeles, CA

The Eocene rodents of the Santa Rosa local fauna of the Amazonian lowlands of eastern Peru are the oldest rodents known from South America. The small to very small rodent fossils, which number in the hundreds, are primarily isolated teeth, but some dentitions occur in maxillary and mandibular fragments. The dental patterns are variations built around a common theme of four large, bulbous cusps and low, rounded lophs. This and hystricognathy of at least some of the genera indicate that the rodents of this local fauna were near the initial stages of rodent radiation in South America and that these rodents were further developed toward the modern rodent families of South America than were rodents of comparable age in North America, Eurasia, or Africa. As such, these fossils suggest a separate, non-paramyid

lineage for the caviids and a possible autochthonous derivation of South American rodents from Gondwanan proto-rodents.

8. **Williamson, C., Strait, S. and Holroyd, P.:** RODENTS FROM A CATASTROPHIC ASSEMBLAGE IN THE EARLY EOCENE MAIN BODY OF THE WASATCH FORMATION, WASHAKIE BASIN, WYOMING

WILLIAMSON, Carrie, STRAIT, Suzanne, Marshall Univ., Huntington, WV; HOLROYD, Patricia, Univ. of California, Berkeley, CA

Rodent specimens are described here from two early Wasatchian (Wa-3) localities, UCMP V71237 and V71238, Washakie Basin, Wyoming. They represent a catastrophic death assemblage and provide new insight into the composition of a unique community. Six sympatric species were identified. *Microparamys hunterae* and *Knightomys reginensis* were the two smallest taxa, both probably weighting <10 g. *M. hunterae* was very common (n=53), whereas *K. reginensis* was quite rare (n=2). Among more moderately-sized rodents, *Reithroparamys* sp. nov. is the most common (n=109) and both *P. taurus* (n=12) and *L. murinus* are more rare (n=7). Twice the size of any other of the Washakie Basin rodents, *P. copei* is only known from a single specimen. This rodent assemblage indicates that the local community was diverse, both taxonomically and ecologically, and was dominated by reithroparamyines. By contrast, many other early Wasatchian assemblages are dominated by paramyines, and their dominance elsewhere potentially reflects taphonomic biases. These fossils also provide new information about the morphology of these taxa. A new species of *Reithroparamys* has been recognized on the basis of its small size and hypolophid morphology. Additionally, prior to this study, several of these taxa were very poorly known. The Washakie Basin sample includes the first known upper teeth of *M. hunterae*. The emended diagnosis includes: P4 lacking a mesostyle and has a more expanded cingula. M1/2 paracone larger and taller than metacone; mesostyle present; protoloph and metaloph typically discontinuous. *L. murinus* was previously only known from three Bighorn Basin specimens. The new Washakie Basin specimens (n=7) permit a more extensive diagnosis including: differs from sympatric *M. hunterae* in that *L. murinus* P4 lacks a mesostyle, has less extensive cingula, and has a relatively smaller hypocone. Differs from later-occurring *L. debequensis* in that the P4 metacone is only slightly smaller than the paracone and lacks the paracone arm.

9. **Bell, C. and Bever, G.:** *MICROTUS* FROM THE IRVINGTON FAUNA, ALAMEDA COUNTY, CALIFORNIA

BELL, Christopher, BEVER, Gabe, Univ. of Texas at Austin, Austin, TX

The mammalian fauna from gravel pits near Irvington, California was the basis for the original designation of the Irvingtonian land mammal age. The original excavation area is now partially overlain by Interstate Highway 680, and knowledge of the Irvington fauna is restricted to published records and specimens housed in the University of California Museum of Paleontology. Significant portions of this fauna remain unpublished or only partially documented. The presence of *Microtus* in the fauna was first noted in 1951, but a complete description of the specimens is lacking.

The earliest reported occurrence of *Microtus (sensu stricto)* in North America is from the Anza-Borrego Desert in southern California, but those specimens have problematic and conflicting locality data and their age cannot reliably be determined. Other presumably early occurrences in Wellsch Valley (Saskatchewan) and the Elsinore Fault Zone in California lack reliable external age control. The Irvington specimens thus assume a greater significance because they are among the earliest occurrences with some form of external age control (within magnetic Chron C1r.2r).

The range of morphological variation within the Irvington *Microtus* sample is not extreme, but is greater than implied in the published literature. The specimens show strong phenetic resemblance to extant *M. californicus* and various authors previously published tentative or definitive referrals to that species. However, phenetic similarity is not an adequate basis for referral of isolated teeth to species within the *Microtus* clade. Analysis of the literature reveals a tacit recognition of this fact, with concomitant utilization by some authors of modern geographic distributions to refine species-level assignments. Our attempt to apply an apomorphy-based approach to the identification of these specimens revealed no discrete characters that permit species-level resolution.

10. **Holbrook, L. and Lucas, S.:** THE SKULL OF *LAMBDOOTHERIUM* (MAMMALIA, PERISSODACTYLA) AND ITS PHYLOGENETIC IMPLICATIONS

HOLBROOK, Luke, Rowan Univ., Glassboro, NJ; LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM

The genus *Lambdaotherium* has historically been allied with the Brontotheriidae, mainly on the basis of sharing a W-shaped ectoloph that gives the upper molars a selenodont appearance. Some workers have claimed that these characters evolved independently in *Lambdaotherium* and brontotheriids, and that these taxa are not closely related. Because the skull and postcranial skeleton of *Lambdaotherium* are not well known, discussion of the phylogenetic position of *Lambdaotherium* has largely focused on dental characters. We describe the most complete skull known of *Lambdaotherium popoagicum*, which is from the Eocene Wasatch Formation near Big Piney in the Bridger basin of western Wyoming. Salient features of this dolichocephalic skull include a tubular rostrum anterior to P2, a supraorbital notch, a tall sagittal crest and tall occiput with a prominent lambdoidal crest, a shallow nasal incision extending posteriorly to above the canine, no preorbital fossa in the maxillary, a small infraorbital foramen above P3, anterior root of the zygomatic arch above M1, anterior edge of the orbit over M1/M2 juncture, a short glenoid fossa with a trapezoidal outline, a peg-like and anteriorly oriented postglenoid process, a narrow external auditory meatus, and a mastoid foramen. A preliminary cladistic analysis of the relationships of *Lambdaotherium* and other perissodactyls places it in a clade with the palaeotheriids *Palaeotherium* and *Plagiolophus* and not with the brontotheriid *Eotitanops*. Thus, the analysis does not support a close relationship between *Lambdaotherium* and brontotheriids, but instead supports the notion that *Lambdaotherium* is most closely related to palaeotheriids.

11. **Bravo-Cuevas, V.:** THE MIDDLE AMERICAN NEOGENE EQUINAE RECORD AND ITS PALEONTOLOGICAL SIGNIFICANCE

BRAVO-CUEVAS, Victor, Univ. Autónoma del Estado de Hidalgo, Pachuca, Hidalgo, Mexico

The Middle American region is widespread from Central Mexico to southern Central America. A great number of fossiliferous volcanosedimentary units of Miocene and Pliocene ages are exposed in this region, whose paleontological study has revealed the presence of abundant and diverse horse material. 90% of known Middle American equids are members of the Subfamily Equinae, including merychippine, hipparionine, and equine taxa, that as a whole reach a total of 18 species of 9 genera. The merychippine record is represented by *Merychippus* sp., *M. cf. M. primus* and *M. cf. M. sejunctus*. The fossil material referable to this species is only known from the late Hemingfordian-late early Barstovian of Southeastern Mexico. Hipparionine horses spanned from late early Barstovian to Blancan. The oldest members are *Neohipparion* aff. *N. trampasense* and *Cormohipparion* sp. from the late early Barstovian of Southeastern Mexico. During Hemphillian, they were more diverse and widespread for the most part of Middle America, represented by *Cormohipparion* cf. *C. occidentale*, *C. ingenum*, *Neohipparion eurystyle* and *Nannipus minor*. Its diversity declines drastically at the end of Hemphillian, so only

*Nannippus peninsulatus* is known from the Blancan of Central Mexico. The equine showed a diversity and geochronological range similar to that of hipparionines. The species *Calippus sp.* and *Pliohippus aff. P. pernix* constitute the oldest members of the group from the late early Barstovian of Southeastern Mexico, whereas, *Equus (Dolichohippus) simplicidens* was the younger from the Blancan of Central Mexico. This group of equids was more diverse during the Hemphillian and it was represented by *Calippus (Grammohippus) hondurensis*, *Pliohippus sp.*, *Astrohippus stockii*, *Dinohippus interpolatus* and *D. mexicanus*, whose records are known for Central Mexico, Honduras and El Salvador. Middle American Equinae record evidences the presence of taxa from late Hemingfordian to Blancan and testifies at least 18 Ma of evolutionary history of this group of equids. Also, it represents 50% of the known genera for North America.

12. **Sanders, W.:** TAXONOMIC AND SYSTEMATIC REVIEW OF ELEPHANTIDAE BASED ON LATE MIOCENE-EARLY PLIOCENE FOSSIL EVIDENCE FROM AFRO-ARABIA

SANDERS, William, University of Michigan, Ann Arbor, MI

Elephantidae includes primitive stegotrabelodontines, with upper and lower tusks, and advanced elephantines, lacking lower tusks. The taxon *Primelephas* was created to accommodate fossil morphologies intermediate between these subfamilies, and was considered as the ancestor of all elephantines, based on its supposed retention of small lower tusks. The consensus view of morphology-based phylogenetic analyses has long been that among elephantines, *Loxodonta* (African elephant lineage) is the sister taxon to *Elephas* (Asian elephant lineage) + *Mammuthus* (mammoth). However, some considered *Primelephas* to be a wastebasket taxon, and molecular studies are divided about the closeness of the Asian elephant-mammoth relationship.

The fossil record of elephants has recently improved dramatically, yielding a wealth of new fossil material of the earliest-known elephants, from the late Miocene-early Pliocene of Afro-Arabia. Morphometric analysis of a comprehensive sample of these fossils is used to test traditional hypotheses of elephant taxonomy and systematics. The results uphold division of Elephantidae into two subfamilies; establish that *Primelephas* is a good taxon, characterized by extremely brachyodont, narrow cheek teeth, transversely straight or anteriorly convex molar plates, loss of accessory conules throughout most of the crown in third molars, and by an absence of lower tusks, and that it was too derived to be ancestral to all elephantines; suggest that Mio-Pliocene *Mammuthus subplanifrons* is a wastebasket taxon in need of revision; demonstrate that the initial adaptive radiation of elephants was a late Miocene, rather than early Pliocene, phenomenon; and do not support *Elephas* + *Mammuthus* as an exclusive clade. Putative synapomorphies in Recent taxa that sustained the old consensus view appear instead to be features that arose independently as parallel adaptive responses to grazing in different lineages. This underscores the value of the fossil record, especially close to branching episodes, for phylogenetic reconstruction.

13. **Mendoza, M. and Janis, C.:** DECISION TREES: A NEW METHODOLOGY TO DETERMINE UNGULATE FEEDING BEHAVIOR FROM CRANIODENTAL MORPHOLOGY

MENDOZA, Manuel, JANIS, Christine, Brown Univ., Providence, RI

Decision trees represent a type of machine learning, whereby computer systems acquire knowledge inductively from the input of a large number of samples. This particular technique is based on the iterative division of the multidimensional space defined by the input variables. In this presentation, our initial input is craniodental measurements of recent ungulate species plus information about their dietary type, which is used by the decision tree technique to characterize the dietary groups according to their craniodental morphology. The main advantage of this machine learning technique is that the knowledge acquired by the system can be explicitly represented as decision trees (or rules of classification). This



contrasts with multivariate statistics, where information is contained in algorithms that are often complex; it is not always easy to determine the steps by which the algorithm has been generated, and thus to untangle the precise relationship between the variables selected by the algorithm and the morphological adaptations. The preferred decision trees are those that contain the fewest number of steps, and the fewest number of classification errors. The resultant trees enable the determination of exactly which morphological characteristics are used for determining the branching points at each stage of the process. Decision trees can thus help to narrow and refine those morphological features that can be used for successful dietary discrimination, and enable the better understanding of the relationship between morphological and behavioral adaptations. Such decision trees then make possible the classification of new samples, such as fossil species, based on the correlations determined with the living species of known behavior. A further advantage of this method is that fossil species known only from incomplete data can be readily compared with the same limited set of data from extant species. This presentation applies this methodology to extant ungulates, demonstrates the important craniodental variables used for discrimination into ecological categories, and then applies the methodology to a diversity of Miocene ungulates.

14. **McDonald, J. and Morgan, G.:** THE EARLIEST RECORDS OF *BISON* IN MIDLATITUDE NORTH AMERICA

McDONALD, Jerry, Granville, OH; MORGAN, Gary, New Mexico Museum of Natural History and Science, Albuquerque, NM

The Macaspalt Shell Pit and Inglis 1A localities on Florida's west coast have yielded vertebrate faunas that date from the late Pliocene (late Blancan). Each fauna includes a partial horn core of a bovid which we refer to *Bison*. These are the earliest records of *Bison* in midlatitude North America.

Macaspalt Shell Pit (Sarasota County) is a sequence of primarily molluscan faunas, Unit 4 of which formed during a marine regression between ca. 2.6 and 2.2 ma and contains nearly 100 vertebrate taxa, ca. 20 being terrestrial mammals. Inglis 1A (Citrus County) consists of deposits that infilled a sinkhole between ca. 2.2 and 1.8 ma and contains some 150 taxa, including 53 mammalian taxa.

The Macaspalt Shell Pit *Bison* specimen (UF100486) consists of a 126-mm-long section of the proximal end of a horn core and a small part of the frontal bone. The exterior of the frontal is smooth and that of the core proper contains numerous shallow but acutely defined ridges and valleys paralleling the longitudinal axis of the core. The transition from frontal to core is abrupt, but a raised burr is absent. The interior is hollow.

The Inglis 1A specimen (UF 18286) is a 128-mm-long section from a medio-distal position of a horn core that includes the exterior surface and solid interior of the core. The dorsal part of the exterior surface is smooth; the lateral part contains 3 prominent longitudinally oriented ridges, the crests of which are deflected ventrad.

Both specimens conform to the morphology of *Bison* horn cores more closely than to that of any other genus of bovid. UF 100486 is unequivocally from a bovine, and UF 18286 is identical to equivalent sections of horn cores of *Bison latifrons*. *Bison* are known from late Pliocene faunas in east Asia and thus were geographically positioned to disperse into North America at that time. Among the problems generated by the recognition of *Bison* in the late Blancan faunas are (1) Why hasn't *Bison* been recognized in Irvingtonian faunas and (2) How could this information affect the role of *Bison* as the index genus for Rancholabrean faunas?

15. **Patel, B.:** THE IMPORTANCE OF OUTGROUP SELECTION IN FUNCTIONAL MORPHOLOGY: A PRIMATE EXAMPLE

PATEL, Biren, Stony Brook University, Stony Brook, NY

In the field of paleoprimatology, the elbow joint complex has been a focus in attempts to reconstruct positional behaviors of early members of the human family (Homininae). The derived nature of elbow joint in the Hominoidea is specifically reflected in the skeletal elements of this joint complex, and is generally regarded as a correlate for possible suspensory behaviors in basal hominins. Comparative analysis of fossil hominins are traditionally taxonomically narrow, and often do not include hylobatids because they are considered to be morphologically more similar to primitive catarrhines than to other extant hominoids. Thus, results from functional analyses of postcrania, interpreted to show that early hominins are African ape-like in their postcranial skeletons and their positional behaviors, maybe an artifact of inadequate taxonomic and morphological breadth of the comparative sample.

To address this problem and better understand hominin positional behavior, this study includes hylobatids in a comparative analysis of the hominoid elbow complex. Specifically, morphometric variables of the proximal radius were derived from measurements from a sample of all genera of extant hominoids and casts of extinct hominin species. Univariate and multivariate analyses were performed on these data. Results show that early hominin fossils are morphologically diverse and are not, as a group, most similar to any single extant taxon (i.e. African apes). Rather, the fossils resemble *Pan*, *Gorilla*, and *Hylobates*. These results suggest that (1) morphology of *Hylobates* is primitive for Hominoidea and may reflect a morphotype for all later hominoids or (2) the similarity between *Hylobates* and *Pan* and *Gorilla* is probably convergent, thus complicating the functional interpretations of fossil hominins. In any case, the implications of these results are that the proximal radius is not a sensitive indicator of locomotor behavior among hominoids since the morphology in hylobatids and *Gorilla* and *Pan* is similar despite different positional behaviors. Furthermore, inferences of function from form in extinct animals can be drastically affected by the selected comparative outgroup.

16. **Froehlich, D. and Froehlich, J.:** LATE WASATCHIAN AND EARLY BRIDGERIAN ADAPIDS FROM THE DEBEQUE FM., GARFIELD COUNTY, WEST-CENTRAL COLORADO

FROEHLICH, David, Vertebrate Paleontology Lab. Texas Memorial Museum, Austin, TX;  
FROEHLICH, Jeffery, Anthropology Department, Albuquerque, NM

The DeBeque Formation from western Colorado contains a moderately continuous sequence of fluvial redbeds that interfinger with marginal and fully lacustrine units from the overlying Green River Formation. In Garfield County, these deposits have produced Graybullian through Gardnerbuttean faunas (Wa<sub>4</sub>-Br<sub>0</sub>) from both sides of the Colorado river, in the Sharrard Park and Mamm Peak areas respectively. The Bridgerian component of the DeBeque was first suggested by Patterson (although based only on one specimen). More recently collections have elaborated on this component with nearly 250 new specimens including *Eotitanops*, *Leptotomus huerfanensis*, *Orohippus*, cf. *Trogosus*, *?Hyrachyus*, and *Selenaletes*. We report here on the adapid primates of these late Wasatchian and early Bridgerian faunas. The Lostcabinian adapids consist of as many as 5 contemporaneous taxa including the first report of *Copelemur* from the DeBeque Fm., and potentially two distinct sizes of both *Pelycodus*, and *Cantius*. The Bridgerian fauna, while substantially smaller than the recovered Wasatchian faunas, also has an interesting diversity of primate taxa, including two *Cantius* species, both with a mixture of primitive small hypocones and derived well developed mesostyles, and neither particularly developed toward their putative Bridgerian relatives, *Smilodectes* or *Notharctus*. The smaller Gardnerbuttean *Cantius* is in the size range of *C. ralstoni*, while the other is larger but not as large as *Pelycodus* or *Notharctus*. The diversity of adapid primates in the upper Wasatchian and lower Bridgerian DeBeque Formation is much more like that of the moderately older adapid fauna from the San Jose Fm. in New Mexico than the contemporaneous faunas from Wyoming and Utah. In the early

and middle Wasatchian deposits of New Mexico there are at least six taxa in three different diverging clades of *Cantius*, *Copelemur* and *Pelycodus*. This suggests that biogeographic and taxonomic similarities of the western Colorado faunas may lie more with the south than the more commonly compared faunas farther north.

17. **McCullough, G., Silcox, M., Bloch, J., Boyer, D. and Krause, D.:** NEW PALAECHTHONIDS (MAMMALIA, PRIMATES) FROM THE PALEOCENE OF THE CRAZY MOUNTAINS BASIN, MONTANA

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Palaechthonids are among the most poorly known of Paleocene primates. Although few fossils are known, palaechthonids contain potential ancestors of at least two other families of plesiadapiforms, and are thus central to understanding early primate systematics. This study documents a diversity of Torrejonian (To) and Tiffanian (Ti)-aged palaechthonids from both the western and eastern Crazy Mountains Basin (CMB), substantially augmenting the available sample for this group.

Prior to this study, the only known palaechthonids from the western CMB were an upper molar of cf. *Palaechthon woodi* and a dentary with m1-3 of *Plesiolestes problematicus* from the earliest Tiffanian Bangtail locality. We report the discovery of five new palaechthonid specimens from the Willow Creek locality in the western CMB, including a dentary with m1-3 of cf. *Plesiolestes problematicus*, a dentary with m1-3 of *Palenochtha minor*, and specimens of at least two other species, possibly new. This unusually diverse assemblage of palaechthonids allows for comparison to southern representatives of the group in the San Juan Basin, documenting possible geographic variability. Furthermore, the co-occurrence of these taxa and the condylarth *Tetraclaenodon puercensis*, constrains the age of this site to between To3 and Ti1.

In addition to previously reported occurrences at Gidley Quarry, palaechthonids have been recovered from four localities in the eastern CMB. Azzara Quarry (To3) has yielded a dentary representing a new species of *Palaechthon*. Three dentaries of *Palaechthon alticupsis*, including one with p4-m2, have been recovered from Hartman and Silberling quarries (To3). The Bingo Quarry (Ti1) sample includes two upper molars referable to cf. *Palaechthon woodi*.

Our results document a previously unrecognized diversity of palaechthonids, and suggest that further collecting in the CMB has the potential to substantially change our understanding of the group. Further study of CMB collections will continue to refine biostratigraphic correlations there and throughout the western interior of North America.

18. **Silcox, M., Rose, K. and Bown, T.:** EARLY EOCENE PAROMOMYIDAE (MAMMALIA, PRIMATES) FROM THE SOUTHERN BIGHORN BASIN (WILLWOOD FORMATION, WASATCHIAN NALMA, WYOMING): TAXONOMY, VARIATION, AND EVOLUTION

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A collection of more than 550 stratigraphically controlled dental and gnathic specimens of paromomyid primates from the southern Bighorn Basin (Willwood Fm., Wasatchian, Wyoming) was studied. As the largest collection of undescribed paromomyids known, this sample allows for a critical review of the alpha taxonomy of Eocene North American Paromomyidae, and for the elucidation of evolutionary changes through time. In addition to documenting numerous previously unpublished specimens of known taxa (e.g., *Phenacolemur simonsi*, *P. fortior*), this collection also contains a new

species from the upper part of the Willwood Formation (“Lysitean”). The new species is referable to *Phenacolemur*, rather than *Ignacius*, based on the presence of a p4 that is similar in size to m1. This new species is intermediate in size between *P. simonsi* and *Phenacolemur citatus*, and has both primitive features (e.g., m2-3 paraconids, buccal cingulid in one specimen) and derived traits (e.g., relatively reduced paraconid on m1 and no p4 paracristid, unlike *Paromomys*), complicating the interpretation of its broader relationships.

Overall patterns of dental evolution in southern Bighorn Basin paromomyids provide some support for previously hypothesized periods of faunal change. In particular, *Phenacolemur praecox* disappears from the record at Biohorizon A, and is replaced by the similarly sized but morphologically distinct *P. fortior*. Identification of possible *P. praecox*-*P. fortior* intermediates suggest an *in situ* speciation event. At Biohorizon B, *P. fortior* is replaced by *P. citatus*. Large sample sizes for these taxa suggest that this pattern is not simply a product of sampling. However, the new paromomyid sample indicates that two taxa believed to have become extinct at Biohorizon A (*Ignacius graybullianus*, *P. simonsi*) persisted well past Biohorizon A, with *P. simonsi* extending past Biohorizon B. Although the new species of *Phenacolemur* is known only from above Biohorizon B, it is a very rare taxon, so the significance of its restricted distribution is unclear.

19. **Akersten, W.:** THE SABER-TOOTH SHEAR-BITE REVISITED

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Many vertebrate paleontologists agree that the upper canines of *Smilodon* and other mammals with hypertrophied upper canines were employed in a shear-bite rather than in a stabbing attack. However, some maintain that in both the dirk-toothed and the scimitar-toothed forms, this bite was directed at the throat. Evolutionary theory predicts that when two different taxa employ identical strategies, one taxon should soon prevail over the other. While this may involve strategies other than bite placement, the differences in canine morphology between dirk-toothed and scimitar-toothed mammals strongly suggest differences in bite strategies. Recent work by M. Anton and A. Galobart made a very strong case for a throat attack by *Homotherium* and, presumably, other scimitar-tooths. If true, this raises an interesting question: Why did the dirk-tooths evolve extremely hypertrophied sabers when the less developed sabers of scimitar-tooths sufficed for a throat attack? The much longer and more fragile sabers of dirk-tooths would be more susceptible to breakage and malocclusion than those of scimitar-tooths. Yet, during their evolution, they must have passed through a canine length stage similar to that of the dirk tooth.

The differences in upper canine serration of dirk-tooths and scimitar-tooths also suggest different bite strategies. The shark-like coarse serration of scimitar-tooths appears ideal for slicing through the thick muscles and relatively tough skin of the throat whereas the fine to absent serration of dirk-tooths seems to be more suited for penetrating thinner skin and muscle and passing between muscle fibers. Personal experience and that of butchers and taxidermists is that the thinnest skin on living North American herbivores from rabbit to Bison is in the posterolateral abdominal region just anterior to the hind limb. Because the skin and the thin, long fibered muscles in this area would be more readily penetrated by the sabers of dirk tooth than the throat would be, a shear bite to the posterolateral area of the abdomen is the more probable mode of attack by dirk-toothed mammals.

20. **Morlo, M. and Semenov, Y.:** NEW CARNIVORA (MAMMALIA) FROM THE EARLY VALLESIAN (LATE MIOCENE, MN 9) OF UKRAINE

MORLO, Michael, Forschungsinstitut Senckenberg, Frankfurt, Germany; SEMENOV, Yuriy, National Academy of Sciences of Ukraine, Kiev, Ukraine

The Carnivora from the Ukrainian Vallesian (MN 9) localities Gritsev (Hrytsiv) and Klimentovichi (Klymentovychi) are revised. Previously known from these localities were the hyaenids *Ictitherium spelaeum* and *Allohyaena sarmatica*, as well as the mustelid *Eomellivora wimani*. Taxa reported for the first time are the ursid *Indarctos arctoides* s. str. (first Eastern European record), very fragmentary amphicyonid remains representing presumably a single, small species, the viverrid *Semigenetta ripolli* (first record outside of Spain), a new, large species of *Semigenetta*, the feline *Felis attica* (earliest known occurrence), the machairodontine *Paramachaerodus ogygius* (first Eastern European record), and the barbourfelid *Sansanosmilus* cf. *vallesiensis*, which is partly represented by the previously unknown lower dp3-4. The carnivoran fauna of Gritsev, where by far the most specimens come from, shows great similarities to other European faunas of MN 9 in containing widely (but rarely) distributed taxa such as *I. arctoides* s.s., *S. ripolli*, *F. attica*, *P. ogygius*, and *S. vallesiensis*, as well as the already described *E. wimani*. Except for *E. wimani*, all of these taxa are reported from Eastern Europe for the first time, even if *F. attica*, *P. ogygius*, and *E. wimani* are also known from Asia. The early presence of *P. ogygius* in Gritsev, with respect to only Turolian (MN 12) records in south-eastern Europe, implies a migration from Asia to Europe by a northern route with a subsequent quick dispersal throughout the whole of Europe down to Spain, where it is also known from MN 9. Unknown outside of Gritsev, and therefore endemic, are the small amphicyonid and the new *Semigenetta* species, as well as the already described hyaenids, thereby producing the specific character of the early Vallesian carnivoran fauna of Ukraine.

21. **Sorkin, B.:** ECOMORPHOLOGY OF THE GIANT BEAR-DOGS *AMPHICYON* AND *ISCHYROCYON*

SORKIN, Boris, Northern Illinois University, DeKalb, IL

Giant bear-dogs of the genera *Amphicyon* and *Ischyrocyon* (Carnivora, Amphicyonidae, Amphicyoninae) were the largest carnivorans in North America from late Hemingfordian to late Clarendonian (17.5-8.8 Ma) with skeletal morphology unlike that of any living carnivoran. Most authors agree that *Amphicyon* and *Ischyrocyon* were carnivorous or hypercarnivorous, but one author has suggested that *Amphicyon* was hypocarnivorous. A number of authors have suggested that the amphicyonines were ambush predators like the living big cats.

The purpose of research presented in this poster was to test the above models for diet and hunting behavior of *Amphicyon* and *Ischyrocyon*. Relative grinding area of the lower molars and the wear pattern on the upper molars of *Amphicyon* strongly suggest that it was carnivorous. Both *Amphicyon* and *Ischyrocyon* possessed distal limb segments that were as short or shorter relative to the proximal ones than those of the living big cats, suggesting that the bear-dogs were incapable of long distance pursuit at high speed. However, the orientation of the olecranon process of the ulna in *A. ingens*, the largest species of *Amphicyon*, indicates that it was incapable of crouching as low as the living big cats and the orientation of the transverse processes of its lumbar vertebrae—that its back was less flexible. All species of both *Amphicyon* and *Ischyrocyon* resembled the living pursuit predators in having narrow muzzles with small infraorbital canals (indicating poorly developed vibrissae). Therefore, *Amphicyon* and *Ischyrocyon* probably did not rely on surprise for catching up to their prey and on severing the spinal cord or clamping the trachea with their canines—for killing it. Instead, they may have preyed on mediportal ungulates, such as the rhinocerotids (*Perissodactyla*), which they pursued for a considerable distance, but at a slower speed than the living pursuit predators. Upon catching up to its prey a bear-dog immobilized it with its forelimbs and killed it by tearing into its body cavity with its canines.

22. **Bailey, B., Hunt, Jr., R. and Stepleton, E.:** A TEMNOCYONINE BEARDOG PRESERVED IN A LOWER ARIKAREEAN PUMICEOUS HORIZON, WILDCAT HILLS, WESTERN NEBRASKA

BAILEY, Bruce, HUNT, JR., Robert, STEPLETON, Ellen, Univ. of Nebraska, Lincoln, NE

A nearly complete skeleton of a rare temnocyonine beardog (Mammalia, Amphicyonidae) was discovered by the senior author in a pumiceous volcanoclastic siltstone in the Wildcat Hills, south of Gering, western Nebraska. The animal possibly expired in a burrow where it was preserved. The subfamily Temnocyoninae is restricted to North America; the three earliest records occur from 29.5 to 28 Ma in the early Arikarean of Oregon, South Dakota, and Nebraska. Two of these records are relatively complete skeletons, representing a small and a larger species: a skeleton from the John Day beds at Logan Butte, Oregon, is the most primitive and smallest North American temnocyonine, whereas the Wildcat Hills skeleton belongs to a larger, more evolved individual, remarkable for its size at this time in the geologic record. In both individuals several defining dental and skeletal traits of the subfamily have already appeared: loss of M3, enlargement of the premolars, inflation of the frontal sinuses of the skull and, in the Wildcat Hills specimen, rudimentary elongation of the distal limbs. Sediments of the Gering Formation in the Wildcat Hills containing pumice, like that entombing the beardog, have been dated at 28.1-28.3 Ma; the pumice is apparently derived from late Oligocene volcanic eruptions at Specimen Mountain, Colorado.

23. **Goedert, J., Crowley, B. and Barnes, L.:** A NEW LATE OLIGOCENE AETIOCETID (MAMMALIA: MYSTICETI) FROM SOUTHWESTERN WASHINGTON STATE

GOEDERT, James, Wauna, WA; CROWLEY, Bruce, Burke Museum of Natural History and Culture, Seattle, WA; BARNES, Lawrence, Natural History Museum of Los Angeles County, Los Angeles, CA

An outcrop of the Lincoln Creek Formation in southwestern Washington State has yielded a small, fragmentary skull (Burke Museum 87135) that represents a new genus and species of the extinct cetacean family Aetiocetidae. The specimen consists of a braincase missing most of the rostrum, the right supraorbital process, and the tympanic bullae. It was found *in situ* in upper Oligocene strata exposed in the intertidal zone along the north shore of the Columbia River, northeast of the townsite of Knappton, in Pacific County. The skull possesses the aetiocetid characters such as premaxillae elevated at the anterolateral corner of the nasals, and a sharp margin at the base of the temporal fossa at the anterior edge of the squamosal fossa. The skull differs from those of the subfamilies Chonecetinae and Morawanocetinae and is more similar to those of the Aetiocetinae in having larger and dorsally arched zygomatic processes, and more robust supraorbital processes. The new skull displays several autapomorphic characters, such as a transversely expanded braincase with very narrow squamosal notches, and more inflated and dorsoventrally expanded zygomatics than other aetiocetines, very similar in appearance to primitive odontocetes in the family Simocetidae. Characters possessed by this skull may be sufficient to warrant the erection of a new subfamily, making the Aetiocetidae one of the most diverse mysticete families known.

24. **Racicot, R., Colbert, M. and Rowe, T.:** INTERPRETING NEURAL AND CIRCULATORY ANATOMY FROM A DIGITAL ENDOCAST OF *TURSIOPS TRUNCATUS* (MAMMALIA, ODONTOCETI)

RACICOT, Rachel, COLBERT, Matthew, ROWE, Timothy, Univ. of Texas, Austin, TX

High-resolution X-ray computed tomography (HRXCT) provides a nondestructive means to visualize the interiors of opaque objects. HRXCT scan data are particularly useful for extracting digital endocasts, which represent casts of cavities, from within vertebrate skulls. Endocasts of mammalian cranial cavities generally reflect the shape of their brains, but can also be used to infer circulatory structures found within the cavities. The potential for visualizing both circulatory and neural features in

extant and fossil mammals is explored using a digital endocast of *Tursiops truncatus*, a Recent odontocete cetacean.

Cetaceans are notable not only for their enlarged and modified brains, but also for the highly derived circulatory anatomy surrounding their brains. The *Tursiops* endocast reflects the overall conformation of the brain, such as the shape and size of the cerebrum, the hypophyseal fossa, the pyramidal tract, and the cerebellum. Other inferred neural elements of the endocast include many of the cranial nerves that exit from foramina and are enclosed within canals in the skull. Numerous circulatory structures that can be interpreted include the hypertrophied retia mirabilia, various meningeal vessels, the straight sinus, the superior sagittal sinus, and the transverse sinus canals. In some ways, the endocast is more informative about the positioning of these structures and the brain's overall shape than conventionally extracted cetacean brains, which are typically deformed when removed from their encasing cranial bones. Volumetric and linear measurements of both the neural and circulatory segments of the endocast can be readily obtained. These results demonstrate the potential this technique has for interpreting the neural and circulatory anatomy in fossils and rare or endangered Recent mammals.

25. **Mannering, J. and Geisler, J.:** PHYLOGENETIC RELATIONSHIPS OF A NEW XENOROPHOID  
MANNERING, Jessica, GEISLER, Jonathan, Georgia Southern Univ., Statesboro, GA

Last year, we reported a new species and possibly a new genus of xenorophoid odontocete from the Chandler Bridge Formation of South Carolina. This taxon is represented by a single specimen (GSM 1098) that includes a skull, dentaries, and atlas, and is herein referred to as the Sangaree Whale. We have since conducted a cladistic analysis and determined its phylogenetic relationships using a published dataset of 304 morphological characters coded for extant and extinct Odontoceti and Mysticeti. We determined that the Sangaree Whale is in a clade with *Archaeodelphis patrius*, *Xenorophus sloanii*, and four undescribed xenorophoids from the Charleston Museum collection. The Sangaree Whale is fairly basal within the xenorophoid clade indicating that it is not congeneric with *Xenorophus*. Xenorophoids, including GSM 1098, share several synapomorphies of the premaxilla. The premaxillae are narrowly separated immediately anterior to the external bony nares, are extended laterally to cover much of the supraorbital processes, and are pachyostotic. The Sangaree Whale is more primitive than *Xenorophus* in having central cusps larger than the accessory cusps and in having a short posterolateral sulcus from the premaxillary foramen. Also, in more derived xenorophoids there is a sagittal crest of the parietals, which is not present in the Sangaree Whale. *Archaeodelphis* is placed in a clade with GSM 1098 and other xenorophoids based on the following synapomorphies: narrow width of the rostrum at the antorbital notch, enlarged lacrimal that covers much of the lateral side of the supraorbital process of the frontal, and the lateral tuberosity of the petrosal is present and elongate. This indicates that *Archaeodelphis* may not be the "most primitive" odontocete.

26. **Tsujikawa, H., Pickford, M., Sawada, Y., Nakano, Y., Nakatsukasa, M. and Ishida, H.:** UPDATED  
MAMMAL FAUNA FROM THE LOWER TO MIDDLE MIOCENE AKA AITEPUTH  
FORMATION, NORTHERN KENYA

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Since 1980, the Japan-Kenya Expedition team has conducted paleoanthropological, paleontological and geological surveys in Nachola, Northern Kenya and has collected numerous mammal remains

including a large hominoid, *Nacholapithecus kerioi* from the early to middle Miocene Aka Aiteputh Formation (16-10 Ma by radiometric dating). Here, we update the mammal fauna including at least 29 taxa in which *Aceratherium* sp., cf. *Ugandatherium*, *Chalicotherium rusingense*, *Brachyodus* cf. *aequatorialis*, *Kenyapotamus ternani* and s.l. *Hypsodontus* sp. are newly added, and discuss faunal correlations between fossiliferous localities, strata and ages, and the probable paleoenvironment based on the associated fauna. In result, we clarify that the fauna from the formation can evidently be divided into at least two strata by its biostratigraphy. The older one which yields *Brachyodus* cf. *aequatorialis* and *Diamantohyus africanus*, for example, correlates with the Unit I of the Aka Aiteputh Formation and the Faunal Set II (18.5-16.5 Ma) of Pickford. The younger one which yields *Nacholapithecus kerioi* and *Diamantohyus nadirus*, for instance, correlates with the Unit III (ca. 16 Ma by radiometric dating) of the formation and the Faunal Set III (16.5-14.5 Ma). Both faunas from those strata suggest a forest or woodland environment based on the predominance of browsing herbivores such as sanitheres, anthracotheres, giraffoids and tragulids. Especially, the fauna from the Unit III yielding the hominoid, enforced the idea that *Nacholapithecus kerioi* is thought to be an arboreal inhabitant by the morphology of forelimbs.

27. **Rodgers, J., George, C. and Bell, C.:** RECOGNITION OF THE OS CORDIS, A NEGLECTED SKELETAL ELEMENT

RODGERS, Jeri, Austin, TX; GEORGE, Christian, BELL, Christopher, Jackson School of Geosciences, Austin, TX

The os cordis is a heterotopic endochondral bone in the heart of some mammals. It is situated within the fibrous trigone between the aortic valve and the right ventricle. It was reported in the Proboscidea by Galen in A.D. 177, and is also known to occur in Artiodactyla (within Bovidae and Cervidae), and Carnivora (within Mustelidae), although its occurrence in other mammalian groups is largely unexplored. The os cordis is poorly represented in zoological collections, probably because an early step in standard skeletal preparation techniques involves evisceration of the specimen. To our knowledge, the os cordis has never been reported in the fossil record. This is likely a result of the lack of comparative material available that would permit paleontologists to recognize the element, not because of its preservation potential.

We obtained 307 hearts from six artiodactyl species (*Antelope cervicapra*, *Axis axis*, *Boselaphus tragocamelus*, *Cervus nippon*, *Dama dama*, and *Odocoileus virginianus*). All specimens were scanned in an ultrafast medical CT scanner to determine presence, number, and location of the os cordis. The specimens with an os cordis were then dissected and the ossified skeleton was prepared and cleaned. In the majority of specimens, only a single ossification was present, but a second ossification sometimes occurred at the intersection of the tricuspid valve and the wall of the right ventricle. The os cordis apparently ossifies relatively late in ontogeny; in our sample of *Odocoileus*, no animals younger than two years (sexual maturity) had an ossified heart skeleton.

There are recognizable morphological differences between species, but a high degree of intraspecific morphological variation is obvious. Ontogenetic and sexual differences account for at least some of the observed intraspecific variation. Any potential systematic significance of the os cordis will have to await further taxon sampling and a better understanding of the sources of morphological variation.

28. **Carrasco, M., Barnosky, A., Kraatz, B. and Davis, E.:** MIOMAP REVISITED: A RELATIONAL AND SPATIAL DATABASE OF FOSSIL MAMMALS (ARIKAREEAN THROUGH HEMPHILLIAN) ON THE WORLD WIDE WEB



CARRASCO, Marc, BARNOSKY, Anthony, KRAATZ, Brian, Berkeley, CA; DAVIS, Edward, Univ. of California, Berkeley, Berkeley, CA

The Miocene Mammal Mapping Project (MIOMAP) database, under construction for the last five years at the University of California at Berkeley, is nearing completion and is now online for use by the vertebrate paleontology community. MIOMAP is a relational database designed for web-based distribution and incorporation into a GIS analytical tool (ARC/INFO 8.3). Developed in Paradox 9.0 following the FAUNMAP data structure, MIOMAP has also been transferred into MySQL for online accessibility. The database includes all published mammal species between 30 and 5 million years old from the western United States as well as some well-identified, unpublished species represented by voucher specimens in museums. Information associated with each species occurrence includes latitude, longitude, relevant taxonomy and synonymies, geologic age, depositional environment, taphonomic attributes, bibliographic information, and, when available, numbers of specimens, among other relevant data. So far the database has been used for a variety of research applications involving (1) the effects of climatic change and tectonism on species richness and (2) the effects of applying different analytical techniques to determine species diversity patterns in the fossil record.

MIOMAP is currently accessible at <http://miomap.berkeley.edu>. Queries of the database can be made through HTML forms or through a preliminary interactive map created using open source MapServer 4.0 software. In addition, all data is downloadable in several commonly used formats including Microsoft Excel and Paradox. Future additions to the web interface include: forms for the submission of new data or corrections to existing data, links to digital photos of type specimens, and full mapping and spatial analyses using a GIS interface.

29. **Kohno, N.:** ECOLOGICAL SHIFT IN THE OTARIID PINNIPEDS FROM PELAGIC TO INSHORE: EVIDENCE FROM THE MIDDLE MIOCENE RECORD OF THE NORTH PACIFIC

KOHNO, Naoki, National Science Museum, Tokyo, Japan

A mandible of a small pinniped was recovered from the late middle Miocene age Aoki Formation (ca. 13-12 Ma), Nagano Prefecture, central Japan. This mandible has following characters: the size is very small (smaller than female Galapagos fur seals); the cheek teeth are double-rooted (except p1); m2 is missing; each cheek tooth is simple with lanceolate crown having very weak internal cingula and no secondary cuspules; and the canine is relatively small (suggesting that the individual was a female). Among these characters, simple cheek teeth are typical of crown-group pinnipeds and the lack of the m2 is a synapomorphy for the otariids (fur seals and sea lions). The specimen from the Aoki Formation is the earliest record of the otariids, and it narrows the stratigraphic and evolutionary gap between the stem pinnipeds and the crown group otariids. Interestingly, the depositional environment of this and other early late Miocene otariids in the North Pacific are regarded roughly as bathyal. It suggests that the habitat preference of the early otariids had been mainly the pelagic ocean except for the pupping and breeding season. Pelagic habitats of living fur seals are generally regarded as the ecological trait that was secondarily derived from the inshore ancestral otariid. However, evaluation of the habitat preference of the ancestral otariid in a phylogenetic context suggests that the pelagic existence is most likely the ancestral condition for the otariids, and entire inshore habitats among sea lions and some of the southern fur seals may be regarded as secondarily. This ecological shift may coincide with the change of the dietary preference of odobenids from inshore piscivory to molluskivory during late late Miocene.

30. **Hoppe, K., Paytan, A. and Chamberlain, P.:** THE POTENTIAL FOR USING CARBON ISOTOPIC ANALYSES OF *BISON* TOOTH ENAMEL CARBONATE AND BONE COLLAGEN AS A PALEODIETARY AND PALEOENVIRONMENTAL PROXY

HOPPE, Kathryn, PAYTAN, Adina, CHAMBERLAIN, Page, Stanford Univ., Stanford, CA

Analyses of fossil and subfossil bison have great potential for providing information about paleoenvironmental conditions in North America. Before European settlement, an estimated 30 million bison (*Bison bison*) ranged across North America from Alaska to Mexico, and bison remains are abundant in Holocene and Pleistocene deposits. Analyses of the carbon isotope ratios of bison can be used to reconstruct the carbon isotope ratios of dietary plants. Since bison are primarily grazers (i.e., their diet typically consists of > 90% grass), the carbon isotope ratios of bison should closely reflect the C-3/C-4 ratio of local grasslands. This ratio in turn correlates with growing season temperatures and precipitation. Therefore, analyses of the carbon isotope ratios of prehistoric bison may not only provide information on paleodiets, but also serve as a proxy for paleoenvironmental reconstructions. However, the accuracy of such reconstructions is currently limited because the relationship between the carbon isotope ratios of modern bison and the C-3/C-4 ratio of local grasslands has not been documented across a broad range of environments, and the baseline variability within different populations has not been quantified. Here we present analyses of tooth enamel carbonate and bone collagen from modern bison from 11 sites that have a C-4 abundance ranging from ~80 to < 10%. These sites are located in California, Kansas, Montana, Oklahoma, Nebraska, North Dakota, South Dakota, and Wyoming. The average carbon isotope ratio of each population was used to reconstruct the average percent abundance of C-4 plants in their diets. We found that dietary reconstructions based on analyses of tooth enamel served as the best predictor for the abundance of C-4 ratios of local grasslands. The carbon isotope ratios of bone collagen correlated with the percent abundance of C-4 grasses, but grassland reconstruction based on collagen often overestimate the absolute abundance of C-3 grasses. These results will serve as a baseline for using the carbon isotopic signals preserved in prehistoric bison to quantitatively reconstruct changes in the abundance of C-4 grasses.

31. **Burger, B.:** NEW FOSSIL VERTEBRATES FROM THE TIFFANY MEMBER OF THE LATE PALEOCENE ANIMAS FORMATION OF SOUTHWESTERN COLORADO, AND THE P/E BOUNDARY ON THE MARGIN OF THE SAN JUAN BASIN

BURGER, Benjamin, American Museum of Natural History, New York, NY

The Tiffanian land mammal age of the late Paleocene of North American was based upon an unique fauna of fossil mammals collected in 1916 from the area between the Los Pinos and Piedra river valleys on the northeastern margin of the San Juan Basin. Preliminary investigations of the area in 2003 revealed two distinct geologic units in the upper Animas Formation, here defined as the Tiffany Member and the Piedra Peak Member. The Tiffany Member consists of numerous horizons of well formed paleosols, indicated by the presence of thick layers of mudstones and siltstones grading from white to dark purple with an abundance of large root traces and ferruginous glaebules. While never abundant, fossil mammals, turtles, fish and crocodiles discovered during 2003 indicate the age of the member is restricted to the Paleocene. Fossil mammals discovered stratigraphically higher than the 1916 Mason Pocket Quarry, include *Phenacodus*, *Ectocion*, *Periptychus*, *Ignatiolambda*, and *Utemylus*. Sheet sandstones increase in frequency in the higher beds of the Tiffany Member. Only a single jaw of *Utemylus* was found higher than Barnes (1953) unit "d," which he interpreted as the Paleocene/Eocene boundary. *Utemylus*, a hyopsodontid condylarth, is distinctively more primitive than the closely related *Haplomylus* and *Hyopsodus* which first appear in the Clarkforkian and are common in the Eocene. The Tiffany Member exhibits a conformity/paraconformity with overlaid beds of finely grained red

mudstones interspersed by cliff forming massive white sandstones. These beds are lithological distinct from the lower Tiffany Member and here named the Piedra Peak Member, after the type locality, 10 miles east of Ignacio, Colorado. Tuffaceous sediments located in exposures near Pargin Mountain can be used for dating, since fossils have yet to be found in these stratigraphically high sediments.

32. **Glowiak, E. and Rowland, S.:** GYPSUM CAVE REVISITED: A TAPHONOMIC ANALYSIS OF A RANCHOLABREAN-TO-HOLOCENE FAUNA IN SOUTHERN NEVADA

GLOWIAK, Elizabeth, ROWLAND, Stephen, Univ. of Nevada Las Vegas, Las Vegas, NV

Gypsum Cave, near Las Vegas, Nevada, was excavated in 1930, yielding a RanchoLabrean-to-Holocene mammalian fauna, along with many human artifacts. The bone assemblage, which is now housed at the Los Angeles County Museum of Natural History, has never before been studied. We are now examining this assemblage to (1) identify the species present and their abundance, (2) reconstruct the taphonomic history of the bones, and (3) test the hypothesis that humans played a role in their deposition in Gypsum Cave.

Two extant species, bighorn sheep (*Ovis canadensis*) and mule deer (*Odocoileus hemionus*) are conspicuous members of the fauna, with the former accounting for approximately half of the bones in the collection. RanchoLabrean species present are Shasta ground sloth (*Nothrotheriops shastensis*), two species of horse (*Equus* sp.), llama (*Hemiauchenia macrocephala*), and camel (*Camelops hesternus*). The assemblage is dominated by herbivores (82%). Predators comprise 18% of the individual animals in the mammalian fauna, and all of the predators are relatively small, extant species: kit fox (*Vulpes velox*), gray fox (*Urocyon cinereoargenteus*), and lynx (*Lynx rufus*).

The bones are typically fractured and dispersed within the cave, clearly reflecting postmortem transport. A high percentage of the bones exhibit spiral fractures, which indicate that they were fractured while the bone was green. Many of the bones are either smoked or calcinated, especially those in Room 4, which contains nearly 50% of the mammal bones. Scanning electron microscopy has been used to determine the maximum temperatures to which the bones have been subjected. Results indicate that some of the bones were heated to approximately 700 C.

Several lines of evidence suggest that humans may have played some role in the deposition of some of the bones in Gypsum Cave. However, our conclusions about this aspect of the study await the completion of radiocarbon dating of selected bones and artifacts, which is currently underway.

33. **Fleagle, J., Perkins, M., Bown, T., Tauber, A. and Dozo, M. T.:** TEPHROSTRATIGRAPHY AND FOSSIL MAMMALS OF THE SANTA CRUZ FORMATION, ARGENTINA

FLEAGLE, John, Stony Brook Univ., Stony Brook, NY; PERKINS, Michael, Univ. of Utah, Salt Lake City, UT; BOWN, Thomas, Erathem-Vanir Geological, Boulder, CO; TAUBER, Adan, Univ. Nacional de Cordoba, Cordoba, Argentina; DOZO, Maria Teresa, Centro Nacional Patagonico, Puerto Madryn, Argentina

The Santa Cruz Formation (SCF) of southernmost Argentina is exposed in outcrops from the foothills of the Andes in the west to the south Atlantic shore in the east, and has yielded many thousands of fossil mammals from over a dozen different localities over the past 115 years. However, except for work by Bown, Fleagle, and Tauber in the last twenty years, most of the fossil mammals from the SCF have little stratigraphic context other than the name of the locality from which they were collected. In addition, the stratigraphic and temporal relationships among different localities are largely unknown and the subject of diverse views.

In two expeditions (2000 and 2004), we have begun a broad attempt to determine the stratigraphic and temporal relationships among the many localities of the SCF and their associated fossil mammals,

using tephrostratigraphy. Analyses of glass shards from tephra collected in 2000 show that there are at least 15 individual tephra in the SCF. Of these tephra, at least 3 are widely distributed and provide correlations between the rich localities of Monte Observacion and Monte Leon along the coast as well as correlations to inland localities along the Rio Chalia and near Lago Cardiel in the foothills of the Andes. Analyses in progress of tephra collected in 2004 should extend these correlations to the rich localities south of the Rio Coyle.

The ability to identify precise stratigraphic horizons among geographically separated fossil localities provides an opportunity to distinguish between faunal differences associated with time from those due to geography.

34. **Bajpai, S. and Thewissen, J. G. M.: EOCENE, OLIGOCENE, AND MIOCENE TERRESTRIAL AND MARINE VERTEBRATES FROM KACHCHH (GUJARAT, WESTERN INDIA)**

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The Kachchh (= Kutch) region represents the western margin of the Indian plate during the terminal phase of its drift history. The region's fossiliferous marine Tertiary sediments overlie the Deccan volcanics.

The Naredi Formation contains thick lignitic deposits overlain by mudstones that contain abundant shark and ray teeth, in addition to turtles, crocodiles, squamates, remingtonocetid whales, halitheriine sirenians, and rare land mammals. The type Naredi Formation is dated as upper Paleocene - lower Eocene (Ypresian) based mainly on larger Foraminifera.

The marine Harudi Formation overlies the Naredi Formation with an unconformable contact marked by lateritic clays. The Harudi Formation yields remingtonocetid, protocetid, dorudontid, and basilosaurid cetaceans, and protosirenid and halitheriine sirenians. Foraminiferal evidence and stratigraphic considerations suggest a middle Eocene (Lutetian) age.

The Harudi Formation is overlain by the Fulra Limestone in a broadly transgressive sequence. This formation is extensively exposed in Kachchh and very rich in marine invertebrates. No vertebrates have been recovered here, and the formation is well dated as upper middle Eocene (Bartonian).

Overlying the Fulra Limestone unconformably is the Maniyara Fort Formation, which contains abundant marine vertebrates, including sharks, rays, sea turtles, sirenians, and rare cetaceans. The Maniyara Fort Formation spans much of the Oligocene, but the known vertebrate-bearing levels are late Oligocene (Chattian) in age.

The Khari Nadi Formation conformably follows the Maniyara Fort Formation. The Khari Nadi Formation consists mainly of marine sands, and contains shark and ray teeth, sirenians and occasional cetaceans. However, most mammalian fossils from this formation are terrestrial and include proboscideans, anthracotheres, and ruminants. Foraminiferal data indicate an early Miocene (Aquitanian) age for this Formation.

35. **Worley, M.: A NEW CHADRONIAN MAMMALIAN FAUNA FROM THE FLORISSANT FORMATION, FLORISSANT FOSSIL BEDS NATIONAL MONUMENT, COLORADO**

WORLEY, Marie, Univ. of Colorado Boulder, Boulder, CO

The uppermost Eocene Florissant Formation is comprised of a series of lake shales, volcanics, and fluvial deposits which are exposed mostly within Florissant Fossil Beds National Monument and the immediate vicinity, in Teller County, Colorado. The formation is well known for its diverse and abundant plant and insect fossils. Discoveries of fossil vertebrates have been relatively rare, consisting mainly of fish and a few birds whose carcasses were buried in the lake shales on the bottom of ancient

Lake Florissant. Fossil mammal discoveries have been scarce and rather serendipitous, the most notable being a skeleton of *Herpetotherium* from the lake shales and a *Mesohippus* jaw from the lower mudstone unit, described by others.

A systematic investigation in the summer of 2003 of the lower mudstone unit greatly increased the known mammalian diversity from the Florissant Formation, especially of micromammals, including rodents, lagomorphs, and insectivorans. The discovery of a single large molar confirms the presence of eubrontotheres in the Park, which had been inferred previously only from a large atlas and tooth enamel fragments.

Two artiodactyl taxa are represented by isolated lower molars, the smaller of which appears to be a species of *Leptomeryx*, while the larger has yet to be identified. Five lagomorph teeth were recovered, representing the first from the Florissant Formation. Three belong to the genus *Megalagus*, while the others are tentatively identified as *Paleolagus*. Additionally, the rodents *Ischyromys*, *Eutypomys*, *Prosciurus*, and *Adjidaumo minimus*, occur in the Florissant mammalian fauna. Three insectivoran jaws were recovered representing the soricid *Domnina*, the geolabidid *Centetodon* and a third yet to be identified.

The mammalian fauna identified thus far is consistent with the Chadronian North American Land Mammal Age (NALMA), correlative to the latest Eocene. This agrees with the  $^{40}\text{Ar}/^{39}\text{Ar}$  age of  $34.07 \pm 0.10$  Ma of the Florissant Formation, as determined by other workers.

36. **Cavin, J. and Martin, J.:** A PLEISTOCENE PALEOFAUNA FROM THE SAND HILLS OF NEBRASKA, GRAVES/POTTER LOCALITIES, CHERRY COUNTY

CAVIN, Jennifer, MARTIN, James, South Dakota Sch of Mines & Technology, Rapid City, SD

The Pleistocene Graves/Potter localities are located in the Sand Hills of Nebraska. A taxonomic review of the vertebrate assemblage from the Graves/Potter localities shows at least two species of fish, three anurans, a salamander, a turtle, a snake, three species of birds, and twenty-five species of mammals. The greatest number of individuals (82%) are represented by ground squirrels and prairie dogs. The fossils are exquisitely preserved, completely permineralized, and resistant to breakage. Some taphonomic features are preserved on the bones, but the bones exhibit very little wear or abrasion.

The paleofauna at the Graves/Potter localities suggest a scrubby grassland environment. Lower vertebrate species indicate a body of water was in close proximity. The species' geographic ranges found at the Graves/Potter localities represent a disharmonious faunal assemblage; the assemblage contains species that no longer coexist in the same region. Therefore, these species had a larger range in the Pleistocene than at the present. Moreover, based on the current ranges of the Graves/Potter species, a cooler, more mesic climate is suggested for the time of deposition of the Graves/Potter localities.

The Graves/Potter localities preserve examples of Pleistocene megafauna including *Equus*, *Camelops*, *Bison antiquus*, and *Mammuthus*. The megafauna restricts the age of the assemblage to Rancholabrean (?late Wisconsinan).

37. **Miller, W., Delgado de Jesus, C. R., Hernandez-Bautista, R., Govez-Nunez, R. And Ramirez-Padilla, L. S.:** PRELIMINARY REPORT OF A LATE PLEISTOCENE VERTEBRATE FAUNA FROM THE STATE OF DURANGO, MEXICO

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Aside from the mention of one or two taxa (generally horse and mammoth) from a given site, very few Pleistocene vertebrate faunas have been reported from states in northern Mexico. Only recently has the first one from the state of Coahuila been reported. This paper provides the first published record of a late Pleistocene vertebrate fauna from the state of Durango, which borders Coahuila on the west.

In the spring of 2004 a small but significant vertebrate fauna was collected in terrace deposits (1.5 to 2.0 m thick) juxtaposed to the Rio Santa Clara. These deposits consist of bentonitic clays intercalated with gravelly sands. This site is located 3.5 km southwest of the village of Simon Bolivar. Pleistocene terrace and other alluvial deposits in the area rest unconformably on late Cretaceous limestones (probably of the Indidura Formation), or on an unnamed conglomerate of Oligocene to Miocene age. The local region constitutes part of the northwestern Central Mexican Highlands.

From the more than 300 specimens thus far collected, 14 different taxa have been tentatively identified. These include a teleost fish, an anuran, a turtle, a snake, cf. *Sylvilagus*, at least two types of rodents (based on postcranial bones), *Canis* cf. *C. latrans*, *Mammuthus* cf. *C. columbi*, *Equus* ?*conversidens*, cf. *Platygonus*, *Hemiauchenia*, cf. *H. macrocephala*, *Camelops* cf. *C. hesternus*, *Tetrameryx* or *Antilocapra*, and ?*Bison*.

The completeness of many specimens, including a horse skull and several jaws of different animals, suggests minimal stream transport. A predominantly grassland environment is indicated by the faunal aggregate. Presence of woody material in the fossil bearing deposits might permit a precise age determination.

38. **Gishlick, A.:** WHERE HAVE ALL THE CARPALS GONE? RECONSTRUCTING WRIST EVOLUTION IN THEROPOD DINOSAURS

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Despite strong phylogenetic evidence for homology between the carpal and metacarpal elements of theropods and extant avians, confusion persists as to the proper identity of the carpal elements in avian and non-avian dinosaurs. This is largely due to conflicting criteria (developmental versus morphological) for determining element identity. These criteria are not consistently applied, leading to differing interpretations of element identity. The impossibility of using developmental criteria to identify wrist elements in fossils compounds the problem. Much of this confusion can be eliminated by combining data from fossil and extant morphology, phylogenetic bracketing, and developmental comparisons.

Across theropod evolution there is a clear trend for the fusion and loss of carpal elements, culminating in the avian condition. Determining the identities of carpals and patterns of loss/fusion is made harder by the frequent lack of preservation of carpal elements; lack of preservation does not necessarily mean lack of presence. By supplementing fossil evidence with phylogenetic and developmental evidence, the identities of the bones preserved in theropods can be determined and the relative size and position of missing elements reconstructed.

Depending on the position of *Herrerasaurus*, theropods started with 3 rows of carpals: a radiale, an ulnare, a centrale, and dc 1-5. In ceratosaurs, there are only 2 rows of carpals. The centrale, digit 5 and its associated carpal were lost, and a fusion of dc1+2. Tetanurines exhibit further reduction having only three digits, a radiale, an ulnare, dc 1+2, which are sometimes fused, and probably a dc3. In coelurosaurs, the avian carpal pattern seems to have been set. Non-avian coelurosaurs possessed a radiale, fused dc 1+2, as well as a probable fused dc 3. Based on phylogenetic and functional concerns an ulnar carpal element was most likely present, but is not preserved. This pattern is consistent with morphology, phylogeny and development and suggests that that avian and non-avian theropods possessed

the same digit and carpal patterns consisting of digits 1-3 a fused dc 1+2, a radial carpal and an ulnar carpal.

39. **Hengst, R.:** GRAVITY AND THE *T. REX* BACKBONE

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Gravitational stresses on the vertebral columns of *Tyrannosaurus rex* or any large theropod, for that matter, were considerable. The only things preventing this anatomical beam from sagging were the combination of bone morphology, connective tissue, and muscle. Vertical stresses during locomotion would have increased these already substantial stresses. Theropod vertebrae typically show broad neural spines with prominent scars where intraspinous ligaments invested the bone. The intent of this study was to examine how much of the total vertebral support load was carried by the connective tissues in bipedal dinosaurs and how much would be required of muscles, which have the potential to tire over the course of a day.

Intraspinous ligament and intervertebral disk attachment points were measured for all vertebral regions in specimens of *Tyrannosaurus rex*, *Gorgosaurus libratus*, and *Maiasaura peeblesorum* from the Field Museum of Natural History, and the Indianapolis Children's Museum. Ligament length and cross sectional areas were determined for representative sites within each vertebral region while body mass was determined from museum reconstructed dimensions.

In theropods, ligaments alone were sufficient for normal postural support. Support values are consistent with those known for load bearing tendons and ligaments in living animals, with the tail somewhat stiffer than the body. *Maiasaura*, in contrast, possesses slender neural spines with little attachment area. This implies a greater dependence on muscle support during bipedal activities. The ossified, tendons frequently associated with hadrosaurid dinosaurs may have been a means of reducing muscular effort necessary for bipedal activities.

40. **Vietti, L. and Hartman, S.:** A NEW DIPLODOCID BRAINCASE (DINOSAURIA: SAUROPODA) FROM THE MORRISON FORMATION OF NORTH-WESTERN WYOMING

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Sauropod cranial material is rarely found and poorly understood in the fossil record. A well-preserved braincase missing the parietals was recovered during the summer 2002 field excavations in the Morrison Formation (Upper Jurassic, Tithonian), of north-western Wyoming. The braincase (WDC-BB 1188) was found in a large polytypic bone bed assemblage with no apparent association. WDC-BB 1188 is referable to the Diplodocidae, on the basis of its slender, elongate parasphenoid rostrum, well-developed fossa between the basiptyergoid processes, and non-spherical occipital condyle. Intrafamilial relationships are less clear, as it displays synapomorphies of both apatosaurines and diplodocines. Diplodocine characters include a fossa located on the ventral side of the paroccipital processes, and a constriction of the paroccipital processes. WDC-BB 1188 shares with apatosaurines a flattened slightly concave dorsal margin on the occipital condyle, relatively reduced and robust basiptyergoids, and an occipital condyle axis orientated to an angle greater than 90 degrees from the long axis of the skull. Autapomorphic characters include anterodorsal tapering of the supraoccipital and elongate paroccipital processes. WDC-BB 1188 is thus referred to Diplodocidae incertae sedis; it is hoped that examination of postcranial remains from the bone bed will allow a more precise taxonomic diagnoses.

41. **Garner, T.:** A BRIEF REVIEW OF ORIGINS OF ANKYLOSAUR SKULL 'ARMOR'

GARNER, Thomas, Denver Museum of Nature and Science, Longmont, CO

Dorsal skull “armor” on ankylosaurs is thoroughly fused to the cranium; two hypotheses have been advanced to explain the origin of this structure. One suggests that osteoderms first developed in the skin and coosified with the skull. The other suggests that the skull surface was remodeled to form the ‘armor’. We have examined these two hypotheses with histological thin sections. The histological thin sections of ankylosaur skulls and a variety of osteoderms from armored dinosaurs and extant reptiles demonstrate that dorsal skull armor in ankylosaurs is mostly remodeled bone and is not a result of coosification of osteoderms. A few ankylosaurs, such as *Minmi*, however, clearly do show small, thin sheets of osteoderms attached to the skull surface. Thus both methods appear to have been utilized, although remolded bone surface predominates.

42. **Evans, D. and Reisz, R.:** ANATOMY OF *LAMBEOSAURUS MAGNICRISTATUS* (ORNITHISCHIA: HADROSAURIDAE)

EVANS, David, REISZ, Robert, Univ. of Toronto, Mississauga, ON, Canada

*Lambeosaurus magnicristatus*, a rare hadrosaurid from the Dinosaur Park Formation (Campanian), Alberta, Canada, is known from two definitive specimens. The holotype consists of a poorly preserved skull and an unprepared postcranial skeleton. Description of the articulated referred specimen provides new information on braincase and postcranial skeletal anatomy of this species.

The referred skeleton is nearly complete and includes a well-preserved skull. The dorsal process of the premaxilla is characteristically well-developed rostrally and dorsally, and forms an acute angle to the snout. The dorsal margin of the crest is incomplete, which accounts for the less full, dorsally excavated profile when compared to the holotype. Like *Lambeosaurus lambei*, the laterosphenoid encloses a canal for the ophthalmic nerve. Position of the rostroventral deflection of the dentary is more typical of other lambeosaurines than in the holotype, and it is therefore of doubtful taxonomic value. The cervical series is complete and consists of 14 vertebrae, including the atlas-axis complex. The forearm is proportionately longer than the humerus. The fourth trochanter of the femur is large and symmetrical across the horizontal plane in lateral view. The tibia is 95 percent the length of the femur. Skin impressions are present in regions of the neck, upper arm and crus.

A preliminary phylogenetic analysis of *Lambeosaurinae* indicates a monophyletic *Lambeosaurus* supported by at least six unequivocal cranial synapomorphies. The relationships between *Lambeosaurus*, a monophyletic *Parasaurolophus*, and ‘corythosaurs’ remain unresolved. Despite significant geographic separation, both *L. magnicristatus* specimens occur within the uppermost Dinosaur Park Formation, stratigraphically higher than all recorded specimens of *L. lambei* or any other Dinosaur Park Formation lambeosaurine. Biostratigraphic data and the incomplete nature of the crest in the referred specimen do not support either of two previous proposals of sexual dimorphism in *L. magnicristatus*.

43. **Ohashi, T.:** PLEUROKINESIS IN A NEW ORNITHOPOD (DINOSAURIA) FROM THE LOWER CRETACEOUS KUWAJIMA FORMATION (TETORI GROUP), JAPAN

OHASHI, Tomoyuki, Univ. of Tokyo, Tokyo, Japan

The Kuwajima Formation (Ishikawa Prefecture; Tetori Group; Neocomian) consists mainly of alternating beds of sandstone, mudstone, and shale. It is thought to represent inter-channel deposits of floodplain origin. It has yielded a diverse fauna of terrestrial vertebrates. Among these is the partial skull of a small ornithopod dinosaur. Although partially disarticulated, it is thought to pertain to a single individual due to the arrangement of the preserved bones (reminiscent of their original positions) and the lack of duplicate elements. The left half of the skull is the best preserved: about 40% of the total cranial elements are present. Length of the skull is approximately 10cm. The specimen can be identified as a hypsilophodontian-grade ornithopod based upon characters such as the crescentic paroccipital process



and the cingulum at the base of the maxillary and dentary tooth crowns. The dentary has a laterally projecting ridge extending along its long axis, but a corresponding ridge is absent from the maxilla. Dentary teeth have deep and concave occlusal wear facets. Maxillary teeth have also occlusal wear, but the wear surface is approximately half of the width seen in the dentary teeth. These differences between the maxilla and the dentary are indicative of a developed pleurokinetic system usually associated with more derived ornithomorphs, such as hadrosaurs. Until recently, only a few fragments, mainly teeth, of hypsilophodontian-grade ornithomorphs were found in the Tetori Group: this specimen represents the first associated example of such an animal from Japan.

44. **Werning, S.:** OSTEOHISTOLOGY OF *TENONTOSAURUS TILLETI* (EARLY CRETACEOUS, NORTH AMERICA)

WERNING, Sarah, Univ. of Oklahoma, Norman, OK

The Early Cretaceous ornithomorph dinosaur *Tenontosaurus tilletti* is known from the Antlers Formation of northern Texas and southeastern Oklahoma, and from the Cloverly Formation of northern Wyoming and southern Montana. It was a numerically abundant taxon in these regions from the Aptian through the mid-Albian, and a large number of individuals have been collected from both areas by personnel from the Sam Noble Oklahoma Museum of Natural History. The specimens from the Cloverly and Antlers Formations form two apparent populations separated by approximately ten latitudinal degrees. Osteohistological samples were collected from specimens of *T. tilletti* representing multiple growth stages from both populations. The samples were then compared to determine differences in bone histology between different growth stages and between the two populations. Additionally, the samples were analyzed to determine the relative growth rates between different bones in a single individual. Preliminary results suggest that the northern and southern populations exhibit differences in bone histology. These may be attributable to differences in environment or latitude, or may suggest the presence of two subspecies. This study also indicates different relative growth rates among various skeletal elements within an individual.

45. **Larson, P., Evans, D. and Ott, C.:** TRICERESIES — A BOLD NEW LOOK AT *TRICERATOPS*

LARSON, Peter, Black Hills Institute of Geological Research, Inc., Hill City, SD; EVANS, Dallas, The Children's Museum of Indianapolis, Indianapolis, IN; OTT, Christopher, Black Hills Museum of Natural History, Hill City, SD

The preparation and mounting of a *Triceratops horridus* [TCMI 2001.93.1] (Ceratopsidae, Chasmosaurinae) from the Lance Formation (Maastrichtian) of Niobrara County, Wyoming has brought to light new details of the axial and appendicular skeleton. A relatively undistorted and nearly complete sacrum and presacral vertebral column and rib cage show a much broader and rotund belly region than previous mounts imply. The rib cage narrows anteriorly mandating articulation of the coracoids. Dorsal ribs 1 through 6 also show a clear depression to accommodate the scapulae, showing incontrovertible positioning of the shoulder girdle and new insight into forelimb locomotion. The complete pelvis, articulated with the dorsal vertebrae and ribs, shows widely diverging pubes. Double articular femoral facets on the ilia, coupled with the wide rib cage and arched femora clearly indicate that the femora diverged broadly away from the center line giving a distinct bow-legged appearance. This awkward gait would indicate that *Triceratops* was a trotter, not a galloper. Anterior caudal centra are longer dorsally than ventrally, giving an almost wedge-shape to the centra when viewed laterally. Since no *Triceratops* preserves a complete caudal series (or even more than 5 or 6 vertebrae) there is a possibility that the tail is much shorter than assumed, directed ventrally and curved somewhat anteriorly.

46. **Schumacher, B. and Liggett, G.:** THE DINOSAURS OF PICKET WIRE CANYONLANDS, A GLIMPSE INTO THE MORRISON BASIN OF SOUTHEASTERN COLORADO

SCHUMACHER, Bruce, USDA Forest Service, La Junta, CO; LIGGETT, Gregory, Sternberg Museum of Natural History, Hays, KS

Picket Wire Canyonlands is a deeply carved, rugged valley of the Purgatoire River drainage in southeastern Colorado. Managed since 1992 by the USDA Forest Service, Comanche National Grassland, the canyon is well known for its extensive dinosaur tracksite, which preserves evidence of gregarious behavior in Upper Jurassic sauropods. The Forest Service carefully monitors the tracksite, protects it through the implementation of erosion control structures, and hosts an aggressive educational and research campaign to ensure that the geologic history of this important area is preserved in perpetuity. Until recently, significant paleontology in the canyon other than the tracksite was largely unknown. Exposures of the Morrison Formation are pervasive throughout the canyon, but are generally masked by vegetation and colluvium. Poor Morrison exposure has led to the misconception that few dinosaur skeletal remains occur in this part of the Morrison basin. However, recent volunteer survey and salvage efforts have revealed a number of important sites, including several partial dinosaur skeletons within the Morrison interval, and a Middle Jurassic conglomerate bearing theropod and crocodylian remains.

To date, partial skeletons attributable to *Camarasaurus* and *Allosaurus* have been excavated in the upper Morrison Formation. Most recently, the discovery of a substantial sauropod skeleton near the middle of the Morrison will add significantly to our growing knowledge of Picket Wire dinosaurs. Another intriguing aspect of Morrison paleoecology here is the common occurrence of “gastroliths.” The possibility that polished, exotic quartzose stones represent true gastroliths is supported by the complete lack of clastic material larger than coarse sand size in any stratigraphic unit exposed in the canyon. Additionally, many “gastroliths” have been noted *in situ* within Morrison floodplain shales, including an associated accumulation of 54 stones, several stones associated with the *Camarasaurus* partial skeleton, and minimally 25 stones associated with the incompletely excavated *Allosaurus* partial skeleton.

47. **Stanton, A.:** TAPHONOMY OF THE CALICO GULCH QUARRY, MORRISON FORMATION, CO  
STANTON, Andrew, Brigham Young Univ., Provo, UT

The Calico Gulch quarry, located in the Morrison Formation, Moffat County, CO, was excavated in 1976 by a Brigham Young University crew. The quarry yielded a partial articulated *Diplodocus* skeleton, preserving the pectoral region through the distal tail, plus material of *Allosaurus*, *Camarasaurus*, *Stegosaurus*, *Dryosaurus*, crocodiles, turtles, and a pterosaur. The quarry is in a sandstone bed interpreted as a crevasse splay from an anastomosing river, which explains the abundance of crocodile and turtle remains. Based on femora there are at least two individuals of *Diplodocus*, and four juvenile *Dryosaurus* individuals representing a range of growth stages. The material was examined for a variety of taphonomic features to determine the extent of subaerial exposure, such as weathering cracks, tooth marks, trample breakage as well as insect pitting. Pitting on the *Diplodocus* material is more prevalent on the left side, which was the side that was subaerially exposed, lending weight to the interpretation that the pitting is due to dermestid beetle larvae rather than leaching by acid soils. Some of the *Diplodocus* material also exhibits distinct tooth marks. Weathering cracks and trample breakage predominate in the associated specimens, while in the articulated specimens these features are rare. It is proposed that the articulated *Diplodocus* skeleton was exposed for less than a year, was partially buried with connective tissue in place, while the bones of the other terrestrial vertebrates were transported from elsewhere on the floodplain and brought into association with this skeleton.

48. **Difley, R., Britt, B. and Policelli, P.:** A TROODONTID NEST IN THE NORTH HORN FORMATION, CENTRAL UTAH

DIFLEY, Rose, BRITT, Brooks, Brigham Young Univ., Provo, UT; POLICELLI, Philip, Utah Friends of Paleontology, Salt Lake City, UT

A nest of 13 dinosaur eggs was found in the uppermost Cretaceous (Maastrichtian) North Horn Formation at Black Dragon Canyon, Emery County, Utah. The nest is from the same stratigraphic level as the *Polyglyphanodon* type locality, slightly below a nest of *Spheruprismatoolithus condensus* eggs and about the same stratigraphic level as the North Horn Mountain *Tyrannosaurus rex* locality. The Black Dragon nest contains smooth-shelled Prismatoolithus eggs which have been attributed to a troodontid theropod dinosaur. A nearby BYU locality at a lower stratigraphic level produced the first reported a nest containing eggs of this type and dimensions in sandstone bed at the North Horn type locality.

The nest occurs in a stacked series of paleosols in a mottled grey horizon just below a rooted oxidized horizon. The paleosols represent weakly developed soils on a vegetated floodplain. Eggs of this type occur in both sandstone and mudstone, indicating both substrates were used as nesting substrates.

Nest dimensions are 61 x 36 cm. Eggs are about 76 mm in diameter with 1.06 mm thick shell. Their upper poles are eroded, but preserved egg lengths up to 85 mm with an estimated restored length of ~170 mm. The elongate, ovoid eggs are arranged upright on rounded bases. The eggs, slightly disordered before burial, were clustered 10-58 mm apart.

49. **Getty, P.:** ORNITHISCHIAN ICHNITES FROM DINOSAUR FOOTPRINT RESERVATION (LOWER JURASSIC PORTLAND FORMATION), HOLYOKE, MA

GETTY, Patrick, Univ. of Massachusetts Amherst, Amherst, MA

A recent survey of footprints at Dinosaur Footprint Reservation in Holyoke, MA has led to the identification of ornithischian dinosaur ichnites referable to the ichnogenus *Anomoepus*. These footprints had been overlooked in previous research but are important to fully understanding the ichnofauna at the site. The identification of these traces brings to 4 the number of ichnogenera in this classic locality, the other 3 ichnogenera being *Eubrontes*, *Anchisauripus* and *Grallator*, which are considered footprints of theropods. Thus, the new footprints represent evidence of herbivorous dinosaurs inhabiting this locality. I examined 9 isolated footprints and 6 trackways; however, there are many more footprints referable to the ichnogenera *Grallator* and *Anchisauripus*, and possibly even *Anomoepus*, that remain unmapped. The *Anomoepus* footprints range from 8.3 cm to 19.2 cm in length, indicating that the animals varied considerably in size. The trackways and footprints show some evidence of directionality, as do the large *Eubrontes* trackways on the same surface. One trackway has a sinuous, intermittent tail drag running through its midline, suggesting that the animal may have been preparing to stop. A more detailed study of the track surface should include remapping the whole site and identifying all of the unmapped footprints so as to provide as complete a picture of the tracksite as possible.

50. **Dalman, S.:** DINOSAUR AND NONDINOSAURIAN FOOTPRINTS FROM THE EARLY JURASSIC, GRANBY, MA

DALMAN, Sebastian, Univ. of Massachusetts, Amherst, MA Dept of Geology, Chicopee, MA

In 1968, while digging up rocks to build a deck on his property, the late Granby, MA. resident Bill Gingras discovered an outcrop of mudstone belonging to the Portland Formation containing dinosaur footprints primarily referable to the ichnogenera *Anchisauripus*, *Eubrontes*, and *Grallator*. The site was eventually sold to the park system of the state of Massachusetts.

Recently, numerous small tracks referable to the ichnogenus *Anomoepus* have been discovered *in situ*. Additionally, four toed and five toed footprints representing possible crocodylomorphs were discovered in 2003. The nondinosaurian footprints are the subject of the present study. Some of the rocks bearing these footprints were excavated in the late 1970's and as a consequence most of the footprints occur on several disarticulated slabs that are now in storage at the Notch Visitor Center in Amherst, MA, and at the Granby site.

With permission of the Skinner State Park, which is in charge of the site, I have documented the footprints using a variety of techniques including photography, mylar tracing, and mapping. Measurements recorded from the fossils include length and width of manus and pes, pace and stride. These ichnites are significant because they provide more evidence of the occurrence of *Anomoepus* and other non-dinosaurian footprints in the Connecticut Valley.

51. **Weishampel, D., Therrien, F., Henderson, D. and Ruff, C.:** BITE FORCE ESTIMATES FOR NON-AVIAN THEROPODS

WEISHAMPEL, David, THERRIEN, Francois, Johns Hopkins Univ. Sch of Medicine, Baltimore, MD; HENDERSON, Donald, Univ. of Calgary, Calgary, AB, Canada; RUFF, Christopher, Johns Hopkins Univ. Sch of Med, Baltimore, MD

A biomechanical approach is used to estimate bite force in non-avian theropods. Mandibles can be modeled as beams undergoing a bending load during food ingestion. Assuming similar bone properties and solid mandibles, the bite force applied at midentary (~mid-tooth row) should be proportional to the external dimensions of the mandibular corpus and inversely proportional to the distance from the articulation ( $Zx/L$ ). Thus, comparison of  $Zx/L$  values with those of extant taxa (*Varanus komodoensis* and *Alligator mississippiensis*) can provide an idea of relative bite force if all mandibles are equally approximated by a solid beam model. However, because CT scans reveal that the dentaries of *Varanus* and *Alligator* are hollow while those of theropods, such as *Tyrannosaurus rex*, are solid, bite force estimates for theropods should be considered minimal values.

Bite force estimates are evaluated for dromaeosaurids, ceratosaurids, spinosaurids, allosauroids, and tyrannosaurids. A dichotomy is observed among dromaeosaurids: while velociraptorines had maximum bite forces close to *Varanus*, that of *Dromaeosaurus* was three times stronger, possibly reflecting a greater reliance on bite as a killing technique. In spite of having similar mandibular lengths, *Dilophosaurus* appears to have had a slightly weaker bite than *Alligator*, suggesting that it may have preferably hunted small prey. *Suchomimus*, *Ceratosaurus*, *Allosaurus*, and "*Antrodemus*" all seem to have been capable of exerting bite forces close to that of *Alligator*, while that of *Majungatholus* and *Carnotaurus* was twice as powerful. Finally, the bite of the large *Acrocanthosaurus* and *Giganotosaurus*, nearly four and five times that of *Alligator* respectively, was only surpassed by that of tyrannosaurids. *Daspletosaurus* had a bite force seven times higher than *Alligator* while that of the average *Tyrannosaurus rex* was nearly 16 times higher! These values for tyrannosaurids are consistent with published values indicative of bone cracking abilities.

52. **Hunt, A. and Lucas, S.:** MULTIPLE PARALLEL DINOSAUR TAIL DRAGS FROM THE EARLY CRETACEOUS OF NEW MEXICO

HUNT, Adrian, LUCAS, Spencer, New Mexico Museum of Natural History & Science, Albuquerque, NM

Clayton Lake State Park in northeastern New Mexico preserves several hundred dinosaur tracks in the spillway of the dam. The majority of the tracks are in the lower Pajarito Formation (Lower Cretaceous: upper Albian). The tracksite preserves at least two ornithopod ichnotaxa, including

*Caririchnium*, three theropods, including *Magnoavipes*, and a crocodile swimming trace. The tracksite is unusual in that the substrate was obviously very wet, as evidenced by many features, including very deep tracks, sediment rebound into tracks, unusual gait (e.g., *Caririchnium* with metapodial impressions) and abundant *Skolithos* burrows. A partial tail drag was discovered in the 1980s. Recent work has uncovered multiple, parallel trackways with tail drags. All the trackways with tail drags were made by large bipedal dinosaurs with a tridactyl pes (pedal impression > 400 mm long). The tracks are wider than long with three wide, blunt-toed digit impressions, so they represent large ornithopods. The sinuous tail drag marks connect individual pedal impressions. In only one instance is a tail drag within a pedal impression, presumably because of compression of the substrate by the foot fall. There are at least five trackways with partial tail drags, and all trend between 280° and 295°. There is no complete map of the tracksite, but the majority of the ornithopod trackways are oriented N-NW, whereas the largest theropod trackways trend 18° and the sole *Magnoavipes* trackway trends 110°. The most obvious explanations for the abundance of trackways with tail drags is that unstable substrate conditions either necessitated the stabilizing support of the tail touching the ground or resulted in slippage. The parallel nature of the tail-dragging trackways suggests the passage of a social group of ornithopods. There are large samples of several thousand Early Permian tracks from New Mexico from an ecological transect from supratidal to piedmont environments that indicate that tail drags are only common in nearshore environments. The Clayton trackways support this hypothesis.

53. **Henderson, D.:** ERODING CONFIDENCE: IMPLICATIONS OF WEATHERING FOR TRACKWAY IDENTIFICATION AND BIOMECHANICAL INFERENCES

HENDERSON, Donald, Vertebrate Morphology & Palaeontology Research Group Dept of Biological Sciences, Calgary, AB, Canada

Trackways represent an important source of information about extinct animals, but are sensitive to the vagaries of weathering and preservation even within the same trackway. Additionally, the shapes and dimensions recorded for a given track will depend on the type of erosion, the sediment type, the size and characteristics of the trackmaker, and finally the subjective judgments of the investigator.

Using digital models of several different types of dinosaur tracks (sauropod, small and large theropod, small and large ornithopod), different types and degrees of erosion were simulated. The effects of these erosional parameters on measured lengths, aspect ratios, inter-digital angles, areas, and depths of penetration were determined.

The edges and corners of impressions of different track types responded differently to the different types and degrees of erosion. Measured lengths, aspect ratios, and especially areas were found to very sensitive to small differences in weathering parameters. Given the confounding effects of erosion, the goal of this study is to provide guidelines for improving reconstructions of original track and trackmaker foot morphologies.

54. **Allen, D.:** THE PHYLOGENETIC STATUS OF *PROCOMPSONGATHUS* REVISITED

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

*Procompsognathus triassicus* Fraas, 1913, is known from Upper Triassic rocks from Germany. The holotype material of *Procompsognathus* comprises three blocks (SMNS 12591) containing skull, hindlimbs and vertebrae respectively. The taxonomic status of *Procompsognathus* has been a topic of a controversy that has proven difficult to resolve.

Early studies indicated that *Procompsognathus* was a basal theropod dinosaur, and this view was supported by Ostrom in 1981. In 1992, Sereno and Wild hypothesized that the postcrania represented a theropod but that the skull belonged to the sphenosuchian crocodylomorph *Saltoposuchus connectens*

Huene, 1921. Further preparation of the skull block later revealed additional details relating to the skull roof, palate and braincase, leading Chatterjee to reassign all of the blocks to Theropoda, one year later, in 1993.

Despite first impressions and published comments to the contrary, the skull of *Procompsognathus* is well preserved, and relatively undistorted in most areas. For instance, the right quadrate is well preserved despite having been pushed inward and upward to artificially occupy the supratemporal fossa. This additional detail has made it possible for the present study to combine detailed description with cladistic methodology to investigate the phylogenetic status of *Procompsognathus*. In particular, additional information regarding the palate has been of value. The analysis compared a broad range of dinosaurian, ornithodiran, sphenosuchian, basal archosaurian and non-archosaurian taxa. Cranial and postcranial characters were considered separately and together with the ultimate conclusion being that *Procompsognathus* is shown to be a non-dinosaurian ornithodiran.

55. **Wideman, N. and Sumida, S.:** TAXONOMIC STATUS OF THE TETRAPOD *LIMNOSTYGIS RELICTUS* AND ITS BEARING ON THE TEMPORAL DISTRIBUTION OF BASAL AMNIOTES

WIDEMAN, Natalia, Raymond M Alf Museum of Paleontology, Claremont, CA; SUMIDA, Stuart, California State Univ., San Bernardino, CA

*Limnostygis relictus* was assigned to the Limnoscelidae in the late 1960s when the family was regarded as a group of basal reptiles. The specimen consists of a partial left maxilla, eight dorsal vertebrae, a right scapulocoracoid, what was interpreted as a right cleithrum, and undescribed materials that are most reasonably interpreted as a partial pelvic girdle. The specimen is of Middle Pennsylvanian age, recovered from a lycopod tree stump at the Florence locality in the Morien Group in Cape Breton County, Nova Scotia, Canada. Comparison with the two known species of *Limnoscelis* allows critical reassessment of the materials described as *Limnostygis*. Medially, the partial left maxilla demonstrates an internal maxillary swelling directed dorsally with obtusely and acutely angled depressions bounding it rostrally and caudally. This condition is not found in limnoscelids, but is common in ophiacodont pelycosaurian-grade synapsids, a group well known from Florence. The scapulocoracoid is also similar to that of ophiacodonts, and the cleithrum is more parsimoniously interpreted as a clavicle, particularly if the dermal sculpturing is interpreted as ventrally directed. The neural arches of the eight dorsal vertebrae are laterally expanded but not to the extent known in any limnoscelid. Rather, the vertebrae are most closely comparable with the captorhinid reptilian genera *Romeria* and *Protocaptorhinus*. If the captorhinid assignment of the vertebrae is correct, it is the earliest record of this basal reptilian family yet reported.

56. **Tsuji, L. and Reisz, R.:** NEW SPECIMENS OF *MACROLETER POEZICUS* AND IMPLICATIONS FOR PARAREPTILIAN PHYLOGENY

TSUJI, Linda, REISZ, Robert, Univ. of Toronto at Mississauga, Mississauga, ON, Canada

The discovery of several articulated skeletons of the enigmatic Permian parareptile *Macroleter poezicus* in localities situated within the Mezen River Basin system allows for a re-description of its anatomy along with a re-evaluation of relationships within the parareptile clade. *Macroleter* offers significant information regarding the biogeography of parareptiles, along with Permian biostratigraphy. Until recently, *Macroleter* was found exclusively in the Mezen River Basin in northern Russia, the most common element in an assemblage containing nycteroleterid, nyctyphuretid and lathanosuchid parareptiles as well as caseid, varanopid, and therapsid synapsids. The recent reassignment of a specimen from the Chickasha Formation of Oklahoma to the genus has led to comparisons between the Middle Permian Laurasian continental tetrapod assemblages of Russia and those of the US. In light of

this new information, the relationship of the taxon to other members of the Permian community becomes increasingly significant, as it provides the first known link between similar, but formerly distinct faunas.

Superbly preserved skeletons with skulls ranging from 7-10.5 centimetres in length show clear evidence of a small lateral temporal fenestra, bounded anteriorly by the jugal and posteriorly by the quadratojugal, with a small dorsal contribution by the squamosal. Also, the abundance of specimens permits thorough examination and illustration of the braincase and the palate in several views. Postcranially, the articulated skeletons show the presence of strongly swollen neural arches. Details of the atlas-axis complex and the sacral vertebrae are revealed for the first time, and despite the presence of a large, massive skull and vertebral column, the limbs are long and slender. This new information permits the reassessment of parareptilian relationships, presented in a new phylogenetic analysis of the clade.

57. **Folinsbee, K. and Reisz, R.:** EVOLUTION AND FUNCTIONAL MORPHOLOGY OF DENTAL OCCLUSION IN THE CAPTORHINIDAE

FOLINSBEE, Kaila, REISZ, Robert, Univ. of Toronto at Mississauga, Mississauga, ON, Canada

Captorhinid reptiles were important members of Permian terrestrial ecosystems. Most Early Permian taxa (including *Romeria*, *Protocaptorhinus*, *Rhiodenticulatus*, and *Labidosaurus*), possess a single row of marginal teeth, whereas the Early Permian *Captorhinus*, and the later *Labidosaurikos*, *Hecatogomphius*, *Rothianiscus* and *Moradisaurus* possess multiple rows of teeth. Phylogenetic analysis indicates that the multiple-tooth rowed condition evolved at least twice within the Captorhinidae: once in the lineage leading to *Labidosaurikos* and *Rothianiscus*, and independently in *Captorhinus aguti*. Because the phylogenetic relationships of the taxa involved are well known, we can test the hypothesis that multiple rows of occluding teeth evolved convergently within captorhinids for the same functional purpose.

Wear on the teeth of *C. aguti* is significantly different from that of *Labidosaurikos meachami*. *C. aguti* appears to incur wear on individual teeth in a relatively accidental and irregular manner on any side of the tooth. Individual teeth do not exhibit wear at regular intervals; the teeth that are worn occur randomly along the tooth row. Tooth wear in *L. meachami* is much more regular, on both maxillary and mandibular tooth rows. There is a clear wear pattern on the lingual and labial sides of many teeth, resulting in the formation of a crest in the middle of each tooth. This crest is not present in newly erupted teeth, indicating it developed through occlusion. We initially predicted dental occlusion and its associated jaw movements to be a complex phenomenon tightly correlated with either common descent or common function. *C. aguti* and *L. meachami* are not sister taxa, and dental occlusion does not occur in their sister taxa, therefore the emergence of this character is not due to common ancestry. Independent acquisition of multiple occluding tooth rows with strikingly different implantation morphology and wear patterns indicates that this character is neither functionally nor phylogenetically homologous.

58. **Suzuki, S.:** FAUNAL TRANSITION OF THE CRETACEOUS TURTLES IN MONGOLIA

SUZUKI, Shigeru, Hayashibara Biochemical Laboratories, Okayama, Japan

Hayashibara Museum of Natural Sciences and Mongolian Paleontological Center Joint Expedition surveyed 48 Cretaceous fossil localities in Mongolia from 1993 to 2002. Turtle remains were collected at 27 of these localities and in total more than 400 specimens. These specimens were studied and identified at familial level and compiled on each geologic formation. Four localities were of the Lower Cretaceous, and the rest are of the Upper Cretaceous. In the Upper Cretaceous localities, eight are of the Bayn Shire Formation, six are of the Djadokhta Formation, and nine are of the Nemegt Formation. No turtle remain was found in the Barun Goyot Formation.

From the Lower Cretaceous, four families such as Macrobaenidae, Trionychidae, Adocidae and Lindholmemydidae were found. Occurrences of the Trionychidae from Dzun Shakhai and Shine Usny Tolgod were the first record from the Lower Cretaceous of Mongolia. From the Upper Cretaceous strata, five families of turtle were recognized, such as Mongolochelyidae, Adocidae, Nanhsiungchelyidae, Trionychidae and Lindholmemydidae. Families Trionychidae and Lindholmemydidae were found from the lower Cretaceous to the uppermost Cretaceous. Adocidae disappeared at the Djadokhta Formation. Nanhsiungchelyidae were found from the Bayn Shire Formation to the Nemegt Formation. Archaic form: Mongolochelyidae was only found from the Nemegt Formation.

59. **Hutchison, J. H., Holroyd, P. and Wilson, G.:** THE POSSIBLE ROLE OF CLIMATE ON SUCCESSIVE TURTLE ASSEMBLAGES FROM THE UPPER CRETACEOUS HELL CREEK FORMATION, MONTANA

HUTCHISON, J. Howard, HOLROYD, Patricia, WILSON, Gregory, Univ. of California, Berkeley, CA

North American latest Cretaceous turtles formed highly diverse assemblages that show significant biogeographic variation. Some of the interregional differences have been attributed to latitudinal gradients that placed physiological constraints on the ranges of some taxa, while local habitat heterogeneity was suggested as a mechanism influencing differences in abundance within a region. However, we have not previously been able to assess the degree to which temporal trends and documented climate change might be a factor in influencing latest Cretaceous turtle diversity.

Recent fieldwork in the lower part of the Hell Creek Formation provides new, older records which permit us to look at temporal trends within the latest Cretaceous turtle fauna. This study focuses on turtle assemblages from 59 localities representing 44 distinct horizons within a 93 meter section that ranges from near the base of the Hell Creek Formation up to the K-T boundary in Garfield County, Montana. This section spans the final 1.8 Ma of the Cretaceous and permits documentation of the ranges of Late Cretaceous turtle taxa within a local chronostratigraphic framework. Additionally, this section has been correlated to areas in North Dakota where megaflores provide data on climate change.

The lower part of the Hell Creek Formation is notably less diverse than expected, with assemblages dominated by chelydrids and plastronine trionychids. A number of taxa make their first local appearances coincident with a presumed warming 400-500 ky before the K-T boundary, and it is only in the upper part of the formation that we find all the components of a more typical Late Cretaceous turtle fauna. The last appearances of three genera usually described as going extinct at the K-T boundary actually occur slightly prior to the boundary and correlate with a drop in paleotemperature. These data are consistent with hypotheses that climate change may have influenced northern range expansions as well as local extinction.

60. **Knoll, F., López-Antoñanzas, R. and Molina-Anadón, J.-A.:** FILLING A GAP: LATE TRIASSIC NONMARINE TETRAPODS FROM THE IBERIAN PENINSULA

KNOLL, Fabien, LÓPEZ-ANTOÑANZAS, Raquel, Museum national d'Histoire naturelle, Paris, France; MOLINA-ANADÓN, José-Antonio, Colegio Santa Ana, Zaragoza, Spain

Despite showing *a priori* favourable facies, the Upper Triassic strata of the Iberian Peninsula have provided quite a few evidences of the existence of nonmarine tetrapods. Yet, during Late Triassic times, the Iberian Peninsula had a particular biogeographical importance as it occupied a hinge position between two major landmasses.

In Portugal, in the area between Cordeiros de Messines and Silves (Algarve) several horizons (? Carnian and ? Rhaetian) of the "Grès de Silves" have yielded remains of indeterminate reptiles and,



especially, temnospondyls. A possible dinosaur track has also been mentioned in the same region at an intermediate level of the “Grès de Silves” (? Norian).

In Spain, problematic footprints of archosaurian affinity are known at Santisteban del Puerto (Andalusia) in a reddish sandstone of possible Carnian age. Interesting saurischian footprints have been found close to the Triassic-Jurassic boundary (“Dolomias tableadas de Imon s.l.” Fm) in the Tiermes area (Castile and Leon).

The Keuper of Manzanera (Aragon) has produced bones and teeth of a variety of marine reptiles such as late nothosaurs (probably the nothosaurid *Nothosaurus*), placodonts (derived cyamodontoids), and primitive ichthyosaurs. More interestingly, remains of temnospondyls (? Metoposauridae) have been unearthed at four localities of this area. They all lay in the Areniscas de Manuel Fm, which is believed to be of Carnian age. Having conducted field prospecting between Torrijas and Manzanera, we believe that facies around the latter locality show significant potential for yielding terrestrial tetrapods.

61. **Tissandier, S. and Caldwell, M.:** COMPARATIVE MORPHOLOGY AND INTRACOLUMNAR VARIATION IN *PALAEOPHIS COLOSSAEUS*

TISSANDIER, Sylvie, CALDWELL, Michael, Univ. of Alberta, Edmonton, AB, Canada

Many snake taxa are known exclusively from vertebral material, however, due to the reduction or lack of limbs it can be difficult to subdivide the vertebral column. Known only from isolated precloacal vertebrae, new material of the giant snake *Palaeophis colossaeus* from the type locality in Mali, and new material from Morocco, sheds light on intracolumnar precloacal variation within the species. This material includes anterior precloacal vertebrae that show morphological features distinguishing them from more posterior precloacal vertebrae. In addition to being smaller in size, the differences between the vertebrae include the presence of a second small anterior hypapophysis under the cotyle, the prezygapophyses extend ventrally to the base of the cotyle and the synapophyses lie horizontally and are primarily visible in the ventral aspect.

The vertebral morphology of primitive palaeophids greatly resembles that of madtsoiids and *Dinilysia*. These groups show general similarities in their vertebral morphology; the vertebrae are short and wide in shape and show no lateral compression. Primary features distinguishing palaeophids from boids include the presence of hypapophyses on all precloacal vertebrae and the presence of pterapophyses. Madtsoiids such as *Wonambi* rival *Palaeophis colossaeus* in size; differences between the two taxa include anterior precloacal vertebrae having only a single hypapophysis, and posteriorly bifid or trifid haemal keels on more posterior precloacal vertebrae. *Dinilysia* also lacks a hypapophysis on mid and posterior precloacal vertebrae, and on the anterior 1/3 of the precloacal vertebrae there are prominent hypopophyseal keels. Despite the uncertain affinities of the palaeophids, their vertebrae do show similarities to those of potentially basal snakes such as *Wonambi* and *Dinilysia*.

62. **Wahl, W. and O’Keefe, F. R.:** JUVENILE PLESIOSAUR FOSSIL ASSEMBLAGE AND PALEOCOMMUNITY OF THE UPPER REDWATER SHALE (OXFORDIAN-CALLOVIAN) OF THE SUNDANCE FORMATION. NATRONA COUNTY, WYOMING

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The predominance of juvenile forms from one taxon is unique in faunal studies. The large amount of juvenile cryptocleidoid plesiosaurs from the Redwater Shale Member of the Sundance Formation may identify such a paleocommunity. Seven out of the ten specimens found in one field collection can be identified as juveniles. Ontogenetic age is determined by the type of bone seen in cross-sections of the limbs and the lack of ossification and facets on the distal ends of the propodials. The dense

pachyosteosclerotic bone of the smaller juveniles is compared to the spongy osteoprotic bone condition of the adults and could indicate a difference in lifestyles and a possible view of social structure. Comparisons to other plesiosaur paleoenvironments in England, Australia, and Antarctica and to Cretaceous fish studies in Morocco show that juveniles are common, but usually in less proportion to adult forms. Indications of social structures in plesiosaurs as regards a consistent food source and possible predation on juvenile plesiosaurs by larger marine reptiles are considered as part of the described paleoenvironment.

63. **Watabe, M. and Tsogtbaatar, K.:** THE FIRST TRITYLODONT FROM THE MESOZOIC IN MONGOLIA

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The first tritylodont specimen was found by the Hayashibara Museum of Natural Sciences - Mongolian Paleontological Center Joint Paleontological Expedition in 2002 from the Upper Jurassic or Lower Cretaceous continental red beds in Shar Teg (Gobi Altai Aimag) in western Mongolia. The specimen is a fragmented skull with lower jaw that was preserved in a concretion in a red mudstone layer of the Ulan Malgait Beds. The beds also yielded several crocodylian forms (small and large), turtles, a sauropod skeleton, and theropod bones.

The tritylodont specimen shows four upper postcanine teeth *in situ*, and four lower postcanines *in situ* in function. It has three upper incisors among which the second is largest. There is one lower incisor with large size and its root occupies large part of the symphysis. The snout portion is short and robust. The upper postcanine teeth exhibit proportionally large buccolingual width. The lateral, medial and internal (lingual) row on an upper tooth have respectively 2, 2, and 3 cusps. The size of the tooth (mesiodistal length: 7.42mm; buccolingual width: 10.12mm for example) is large among ever discovered tritylodonts in China and North America.

The dental and rostral morphology of the specimen differs from that observed in Chinese taxa such as *Bienotherium*, *Bienotheroides*, and *Yunnanodon*, and from North American forms such as *Kayentatherium* and *Oligokyphus*. The dental morphology (not in size) of the specimen is similar to that of *Xenocretosuchus* from Shestakovo, Kemerovo region of western Siberia, Russia (Lower Cretaceous). The geologic age of the red beds in Shar Teg is still controversial. However, the specimen gives new data on biogeographical and geochronological range of the Tritylodonta.

64. **Tumarkin-Deratzian, A., Grandstaff, B., Lamanna, M. and Smith, J.:** NEW MATERIAL OF *LIBYCOSUCHUS BREVIROSTRIS* FROM THE CENOMANIAN BAHARIYA FORMATION OF EGYPT

TUMARKIN-DERATZIAN, Allison, Vassar College, Poughkeepsie, NY; GRANDSTAFF, Barbara, LAMANNA, Matthew, Univ. of Pennsylvania, Philadelphia, PA; SMITH, Joshua, Washington Univ., St. Louis, MO

In the early 20th century, Bavarian geologist Ernst Stromer named *Libycosuchus brevirostris*, a small “mesosuchian” crocodyliform from the Cenomanian Bahariya Formation of the Bahariya Oasis, Egypt. Although the majority of Stromer’s Bahariya collection was destroyed during World War II, the type specimen of *Libycosuchus* (skull, lower jaw, and four vertebrae) survives. During expeditions in 2000 and 2001, the Bahariya Dinosaur Project returned to the region of Stromer’s original discoveries. Among the crocodyliform remains recovered are new specimens referable to *Libycosuchus brevirostris*.

The new material comprises articulated dentaries and two associated vertebrae collected from a second locality. The vertebrae are essentially identical to the “lumbar” vertebra of the holotype. The

short rostrocaudal length of the dentaries and the strong divergence of the rami in the new specimen are consistent with the lower jaw of the holotype, as is the overall size of the specimen. The dentigerous portion of the type dentary is confined to the rostral-most portion of the rami, an area represented by the preserved portion of the new specimen. The rami of the two specimens possess nearly identical angles of divergence, and share an unusual squared-off contour of the lingual symphyseal margin. The dentary teeth appear to have been small (2.5-3.0 mm in diameter), conical, uniformly sized, and closely spaced in a dental groove with little or no interalveolar septa. Orientation of the dental groove suggests the teeth became more procumbent mesially along the tooth rows. There is no evidence in either the new specimen or the type dentaries for the enlarged caniniform teeth present in the type maxilla.

Small extant crocodylians, including juveniles of large species, eat insects, crabs, snails, shrimp, and small fish. Large living crocodylians with procumbent incisiform teeth (i.e. *Gavialis*) are primarily piscivorous. However, based on the small size (skull length approximately 200 mm) and presumed terrestrial habits of *Libycosuchus*, we hypothesize that it may have been largely insectivorous. Small crabs found at Bahariya may have also contributed to its diet.

65. **Wiersma, J., Hutchison, H. and Gates, T.:** CROCODYLIAN DIVERSITY IN THE UPPER CRETACEOUS KAIPAROWITS FORMATION (UPPER CAMPANIAN), UTAH

WIERSMA, Jelle, Utah Museum of Natural History, Salt Lake City, UT; HUTCHISON, Howard, Museum of Paleontology, Univ. of California, Berkeley, CA; GATES, Terry, Utah Museum of Natural History, Salt Lake City, UT

A goniopholid and four alligatoroid crocodylians from the Kaiparowits Formation are represented mostly by teeth, osteoderms and bone fragments. Osteoderms, skull fragments and teeth of the goniopholid indicate individuals in excess of three meters. A probable new species of *Brachychampsia* with an estimated length of more than two meters is represented by a skull and jaws and a partial juvenile skeleton. Osteoderms and skull fragments indicate a probable *Leidyosuchus*. The anterior part of a lower mandible compares well with the Caimeninae, and a dentary fragment indicates a small alligatoroid similar to *Alliganathosuchus*.

Based on functional morphology and analogy to extant taxa, ecological separation of these taxa is probably achieved by a combination of body size and habitat and prey selection. While the goniopholids were large enough to consume a diversity of prey, the long and relatively narrow rostrum suggests piscivory. Some of the fish (the amiid *Melvius* and sturgeons) reach one to two meters in length. The globular teeth of *Brachychampsia* indicate a durophagous diet, possibly turtles and hard-bodied fish such as gars. The remaining smaller alligatoroids were probably more generalized feeders as are their extant analogues.

Paleoenvironmental interpretation of the Kaiparowits indicates a lush, humid, ever-wet habitat, ideal for supporting a large number of crocodylians. Regardless of the ultimate identifications of these taxa, the crocodile assemblage of the Kaiparowits Formation is the most diverse known thus far in North America.

66. **Mehling, C. and Johnson, R.:** A NEW COLLECTION OF UPPER MAASTRICHTIAN VERTEBRATE FOSSILS FROM THE NEW EGYPT FM. OF MONMOUTH CO., NJ

MEHLING, Carl, American Museum of Natural History, New York, NY; JOHNSON, Ralph, Monmouth Amateur Paleontological Society, West Longbranch, NJ

Vertebrate fossils have been well known from New Jersey for two centuries. Generally consisting of isolated elements recovered from lag deposits, New Jersey specimens tended to discourage vertebrate workers and thus helped the more complete remains of the American west stand out early on. Recently

collected specimens from three New Egypt Fm. sites in Monmouth Co., New Jersey are offering a rare look at some of the ancient residents of the state by providing associated Maastrichtian remains that can be compared to more complete western counterparts as well as flesh-out the variation among endemic species. Associated remains from Locality 1 include specimens of a *Peritresius* (several carapace bones) and a very large shark (about 8 vertebrae: some collected *in situ*). For both of these specimens, additional elements were collected on successive trips to the site. Other vertebrate specimens include a dinosaur limb bone fragment with bite marks (a possible first occurrence in New Jersey), *Mosasaurus* elements (teeth, 2 vertebrae, alveoli, skull chunks, and misc. bone chunks), a possible crocodile scute, *Toxochelys atlantica* carapace fragments, 3 shark teeth (of 3 genera), an *Ischyodus* jaw fragment, *Enchodus* jaw fragments, and indeterminate bone fragments. Locality 2 has produced a mosasaur vertebra. Vertebrate fossils from Locality 3 consist of several associated mosasaur vertebrae found *in situ*, shark teeth, and indet. fish scales. The comparative abundance of associated remains at these sites is due to the fact that these beds are not the common lag deposits of most of New Jersey's Maastrichtian vertebrate sites, but instead, represent the relatively undisturbed, deep-water glauconite, resting places of the carcasses.

67. **Maxwell, E. and Caldwell, M.:** A PLATYPTERYGIID ICHTHYOSAUR FROM THE LOWER CRETACEOUS OF WESTERN CANADA

MAXWELL, Erin, Redpath Museum, Montreal, QC, Canada; CALDWELL, Michael, Univ. of Alberta, Edmonton, AB, Canada

*Platypterygius* is the most widespread genus of Cretaceous ichthyosaur and the only one that is universally acknowledged as being valid. Specimens representing several species have been found worldwide. *Platypterygius* is diagnosed by the presence of four bones in the epipodial row of the forefin. The number of these elements that contact the humerus is used to define species within the genus. *Platypterygius* has seven primary digits in the forefin, and at least one accessory digit, as well as a large number of presacral vertebrae, reduced eyes and an elongate maxilla compared to many Jurassic ichthyosaurs.

All Cretaceous North American ichthyosaur material has been assigned to the species *Platypterygius americanus* and all diagnostic specimens come from the Graneros Formation of Wyoming, which is Albian in age. Vertebral centra and other isolated bones have been reported from numerous sites in western North America. *Platypterygius americanus* differs from Australian and European species in having only three of the epipodial elements articulating with the humerus.

Here I describe an ichthyosaur specimen consistent with the genus *Platypterygius*. This large individual was recovered from the Loon River Formation, Northwest Territories, Canada, which is Albian in age. It differs from *Platypterygius americanus* by the presence of four articular facets on the humerus. This find suggests ichthyosaur diversity in the western North American epicontinental seaway was higher than previously reported.

68. **Wilson, L.:** PRELIMINARY TAPHONOMIC AND PALEOECOLOGICAL ANALYSIS OF A MICROVERTEBRATE LOCALITY FROM THE LOWER HELL CREEK FORMATION, GARFIELD COUNTY, EASTERN MONTANA

WILSON, Laura, Museum of the Rockies, Bozeman, MT

The Hell Creek Formation has been studied for decades during which faunal assemblages have been reconstructed using data from microvertebrate localities. However, few, if any, microsite data from the formation (particularly the western exposures) has been presented in association with a taphonomic study. Additionally, lower portions of the Hell Creek Formation have historically been under-sampled.

Presented here are preliminary results from a taphonomic and paleoecological study of a microsite in the lower Hell Creek Formation of eastern Montana.

The fossil horizon studied is restricted to an overbank fluvial mudstone interbedded with thin silt and very fine grained sand lenses. The lower boundary is clearly marked by an abundance of *in situ* plant stems and root traces contained in a massive mudstone unit. The top of the fossil horizon is marked by carbonized wood fragments. The assemblage is approximately 60cm at its deepest point and is thickest at the western extent of the quarry. Orientation and horizontal and vertical distribution data was collected on a 1/4 M2 grid system for over 3000 quarried specimens; size, shape, and abrasion data was recorded for each specimen in the lab, as well as taxonomic identification to the lowest level possible. Additional specimens were recovered through surface collection and screen washing to enhance faunal reconstruction.

Vertebrate taxa contained in the assemblage include fish, amphibian, turtle, lizard, crocodylian, dinosaur, and mammal specimens. Gastropod and plant fossils are interbedded among the vertebrate fossils (though the gastropods are locally contained to the western end of the quarry). The assemblage is dominated by specimens distinctly flattened in shape and showing little or no abrasion. Many of the specimens, however, are fractured due to preservation or collection. Presenting faunal assemblages in a taphonomic context allows for a better understanding of the biases represented in a given microsite, and thus its usefulness as a paleoecological indicator.

69. **Weil, A., Williamson, T., Pignataro, F. and Colon, J.:** THE TEIID LIZARD *PENETEIUS* DISCOVERED IN THE UPPER CRETACEOUS NAASHOIBITO MEMBER OF THE KIRTLAND FORMATION, SAN JUAN BASIN, NEW MEXICO

EIL, Anne, Duke Univ. Dept of Biological Anthropology & Anatomy, Durham, NC;  
WILLIAMSON, Thomas, New Mexico Museum of Natural History and Science, Albuquerque, NM;  
PIGNATARO, Francesca, COLON, Jacques, Duke Univ., Durham, NC

Four teeth from the Naashoibito Member of the Kirtland Formation can be referred to the unusual teiid lizard *Peneteius*. Specimens NMMNH P-36544, P-41223, P-41224, and an as yet uncatalogued specimen were recovered by screenwashing from NMMNH locality L4005. The locality has also yielded mammal teeth, including the Lancian (Maastrichtian) index taxon *Essonodon browni*, dinosaurs, crocodylians, turtles, a salamander, and jaw fragments of other squamates.

P-41223 is an isolated lower tooth. It is antero-posteriorly compressed and has transversely oriented, bicuspid crowns. A transversely oriented, U-shaped ridge connects these cusps. P-36544 and P-41224 are upper teeth. Each of the upper teeth has a subpleurodont attachment to a fragment of maxilla. The maxillary fragment has a wide, shallow supradental gutter. The teeth each have six cusps arranged in three parallel, transversely oriented pairs. The central pair is the largest and is connected by a sharp, transversely oriented, V-shaped ridge and is flanked by the anterior and posterior pairs of cusps, each connected by smaller and lower U-shaped ridges. Isolated osteoderms (P-36543) from locality L4005 may belong to the same taxon.

The age of the Naashoibito has proven difficult to constrain by means other than vertebrate biostratigraphic correlation, as the unit is bounded by erosional surfaces and has yielded no diagnostic palynomorphs or datable volcanic ashes. While the *Peneteius* teeth from L4005 closely resemble the teeth of *P. aquilonius*, from the upper Maastrichtian Hell Creek Formation of Montana, *Peneteius* is also known from the Campanian of Utah and Texas. Thus, its presence in the Naashoibito is consistent with a Maastrichtian age but is not a narrow constraint.

70. **Woods, A.:** MICROFAUNA ASSOCIATED WITH A MOSASAUR SKELETON  
(*PLIOPATECARPUS* SP.), JOHNSON COUNTY, WYOMING

WOODS, Arnold, Casper, WY

The partial skeleton of an adult *Plioplatecarpus* is currently undergoing preparation at the Tate Museum, Casper College, Wyoming. In addition to cleaning and repair of the skeletal elements, all removed matrix is also sieved through 2mm and 1mm screens and the remaining coarser fraction examined. Matrix directly associated with bone is rich in faunal material, including shark teeth (*Squalicorax*), teleost bone fragments, gastropods, bivalves, scaphopods and ammonites. Of particular interest is the discovery of several small (embryonic?) mosasaur teeth, indicating that this mosasaur was either a pregnant female or an adult that had recently consumed one or more small mosasaurs.

Matrix material even a short distance removed from bone appears to have a sparse fauna. This, combined with the small (stunted) size of all fauna associated with the *Plioplatecarpus* specimen, implies a relatively impoverished trophic environment for the seafloor. Benthic marine organisms likely clustered around carcasses, which served as trophic 'islands'.

71. **Druckenmiller, P. and Russell, A.:** A NEW PLEISOSAUR FROM THE LOWER CRETACEOUS  
(LOWER ALBIAN) CLEARWATER FORMATION FROM NORTHERN ALBERTA, CANADA

DRUCKENMILLER, Patrick, RUSSELL, Anthony, Univ. of Calgary, Calgary, AB, Canada

Open pit mining by Syncrude Canada, Ltd. in the Athabasca Oil Sands deposit of northeastern Alberta, Canada has resulted in the serendipitous discovery of an exceptionally complete new plesiosaur. The skeleton was collected from a heterolithic, glauconitic sandstone of the Lower Cretaceous Wabiskaw Member of the Clearwater Formation, deposited during the first major marine transgression of the Boreal Sea southward into the Western Interior Basin of North America during the Early Albian.

The 2.6 meter-long specimen is fully articulated and nearly complete, preserving the entire skull, vertebral column, pelvic and pectoral girdles, and three of the four paddles. It represents a new taxon that bears superficial resemblance to the cosmopolitan Early Cretaceous genus *Leptocleidus*, known from England, South Africa, and Australia. Similar to *Leptocleidus*, the skull is relatively small and bears a prominent dorosomedian ridge on the premaxillae. Features unique to the new specimen include the possession of a gracile, narrowly triangular skull lacking a rostral constriction; relatively large orbits; a vertically oriented suspensorium; a flat parietal table perforated by a large, ovoid pineal foramen; a squamosal vertex lacking a prominent crest; a lightly built, narrow mandibular symphysis that includes the first five dentary teeth; a relatively homodont dentition that lacks caniniforms; and a neck consisting of 24 cervical vertebrae. The lateral surface of the dentary is unique among any known plesiosaur in that it bears two conspicuous, longitudinal grooves along most of its length. Assignment of the new taxon to a family is pending the outcome of ongoing phylogenetic analyses of the Plesiosauria.

72. **Dutchak, A.:** ON *OPETIOSAURUS BUCCHICHI* AND THE SYSTEMATICS OF BASAL  
MOSASAUROIDS

DUTCHAK, Alex, Edmonton, AB, Canada

Aigialosaurs are poorly known, semi-aquatic lizards from the Cenomanian/Turonian of the Mediterranean. The presence of mosasaurian skull characteristics combined with terrestrial lizard postcrania led to the placement of aigialosaurs as the sister group to mosasaurs. Recent analyses suggest that the family "Aigialosauridae" is a paraphyletic series of sequential sister taxa to mosasaurs.

To examine the question of aigialosaur monophyly, *A. dalmaticus*, *O. buccichi*, *Carsosaurus marchesetti*, and the Trieste aigialosaur were studied. Paramount among these specimens was the

counterpart slab of *O. buccichi* that possesses the posterior two thirds of the skull. Despite crushing during fossilization, the elements of the braincase and temporal arcade are well preserved. The right pterygoid is twisted and distorted, but pterygoid teeth, previously unknown in aigialosaurs, are plainly visible. Preserved in a groove of the parietal is the stapes, also previously unknown in aigialosaurs.

*A. dalmaticus* and *O. buccichi* have previously been considered separate genera on the basis of several cranial characters. This study indicates only a single character that differs between the two taxa: the size of the parietal foramen. Based on these findings it is suggested that *O. buccichi* be placed in the genus *Aigialosaurus*.

The systematics of the family “Aigialosauridae” remain somewhat of a mystery. The “Dallas” and “Trieste” aigialosaurs have not been properly described in the literature and *C. marchesetti* lacks cranial material, making all three specimens difficult to code in a character matrix. Including these three taxa in a systematic analysis with mosasaurs results in a paraphyletic “Aigialosauridae,” but the results are poorly supported due to the amount of missing data. When including all well described and relatively complete aigialosaur specimens (all two of them) in a systematic analysis, it is hardly surprising that aigialosaurs are recovered as a monophyletic sister group to mosasaurs.

73. **Stocker, M., Parker, W., Irmis, R. and Shuman, J.:** NEW DISCOVERIES FROM THE UPPER TRIASSIC CHINLE FORMATION AS THE RESULT OF THE ONGOING PALEONTOLOGICAL INVENTORY OF PETRIFIED FOREST NATIONAL PARK, ARIZONA

STOCKER, Michelle, Ann Arbor, MI; PARKER, William, Petrified Forest National Park, Petrified Forest, AZ; IRMIS, Randall, Northern Arizona Univ., Flagstaff, AZ; SHUMAN, Jeffery, Univ. of Massachusetts, Amherst, MA

Continuation of the paleontological inventory of exposures of the Upper Triassic Chinle Formation in Petrified Forest National Park has resulted in the discovery and collection of numerous significant specimens. New finds include an associated postcranial skeleton of a phytosaur probably referable to the species *Leptosuchus adamanensis*, a complete skull of the phytosaur *Leptosuchus crosbiensis*, and a partial phytosaur skull referable to the poorly known species *Pseudopalatus mccauleyi*. The *L. crosbiensis* specimen represents the first complete phytosaur skull to be recovered from the park in almost two decades.

In addition, much aetosaur material has been recovered resulting in the addition of two new taxa to the known fauna of the park. Both taxa are closely related to *Paratypothorax* with the first representing a new genus and species, and the second being referable to the recently described “*Desmatosuchus*” *chamaensis*. This find represents the first occurrence of “*D.*” *chamaensis* outside of New Mexico. In all known occurrences, “*D.*” *chamaensis* co-occurs with the aetosaur *Typothorax*, while its strong similarities to *Paratypothorax* and dissimilarities to *Desmatosuchus* warrant placement of this species in a distinct genus.

Other significant finds include cranial and skeletal material of several small reptiles including *Trilophosaurus*, *Vancleavea*, and a possible new form. An important new site from the Petrified Forest Member has produced new material of the herrerasaur *Chindesaurus bryansmalli*, several theropods, a poposaur, and the first cranial and possibly postcranial material of the purported ornithischian dinosaur *Revueltosaurus*.

74. **Stoecker, N. and Froebisch, J.:** A LOWER JAW FROM THE RHAETIAN OF THE NORTHERN CALCAREOUS ALPS OF SWITZERLAND REPRESENTING A POSSIBLE NEW TAXON OF EUDIMORPHODONTID PTEROSAUR

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A reptilian lower jaw with multicuspid teeth and unique characteristics was discovered in an extensive outcrop of the Upper Triassic Koessen Formation in the Northern Calcareous Alps. Its sediments represent lagoonal deposits that are well known for their vertebrate fauna, including the remains of pycnodonts, ichthyosaurs and sharks in great numbers, but typically in a disarticulated and isolated preservational condition.

The lower jaw is characterized by a number of distinct morphological features. Two teeth are still preserved within the dentary, which are noticeably small in comparison to overall size of the ramus. Isolated teeth similar to those preserved in the lower jaw are frequently found in Upper Triassic deposits, e.g. in Belgium and New Mexico, and have been assigned to a number of different taxa, such as pterosaurs, cynodonts, and 'prolacertiforms', on the basis of overall tooth morphology and number of cusps. In the studied specimen two teeth of somewhat different morphology can be investigated in articulation with the tooth bearing bone.

One tooth is tricuspid, whereas the other bears four cusps. The presence of more than three cusps differentiates the dentition from that of a juvenile *Tanystropheus*. In addition, the accessory cusps are small in comparison to the main cusp and they are typically arranged in a single vertical plane. This feature rules out an affiliation to cynodont therapsids, which is also supported by the lack of a cingulum.

The ramus of the jaw is very deep and is dominated by a distinct row of eight large, oval foramina that runs parallel to the tooth row. In the anterior portion of the jaw at least four indentations are well visible, which represent overbite structures of premaxillary and/or maxillary teeth of the upper jaw.

The similarity of the teeth to those of the well known pterosaur genus *Eudimorphodon*, the lightly built jaw bones, as well as the distinct overbite structures suggest that the jaw belongs to an eudimorphodontid pterosaurs, which however differs from the known species *E. ranzii* and *E. cromptonellus* in the overall morphology of the jaw ramus, such as its depth and the presence of the distinct row of foramina.

75. **Sayao, J., Kellner, A., Calvo, J. And Porfiri, J.: BONE HISTOLOGY OF A LARGE PTEROSAUR FROM THE PORTEZUELO FORMATION, NEUQUEN GROUP, PATAGONIA, ARGENTINA**

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Thin sections of pterosaur bones from Argentina have not been studied so far. Until now only teeth of the Argentinean archaeoptero-dactyloid Pterodaustro were subject to this type of analysis. Here we present the histological features of a pterosaur bone recovered from the Futalognko site, which is situated in the region known as Loma de La Lata, some 90 km northwest of the Neuquen City. The main fossiliferous unit in this area is the Portezuelo Formation (Turonian-Early Coniacian) and consists of green sandstones intercalated with red siltstones and conglomerates. The pterosaur specimen consists of the proximal end of a right large ulna. The articulation is expanded reaching 88mm. The preserved distal part of the shaft has a sub-circular transverse section with the longest axis directed dorsoventrally (46 mm). The bone is hollow and the cortex extremely thin (1-2 mm thick). A system of well developed trabeculae can be observed. Based on the overall morphology this bone is referred to the pterodactyloid clade Azhdarchoidea. The bone shaft was sectioned and a thin section examined under ordinary light. The thin sections were processed only in transverse orientation. The cortex is composed mainly of primary tissue. Most of the structures up to its subperiosteal surface are made of reticular fibro-lamellar bone with many osteocytes lacunae. The vascular canals are numerous and small in diameter and their orientation is longitudinal with irregular anastomoses. Few primary osteons are present in the cortex.



There is no evidence of bone erosion and reconstruction such as secondary osteons, nor lines of arrested growth. The external fundamental system are also absent. The histological pattern observed in this specimen, especially the reticular fibro-lamellar bone is commonly reported in primary fast-growing tissue, involved in the formation of the cortex. The estimated wingspan of this pterosaur is around 6 meters. The histological features indicate that this specimen represents a young animal that was still in the process of growing at time of death, making this one of the largest pterosaur recovered from Gondwana so far.

76. **Colombi, C. And Alcober, O.:** TAPHOFACIES CHARACTERIZATION OF THE ISCHIGUALASTO FORMATION (UPPER TRIASSIC)

COLOMBI, Carina, ALCOBER, Oscar, Instituto y Museo de Ciencias Naturales-UNSJ, San Juan, Argentina

The Ischigualasto Formation is known by the abundance of Upper Triassic vertebrates. In some places the concentration of them is high enough to permit taphonomic analysis of the interrelation between fossils and paleoenvironments and construct a taphonomic model for each environmental context. Four taphofacies were defined using the association between the fluvial subenvironment of the Ischigualasto Formation and preservational classes of the fossils. They were defined according with the preservational features representative of time of weather exposure before final burial and geochemical environmental conditions.

The resulting taphofacies are: A) *Paleo-channel taphofacies*, formed by pieces of bone that experienced long weathering intervals under variable geochemical conditions. The bones were moved on the floodplain surface during channel avulsion and immediately thereafter were buried in the bar deposits; B) *Crevasse splay taphofacies*, characterized by pieces with different times of exposure before burial and buried in oxidized sandstone during channel overbank floods; C) *Proximal levee taphofacies*, formed by fossil bones with variable times of subaerial exposure, buried near the channel by wet sediment from continuous and smaller overflows; and D) *Distal levee taphofacies*, with bone fragments, which experienced similar conditions to those in the proximal levee taphofacies but with more time exposed to the weather because of lower sedimentation rates in the distal portion of the floodplain. Lastly, analyzing all of the vertebrate fossils shows a bias in the number of fossils per taphofacies, indicating the condition in the C taphofacies were most conducive to paleovertebrate preservation in the Ischigualasto Formation.

77. **Gathogo, P.:** THE GEOLOGY OF ILERET AREA (KENYA): LINKING FOSSIL OCCURRENCES TO DEPOSITIONAL ENVIRONMENTS

GATHOGO, Patrick, Univ. of Utah, Salt Lake City, UT

The Ileret area is located along the northeastern shores of Lake Turkana, Kenya, and it occupies an area about 450 km<sup>2</sup>. Strata deposited in the area during the Pliocene and the Pleistocene Epochs compose a cumulative thickness of at least 490 m. These strata are interpreted as having been deposited in six depositional environments; fluvial channel, fluvial floodplain, pelagic lacustrine, marginal lacustrine, distributary channel, prodeltaic and delta front. For geochronology isotope dates from volcanic feldspar, and chemical correlation of vitric tuff beds have been employed. A major unconformity in area is identified for the period between 2 Ma and 3.9 Ma based on scarcity of deposits, or stratigraphically thin units that are not differentiable in most cases. Most of the mammalian fossils derive from deposits that are interpreted as having been deposited in situations where fluvial floodplain and marginal lacustrine depositional environments occur sequentially.

During the Pliocene and Pleistocene Epochs in the Ileret area, lacustrine transgressions were from west to east. The oldest mammalian fossil from the area derives from marginal lacustrine deposits in the eastern part of Ileret, and has an approximate age of 4.0 Ma. Other mammals from similar deposits derive from outcrops that are dated 1.9 to 1.4 Ma, which is the time interval with the most mammalian fossils. There is a general regression during this time interval, which is matched by an increase in fossil abundance from east to west.

In fluvial-related depositional environments, sediments were transported into Ileret from the regions to the north. Most of the fluvial sequences were deposited by perennial river systems that entered the area from the NW periodically, formed major floodplains, and commonly exited to the SE. Most mammalian fossils that derive from deposits related to these depositional environments occur in the central and eastern part of the Ileret area, and range in age from 1.9 to 1.4 Ma, but are locally confined to much shorter time intervals.

78. **Ivanov, A. and Lucas, S.:** VERTEBRATES FROM THE PALEOZOIC SLY GAP FORMATION OF NEW MEXICO

IVANOV, Alexander, St Petersburg Univ., St Petersburg, Russia; LUCAS, Spencer, New Mexico Museum of Natural History & Science, Albuquerque, NM

The vertebrate assemblage from the Sly Gap Formation in the Sacramento Mountains of southern New Mexico includes ptyctodontid and brachythoracid placoderms, chondrichthyans, acanthodians (“*Acanthodes*” scales), and actinopterygians, which are palaeoniscoid scales and teeth (e.g., *Moythomasia*). The chondrichthyan teeth are from stethacanthids, phoebodontids, protacrodontids, polyacrodontids, petalodontids, helodontids, psephodontids and probably eugeneodontids. The scales belong to protacrodontid, orodontid, ctenacanthid and neolelachian types. The stethacanthid teeth belong to *Stethacanthus wildungensis* and *S. cf. S. thomasi*. The phoebodontids are *Phoebodus typicus*, *P. gothicus*, *Thrinacodus incurvus*. The teeth of *P. gothicus* belong to the morphotype with a lingually narrowing base and wide apical button. *Thrinacodus incurvus* includes both *nanus* and *ferox* morphotypes. Protacrodontids are *Protacrodus aequalis*, *P. cf. P. vetustus*, *Deihim* sp., and teeth with lateral cusps considerably higher than intermediate cusps. The polyacrodontid teeth of *Lissodus* are of two morphotypes, with laterally elongated crown and with almost rounded crown, and belong to a new species. The tooth of *Petalodus* most resembles *P. acuminatus*. Teeth of *Helodus* and psephodontid tooth plate fragments are very common. *Stethacanthus wildungensis* is known from the Late Frasnian-Famennian. *Phoebodus typicus* occurs in the *Famennian triangularis* and *marginifera* conodont zones, *P. gothicus* in the *marginifera* and *praesulcata* zones and *Thrinacodus incurvus* is Late Famennian-Early Carboniferous. *Protacrodus aequalis* is Famennian and early Tournaisian; *Deihim* is from the Famennian *crepida* and *expansa* zones. Devonian *Lissodus* is from the *expansa* zone. *Petalodus* and psephodontids first occur in the Lower Carboniferous. Thus, the Sly Gap vertebrate assemblage is a mixed assemblage of Famennian and Early Carboniferous taxa.

79. **Robb, III, A. and Purdy, R.:** ADDITIONS TO THE FISH FAUNA OF THE CASTILLO FORMATION (LOWER MIOCENE) OF NORTHWESTERN LARA STATE, VENEZUELA

ROBB III, Albert, ExxonMobil de Venezuela, Caracas, Venezuela; PURDY, Robert, Smithsonian Institution, NMNH, Washington, DC

At least five sharks (*Hemipristis serra*, *Carcharhinus falciformis*, *Carcharhinus* spp., Squalidae indet.), two batiods (*Rhinoptera* sp., Myliobatiformes indet.), and seven bony fish (*Sphyraena* sp., *Acanthocybium* sp., *Protosciaena neritica*, cf. *Arius* sp., cf. *Bagre* sp., *Colossoma macropomum*, *Mylossoma* sp.) were previously recognized as part of the fauna of the lower Neogene Castillo

Formation of Venezuela. Although vertebrate remains are not common within the Castillo Formation, additional prospecting of this unit at the Cerro La Cruz locality in northwestern Lara State has yielded 44 new specimens (shark teeth, ray mouth plates, bony fish tooth and otoliths) resulting in the recognition of additional fishes in this fauna. Newly recognized taxa include the sharks *Nebrius obliquus* (Museo de Biología de la Universidad del Zulia, Maracaibo - MBLUZ-P-5130), *Galeocerdo* cf. *G. cuvier* (MBLUZ-P-5126), *Negaprion brevirostris* (MBLUZ-P-5127), *Sphyrna zygaena* (MBLUZ-P-5128), confirmation of the presence of *Carcharhinus perezii* (MBLUZ-P-5129), and based upon otoliths the bony fish *Sciaena* sp. (MBLUZ-P-5132) and cf. *Diplodus* sp. (MBLUZ-P-5133). These vertebrate remains are characteristically fragmentary and abraded, suggesting a high-energy depositional environment. The very common molluscan fauna (gastropods, pelecypods, scaphopods) suggests a shallow, nearshore, warm water marine depositional environment for most of the section at this locality. The fish otoliths were recovered from well-sorted, finer-grained lithologic intervals of the formation that suggest cyclic regressive coastal conditions are preserved at this location. The previously reported stratigraphic ranges of the newly identified fish are consistent with an early Miocene age for this fauna; the paleogeographic range of several taxa are herein extended into the southern Caribbean region.

80. **Massa, R., Gallo, V. and Figueiredo, F.:** NEW DATA ON SOME ELOPOMORPH FISHES FROM THE EARLY CRETACEOUS, NORTHEASTERN BRAZIL

MASSA, Renato, GALLO, Valeria, FIGUEIREDO, Francisco, Univ. do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

The osteology of *Brannerion latum* and *Paraelops cearensis*, two elopomorph fishes found exclusively in the Lower Cretaceous strata of the Araripe (*B. latum* and *P. cearensis*) and Parnaíba (only *B. latum*) basins, is reviewed here. This study revealed some new information concerning the neurocranium and the vertebral column and associated bones of both taxa. The skull roof of *B. latum* is described here for the first time and it shows shape and arrangement similar to verified in the extant elopomorph *Albula vulpes*, in addition to new data on the neurocranium of *P. cearensis* (for instance, the presence of a prootic-intercalary bridge). Aspects of the exoccipital (arrangement pattern of the foramina), supraneural and intermuscular bones (number and extension) of *B. latum* are also discussed. A preliminary phylogenetic analysis comprising both fossil and recent taxa of Elopomorpha was accomplished, revealing *P. cearensis* as part of a monophyletic group, the Aubuliformes, with *B. latum* appearing as a basal taxon of this clade.

81. **Gallo, V. and Coelho, P.:** ENCHODONTOID FISHES FROM THE EARLY CRETACEOUS, NORTHEASTERN BRAZIL

GALLO, Valeria, COELHO, Pablo, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

Some almost complete fishes from the Coqueiro Seco Formation, Sergipe-Alagoas Basin, Northeastern Brazil, are presented here. The strata of this formation were deposited by short deltas in a lacustrine paleoenvironment. Based on non-marine ostracods and palynomorphs, these deposits were formed during the Lower Aptian. The specimens are preserved in carbonate concretions showing some of their three dimensional characteristics. The fishes exhibit a well ossified, very elongated, and deep dentary bearing stout caniniform teeth; deep and constrict dentary symphysis with a typical tooth; long, arched, and toothed ectopterygoid; preopercle lacking a prominent ventral spine; and interopercle absent. Based on this combination of features, we preliminary assigned the specimens to the family Enchodontidae. The relevance of this occurrence is due to the presence of this taxon in a continental

paleoenvironment from the Lower Cretaceous. This worldwide group was only found in marine strata of the Upper Cretaceous.

82. **Figueiredo, F.:** NEW APPRAISAL AT THE ANATOMY AND RELATIONSHIPS OF THE TELEOSTEAN *SCOMBROCLUPEOIDES BAHIAENSIS* FROM THE LOWER CRETACEOUS OF BAHIA, NORTHEASTERN BRAZIL

FIGUEIREDO, Francisco, UERJ, Rio de Janeiro, Brazil

*Scombroclupeoides bahiaensis* is a teleostean of uncertain affinities known from the Neocomian (non-marine lowermost Cretaceous) of the Ilhas Group, State of Bahia. It is very scarce in paleontological collections and most of specimens are poorly preserved. In order to decipher its phylogenetic relationships five relatively complete specimens of the paleontological collection of the DNPM were studied. The result indicates a constant presence of the following features: absence of suborbitals; preopercular sensory canal with few tubules; three epurals, six hypurals; absence of diastema between lower and upper set of principal fin-rays of caudal fin; three uroneurals, being the first the largest and extending forward reaching the second preural centrum; shallow anterior outgrowth of uroneural (stegural?); slender neural spine of second preural centrum; very reduced neural spine and arch of first preural centrum; and presence of ventral and dorsal caudal scutes. There is no evidence of epicentralia but epipleuralia and epineuralia are present. Reduced conical teeth are present on the oral border of premaxilla and maxilla but they are lacking in dentary. A preliminary overview of the morphology of *S. bahiaensis* pointed out that it is advanced in relation to so-called leptolepids and proleptolepids by various derived features (e.g. absence of suborbitals, absence of fringing fulcra, reduced number of branchiostegals, absence of preopercular process of hyomandibula) and some other derived features suggest putative affinities with primitive euteleostean fishes.

83. **Kohl, M., Martin, L. and Brinkman, P.:** A *TRICERATOPS* HUNT IN FRONTIER WYOMING: THE UNIVERSITY OF KANSAS EXPEDITION OF 1895

KOHL, Michael, Clemson Univ. Libraries, Clemson, SC; MARTIN, Larry, Univ. of Kansas, Lawrence, KS; BRINKMAN, Paul, The Field Museum, Chicago, IL

After long years of journeyman work for O.C. Marsh during the 1870s and 1880s, Samuel Wendell Williston had established himself as an leading pioneer paleontologist. In 1890 Williston joined the University of Kansas and inaugurated that institutions long tradition of teaching and research in paleontology. Using a special appropriation from the Kansas State Legislature, Williston led a field expedition to Wyoming in 1895. This expedition included future paleontologists Barnum Brown and Elmer Samuel Riggs as student assistants. It was on this expedition that they helped to collect their first dinosaur fossils and served as a key experience for their careers. The expedition also included Univ. regent, James Polk Sams and Will Snow son of the president of the Univ.. Williston took thirty to forty glass plate photographs of the expedition that have never been published. Both Brown and Sams wrote journals of their experiences that now have been edited by the above authors and will be published along with some of the photographs.

Brown's journal is much shorter and covers his trip with a teamster and wagon through Kansas and Nebraska along sections the old Oregon Trail. He rendezvoused with the rest of the expedition near Fort Laramie, Wyoming. With the exception of one brief entry, his journal ends there. Sams' journal is much more complete, following the entire course of the expedition from 13 June through 9 August 1895. Sams describes the discovery, excavation and transport of *Camerasaurus*, *Merycoidodon*, and most spectacularly, a *Triceratops* skull.

The journals however are more travelogue than science. They weave together a record of a rapidly changing West still wild in the minds of visitors from Kansas. There are accounts of devoted pioneer women bringing religion to godless Wyoming; public alarms over forays by armed bands of Native Americans only five years after Wounded Knee; conflicts between cattlemen and homesteaders still being settled by bullets; and allusions to Buffalo Bill, a popular symbol of a Wild West that was already fading into myth.

84. **Castillo, J., Cabral-Perdomo, M. A., Bravo-Cuevas, V. and Gonzalez-Rodriguez, K.:** THE FOSSIL VERTEBRATE COLLECTION OF THE MUSEUM OF PALEONTOLOGY AT THE UNIVERSIDAD AUTÓNOMA DEL ESTADO DE HIDALGO, MEXICO

CASTILLO, Jesus, CABRAL-PERDOMO, Miguel Angel, BRAVO-CUEVAS, Victor, GONZALEZ-RODRIGUEZ, Katia, Univ. Auton de Hidalgo Museo de Paleontologia, Pachuca, Hidalgo, Mexico

Paleontological research in the Universidad Autónoma del Estado de Hidalgo in Mexico started in 1994. By 1995 the Museum of Paleontology in this University was created, mainly with fossil vertebrates. At present, the museum contains a collection of 1948 fossil vertebrate specimens, including fishes (390 specimens = 20.02%), amphibians (37 specimens = 1.9%), reptiles (182 specimens = 9.34%), birds (3 specimens = 0.15%) and mammals (1336 specimens = 68.59%). 28.95% of the collection (564 specimens) are fishes and macromammals and 1384 specimens are microvertebrates (71.05%). The last group includes 37 anurans, 104 turtles, 66 lizards, 8 snakes, 4 crocodylians, 3 birds, 58 shrews, 995 rodents, 67 rabbits, 27 bats and 15 carnivores. The macrovertebrates are represented by 24 xenarthrans, 10 carnivores, 20 mammoths and mastodons, 70 artiodactyls, 50 perissodactyls and 390 fishes.

The fossil material comes from 92 localities distributed in three states: Hidalgo (52 localities with 1823 specimens = 93.58%), Puebla (24 localities with 78 specimens = 4%) and Tlaxcala (16 localities with 47 specimens = 2.42%). The localities in Hidalgo correspond to Late Cretaceous, Miocene, Pliocene and Pleistocene in ages; in Puebla all localities are from the Pleistocene and in Tlaxcala from the Pliocene and Pleistocene. Most of the fossil material comes from the Miocene/Pliocene, specifically from the Hemphillian (1050 specimens = 53.9%); it is followed by the Pleistocene, with 508 specimens (= 26.08%) and by the Cretaceous, with 390 specimens (= 20.02%).

In the course of these 10 years, the Museum of Paleontology has received diverse support and grants for the accomplishment of investigation projects in vertebrate faunas in the center/east region of Mexico from the last 110 million years. This collection is used as a reference for research in the area and in the ages listed above.

At the moment the museum has four full time researchers: a paleoichthyologist, two specialists in megavertebrates and one in microvertebrates.

85. **Houle, M. and Mueller, B.:** A NEW OCCURRENCE OF *BUETTNERIA BAKERI* (TEMNOSPONDYLI: METOPOSAURIDAE) FROM THE NORIAN (COOPER CANYON FORMATION, DOCKUM GROUP) OF WEST TEXAS

HOULE, Matthew, MUELLER, Bill, Texas Tech Univ., Lubbock, TX

In 1931 and 1932 E. C. Case described a population of *Buettneria bakeri* (Temnospondyli: Metoposauridae) from the Elkins Place Bone Bed, reported to be in Scurry County, Texas. Two additional specimens of *Buettneria bakeri* have been reported: A partial skull imprint was found in the Wolfville Formation, Fundy Basin, Nova Scotia, and a skull was collected in the 1940s from the classic Otis Chalk Quarry 2 in Howard County, Texas. Both localities are generally considered Carnian in age.

A recent discovery of a complete skull of *Buettneria bakeri* from MOTT VPL 3869, Garza County, Texas, extends the range of the species temporally. A fragmentary skull, clavicles, and interclavicles recovered from this locality appear to be from the same taxon. The specimens from MOTT VPL 3869 are found in the Cooper Canyon Formation, Dockum Group (Norian). There are some distinct differences between the Elkins Place population, the Otis Chalk specimen, and the newly discovered population that may lead to the designation of separate subspecies of *Buettneria bakeri*.

86. **Ralrick, P.:** PRELIMINARY OBSERVATIONS OF THE SUBFOSSIL VERTEBRATE MASS MORTALITY EVENT AT LITTLE FISH LAKE, ALBERTA, CANADA

RALRICK, Patricia, Bellevue, NE

Little Fish Lake preserves a unique subfossil vertebrate mass mortality assemblage. Found on the beach of this glacio-fluvial lake are countless disarticulated bones, dominated by the White Sucker (*Catostomus commersoni*), Yellow Perch (*Perca flavescens*), and Leopard Frog (*Rana pipiens*) as well as hundreds of Buffalo (*Bison bison*) bones. Several Rocky Mountain Wolf (*Canis lupus* cf. *irremotus/nubilis*) skulls have also been found. As many as a dozen articulated White Sucker skeletons have been located indicating rapid burial. Today the bone layer is a complex depositional environment with *in situ* material being exposed, reworked, and reburied by shifting aeolian sands. Four kilometers of beach have been explored thus far and the bonebed has proven to be laterally extensive. Four random test areas of the bonebed layer each measuring 61 cm<sup>2</sup> were dry screened and yielded between 166 and 523 bones and bone fragments. Biological and historical evidence suggests the bonebed formed between 120 and 275 years ago. It is speculated that a bloom of toxic blue-green algae, which have been known to occur at this lake, was the cause of the mass mortality. Winterkill is another possibility. Age determination of the animals involved will help to clarify the etiology of this mass mortality assemblage. This site is significant because it provides a relatively modern example of the accumulation of vertebrate skeletal remains and will provide a reliable indicator as to whether a bonebed accurately denotes the local fauna present at the time of the accumulation. As such, the Little Fish Lake locality may have important ramifications in the study and interpretation of fossil microvertebrate and bonebed accumulations.

## STUDENT POSTER SESSION

Posters will be set up by 8:00 a.m. on Thursday, November 5, and remain until 6:00 p.m.

87. **Adam, P.:** PATTERN AND PROCESS IN THE CENOZOIC CARNIVOROUS MARINE MAMMAL GUILD OF THE NORTH PACIFIC OCEAN

ADAM, Peter, UCLA, Los Angeles, CA

Competition for resources drives evolutionary adaptation and diversification. Faced with competition, a lineage must modify existing strategies to outcompete competitors or adapt novel strategies for utilizing resources that are less intensely contested if it is to survive. Excluding herbivorous sirenians, marine mammals are a diverse and paraphyletic assemblage of predators that constitute the marine mammal carnivore guild (MMG). Although often assumed to have generalist feeding habits, many extant marine mammals have adapted specialized feeding behaviors and restricted diets. Using functional morphology, analogy, and phylogeny, one can infer feeding strategies of fossil forms. When coupled with temporal and geographic distributions (and accounting for paleoceanographic, taphonomic, and other factors that may have influenced their evolution) a firm understanding of patterns and processes shaping past and present MMGs can be attained.

I assembled data on temporal and geographic distributions of north Pacific cetaceans, pinnipeds, and sea otters, and assessed the feeding strategy of each using 108 functional craniodental features. Oligocene and earlier MMGs are characterized by generalist fish and squid predators. A middle-late Miocene surge in marine mammal diversity correlates with enhanced coastal upwelling brought about by isolation of circum-Antarctic currents and latitudinal stratification of thermal gradients. During this time novel adaptations for suction, filter, and grip and tear feeding types appear. A surplus of available food (from increased coastal upwelling) allowed experimentation in feeding strategies and led to some taxa becoming more specialized for preying on benthic invertebrates, zooplankton, and large marine tetrapods. From the Pliocene through the recent, instances of competitive replacement are evident. Among pierce feeders, delphinids diversified and outcompeted most other odontocete lineages. A greater diversity of body sizes is also evident, suggesting niche partitioning among pierce predators. Among benthic suction feeders (primarily odobenids), at least 3 instances of competitive replacement are documented.

88. **Bennett, G.:** ANCIENT ISLANDS AND THE SPECIES-AREA CURVE: A NEW METHOD FOR ESTIMATING THE INCOMPLETENESS OF THE FOSSIL RECORD

BENNETT, Geb, Shenandoah Valley Discovery Museum and George Mason Univ., Winchester, VA

Modern studies of island biogeography have revealed a correlation between species richness and island area. Diversity increases with island area in a log-linear relationship whereby the slope of the line approaches 0.30. Such species-area curves have been constructed for modern islands in a wide range of climatic regimes and for multiple taxa. Thus, if land area can be estimated for an ancient island, the expected species diversity can be predicted. This figure, less the biota preserved in the fossil record, will approximate the number of undiscovered species.

The Hateg Basin in western Romania is thought to represent one in a series of volcanic islands dotting central and Eastern Europe during the late Cretaceous. Ancient Hateg island, home of the dwarf dinosaurs of Franz Nopcsa, has been characterized as tropical to warm temperate and estimated to be ~75,000 km<sup>2</sup>. The upper Maastrichtian Sinpetru Formation consists of non-marine strata deposited in the Hateg Basin and has produced a significant herpetile fauna, including six anurans, an albanerpetontid, a turtle, five lizards, and a crocodile. Utilizing the species-area curve for reptiles and amphibians of climatologically similar islands, it is hypothesized that the herp fossil record of ancient Hateg island is at

least 85% incomplete. When using this method, accounting for faunal turnover will lower completeness estimates, and accuracy will be increased by taking into consideration turnover rates and temporal scale.

89. **Bi, S.:** THE SKELETAL ANATOMY OF A NEW SPECIES OF CRICETODONTINI (RODENTIA, CRICETIDAE) FROM THE NORTHERN JUNGGAR BASIN OF XINJIANG, CHINA

BI, Shundong, Washington, DC

I describe here the almost complete skeleton of a new species of cricetid from the northern Junggar basin, Xinjiang, China. The well preserved cranial and postcranial remains attributed to this taxon were recovered in 1998 from a small hillock in the Halamagai Formation, at the Tieersihabahe locality, which date to the early middle Miocene (European Neogene land mammal age MN6). This sample contains skulls and mandibles with complete dentitions and partially articulated vertebrae, ribs, forelimb and hindlimb elements. They comprise the most complete skeletal remains of early cricetids known to date, and provide critical information upon cranial and postcranial anatomy, intraspecific variation and phylogeny of this group.

The new material is here named *Cricetodon orientalis* sp. nov., and is characterized by medium size; interorbital region relatively narrow and hourglass shaped with dorsally raised beads; zygomatic plate broad, notch well inscribed; bony plate long and wide, extending beyond the end of M3s; the M1 having a distinctly divided anterocone, the posterior paracone spur, four roots; the M2 having a pronounced paracone spur and four roots; the m1 having a double metalophulid.

*Cricetodon orientalis* is the first record of this genus ever recorded from Central Asia and is an immigrant from SW Asia. It probably migrated to Central Asia in the middle Miocene (MN6) and become extinct at the end of MN6.

90. **Cote, S.:** NEW RUMINANT SPECIMENS FROM THE EARLY MIOCENE OF KARAMOJA DISTRICT, UGANDA

COTE, Susanne, Harvard Univ., Cambridge, MA

Whitworth published descriptions of early Miocene ruminants from East Africa in 1958, naming the species *Walangania gracilis* and *Palaeomeryx africanus*. Ginsburg and Heintz later suggested that *P. africanus* should be removed from *Palaeomeryx*, and placed it in a new genus *Kenyameryx*. In 1973, Hamilton reviewed the material and determined that both the *Walangania gracilis* and *Kenyameryx africanus* material represented the same taxon, and combined them under the name *Walangania africanus*. Most researchers today agree that *Walangania* is the proper name for this material, but retain a specific distinction between *W. gracilis* and *W. africanus*. *Walangania* is one of the earliest ruminants in Africa, but its phylogenetic relationships remain controversial. While it traditionally has been viewed as a potential ancestor to the Bovidae, Janis and Scott suggest that it may be more closely related to the Cervidae.

New ruminant material has been collected from the early Miocene sites of Moroto and Napak in the Karamoja District of Uganda. Radiometric dating has shown that the Moroto fossil localities are older than 20.6 Ma, while the Napak localities are thought to be approximately 19 Ma using radiometric dating and faunal correlations with other sites in East Africa. Preliminary analysis suggests the new material belongs to the species *Walangania africanus*, which has previously been recognized from these localities. The new specimens from Uganda include several new postcranials and the most complete upper tooth row known from *Walangania*, which preserves aspects of both the deciduous and adult dentition. This new material will help resolve issues regarding the phylogenetic relationships of *Walangania*.



Ugandan *Walangania* has been compared to roughly contemporaneous ruminant material from the Zinda Pir region of Pakistan, and to the recently named species *Bugtimeryx pilgrimi* from Dera Bugti, Pakistan. Preliminary comparisons suggest many dental similarities between the African and Asian specimens. Further study of the Zinda Pir and Ugandan material may shed light on the paleobiogeography of early Miocene ruminants.

91. **Dewar, E.:** MICROWEAR OF CARNIVOROUS MAMMALS DESCRIBED BY LOW-MAGNIFICATION DENTAL STEREOMICROSCOPY

DEWAR, Eric, Univ. of Massachusetts, Amherst, MA

Low-magnification dental stereomicroscopy has increased the sample sizes and speed in dietary reconstruction of fossil mammals. This microwear technique counts the wear features left by the abrasion of food items. It has been found that mammals chewing similar foods have similar wear fabrics, regardless of their particular chewing stroke or taxonomic affinity. Several workers have built up a robust database of microwear patterns for living and extinct mammals. Though the database currently samples a range of herbivorous and omnivorous diets in artiodactyls, perissodactyls, primates, rodents, and proboscideans, microwear patterns of carnivorous mammals are not yet well represented.

Many indicators of carnivory do not require microwear analysis. For example, several clades of carnivorous mammals developed large carnassial teeth, but others within those clades have more omnivorous dietary modes. There are also extinct creodonts and archaic ungulates whose diets probably included varying amounts of vertebrate flesh but lacked carnassials. Microwear observations focused on the molars allows the diets of more generalist Tertiary mammals to be studied.

For this research, I counted wear features of a sample of teeth from extant carnivorans as well as from a number of Tertiary carnivorans, creodonts, and archaic ungulates. For my modern sample, I made observations on teeth from species of *Lycaon*, *Canis*, *Ursus*, *Procyon*, *Otocyon*, *Urocyon*, and *Ailuropoda*. These species represent a substantial range of carnivory and body size. I counted pits and scratches of various sizes on the paracone of the upper first molar (M1) of these animals. Previous research on ungulates and primates used M2, but I chose to standardize my observations on M1 in order to account for the loss of postcarnassial teeth in carnivorans that specialize on vertebrate flesh. There is substantial overlap in wear fabric between hypocarnivores and the extant ungulate sample, grading to increasing attrition in more carnivorous forms.

92. **Edmunds, B.:** ANTEATER, ARMADILLO AND SLOTH EVOLUTION: MORPHOLOGICAL AND BIOMECHANICAL ANALYSES, AND THE RELATIONSHIP OF *ERNANODON ANTELIOS* TO XENARTHRA

EDMUNDS, Barbara, Portland State Univ., Portland, OR

The order Xenarthra (sloths, anteaters and armadillos) is the only eutherian cohort represented by a single order. They 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 unusual or primitive characteristics (i.e. a septomaxilla, found only in Reptilia and Monotremata, tympanic ring, and dermal ossification) when compared to other mammals. In addition, the order is thought to have originated and diverged in the Neotropics temporally between Cretaceous and Paleocene. However, a fossil, *Ernanodon antelios* laid down during the Paleocene in Guangdong, China has been attributed to Xenarthra.

The biomechanics of this taxon are unique due to xenarthrous articulations of the vertebrae (doubly articulated vertebrae, vs. remaining mammals' single articulation), solid pelvis with the transverse process of the caudal vertebrae fused with the ischium. These characters impose a constraint on the

entire taxon's mobility. When the animal arches, the backbone is braced and rigid, but is not restricted when the animal curls.

One hundred and sixty-eight morphological characters and forty-four biomechanical measurements of extant and extinct specimens housed in museum collections were analyzed and compared for compatibility. The fossil, *Ernanodon antelios*, is compared to these data to support the inclusion or exclusion from Xenarthra.

93. **Friedman, V.:** SINCLAIR OIL AND BARNUM BROWN — A REMEMBRANCE

FRIEDMAN, Virginia, Univ. of Texas at Dallas, Suisun City, CA

Barnum Brown is considered the greatest dinosaur hunter of the early twentieth century and one of paleontology's most legendary figures. His successful career spanned 66 years beginning in 1897 at the American Museum of Natural History in New York City. In 1902, while prospecting in Montana's Hell Creek Formation, he came across the bones of a huge theropod dinosaur. The find was so big that it took two summers to excavate using dynamite to uncover large stretches of bone. The dinosaur bones were shipped by railroad back to the American Museum of Natural History. It took years of hard work to liberate the bones from their encasing rock matrix. In 1905, H.F. Osborn described the new dinosaur, naming it *Tyrannosaurus rex* — "the tyrant king of the lizards." The giant predatory dinosaur was an immediate hit with the public back then and remains just as popular today.

Barnum Brown enjoyed a great amount of fame during his lifetime. In the 1930s and 1940s he agreed to write a series of dinosaur booklets for the Sinclair Oil Company to further connect the company's dinosaur logo with the public. Sinclair looked for this association in order to give academic stature to its promotions. In return, Sinclair financed Brown's dinosaur fossil search expeditions for several years.

Since the 1930s, a friendly green *Apatosaurus* (*Brontosaurus*) has roamed North America's highways helping spread the word about Sinclair Oil. Dino, the Sinclair Dinosaur, was created to help people understand that Sinclair oils were made from Pennsylvanian crudes laid down millions of years ago. Unlike his real-life ancestors, Dino has never been threatened with extinction, and continues to be Sinclair's trademark. With the current popularity of dinosaurs, the Sinclair trademark is unlikely to fade away. "Dino" still remains one of the most recognizable logos in the world.

94. **Goodchild Drake, B.:** A NEW SPECIMEN OF *ALLOSAURUS* FROM NORTH-CENTRAL WYOMING

GOODCHILD DRAKE, Brandon, Cheyenne, WY

Specimen WDC-TYA is currently being excavated from the Morrison formation in north-central Wyoming and is referable to *Allosaurus* sp. Fragmentary remains suggest a smaller individual is also present in the quarry. The site is composed of a calcareous mudstone; remnants of small shells indicate a lacustrine environment. Excavated and prepared elements of the allosaur specimen include a left premaxilla, both scapulae, right fibula, dorsal vertebrae, one caudal, 2:1 left pes, and 1:1 and 1:2 right manus. Multiple elements remain in the field, including a right dentary, left maxilla, and unidentified pes elements. Despite its large size (estimated total length 8 meters) the specimen appears to be a subadult, based on unfused dorsal zygapophysis. Shed allosaur teeth found in close proximity to theropod rib fragments are consistent with cannibalistic feeding behavior. Tooth marks also appear to be present on the right scapula (WDC-TYA 58), and may be responsible for mechanical removal of the acromial process. The scapula has other peculiarities, including a pathological surface of the glenoid fossa.

95. **Hamm, S.:** PTYCHODONTID SHARKS FROM THE UPPER CRETACEOUS AUSTIN GROUP OF NORTH TEXAS

HAMM, Shawn, Wichita, KS

The Austin Group in north Texas is dominated by thick chalk sequences and documents an environmental change from the quiet shallow water formations of the underlying Eagle Ford Group. The chalks of the Austin Group were formed as a result of a major marine transgression of the Western Interior Seaway during the Coniacian and Santonian stages of the Late Cretaceous. The invertebrate fauna of the Eagle Ford Group is well represented by abundant ammonite, decapod and inoceramid remains. These taxa may have been the preferred prey of selachians with durophagous dentitions including the shark genus *Ptychodus*. In contrast, exposures of the Austin Group are relatively devoid of fossils, including invertebrates, except for the phosphatic pebble zone of the basal Atco Formation (Early Coniacian). This phosphatic zone is rich in *Inoceramus* bivalves, gastropods and vertebrate remains, although with far less diversity than the underlying Eagle Ford Group. The presence of large numbers of ptychodontid shark teeth indicates that this group continued to thrive. Three species of ptychodontids from the Eagle Ford Group, (*P. whipplei*, *P. mortoni*, and *P. mammillaris*) are also present in the basal Atco Formation of the Austin Group. In addition, two new species of *Ptychodus* (*P. latissimus* and *P. sp.*) make their first and only appearance. The occurrence of *Ptychodus* is extremely rare above the basal Atco Formation, with only one specimen (*P. rugosus*) being reported from the Austin Chalk (Santonian) throughout the remainder of the Austin Group. The basal Atco Formation represents the end of an era for the ptychodontid sharks in north Texas.

96. **Hart, M.:** BIOSTRATIGRAPHIC DISTRIBUTION AND CRANIAL SIZE COMPARISONS OF *TOXOCHELYS* (TESTUDINES; CHELONIIDAE) OF THE CAMPANIAN PIERRE SHALE OF SOUTH DAKOTA

HART, Margaret, South Dakota School of Mines and Technology, Rapid City, SD

The Campanian Pierre Shale contains a diverse assemblage of marine reptiles, including the sea turtle, *Toxochelys*. The Museum of Geology at the South Dakota School of Mines and Technology houses seventy-two chelonians, twenty-three of which have been identified as belonging to the genus *Toxochelys*. Of the chelonians, eight have been recovered from the Gammon Ferruginous Member, the basal member of the Pierre Shale. Twenty-nine have been collected from the overlying unit, the Sharon Springs Member. In western South Dakota, supradjacent to the Sharon Springs Member is the Mitten Black Shale Member. This unit has produced six chelonians. In central South Dakota, the Gregory rests upon the Sharon Springs Member and has produced one turtle. The Crow Creek Member overlies the Gregory; no specimens have been recovered from this member as of yet. The DeGrey Member lies above the Crow Creek Member and has yielded sixteen individuals. The youngest Campanian unit, the Verendrye, has produced four of the chelonians collected by the Museum of Geology. The remaining eight have little biostratigraphic data accompanying them. However, based on their known localities, it can be inferred that they were collected from either the Sharon Springs or the Mitten Black Shale members. Field notes from various field crews were used to correlate the biostratigraphic distribution of these specimens and their localities.

Of the twenty-three toxochelids identified, fourteen include cranial material. Forty-six characters of the skull and lower jaw were measured for each of the toxochelids. These measurements were first analyzed, with concentration on morphological proportions of the skull and differential growth trends. Next, the morphological data was utilized for biostratigraphic distribution. Final comparisons were made with toxochelids recovered from older formations. Results from these comparisons may assist in solving taxonomic questions regarding Campanian toxochelids.

97. **Jones, M.:** SKULL EVOLUTION IN RHYNCHOCEPHALIA

JONES, Marc E.H., Univ. College London, London, United Kingdom

The living Tuatara, *Sphenodon*, is the last representative of the Rhynchocephalia, a widespread and successful Mesozoic group characterised by the development of acrodonty, an enlarged lateral palatal tooth row, and posterior extension of the dentary. Although traditionally regarded as morphologically conservative, the group radiated towards an aquatic lifestyle at least twice, and new fossils have demonstrated unexpected diversity in structure, body proportions, and feeding adaptations.

Basal taxa like *Gephyrosaurus* had numerous, relatively simple, pleurodont teeth, a divergent lateral palatine tooth row, and an incomplete lower temporal bar. More derived genera show a trend towards increased acrodonty, a more parallel alignment of the lateral palatal row, a reduction in tooth number, and, in some lineages, the reacquisition of the lower temporal bar. These changes reflect a shift towards a more sophisticated shearing mechanism, propalinal in some (e.g. *Sphenodon*), orthal in others (e.g. clevosaur). Orthal shear requires greater precision at the tooth-tooth interface, with speed reduced in favour of power. Clevosaur achieved this with smaller numbers of blade-like flanged teeth. By contrast, *Eilenodon* and *Priosphenodon* had a propalinal jaw action, with a low coronoid process, a deep jaw and a battery of transversely expanded teeth more suitable for processing plant material. *Sphenodon* also employs propaliny, but is mainly insectivorous (males seasonally carnivorous), with a tall coronoid process and large premaxillary teeth.

Cranial proportions and architecture have changed in tandem with the dentition. We explored the interrelationships of these changes using Morphologika, a geometric morphometric programme that employs Procrustes analysis to align and compare landmark constellations, followed by principle component analysis to identify major trends. Relative warp analyses permit illustration of morphological changes associated with major radiations. These include alterations in rostral and temporal lengths, orbit size, parietal width, and the structure of the lower temporal bar and squamosal.

98. **Juarez Valieri, R.:** THE COMPOSITION OF THE NON-AVIAN THEROPOD FAUNAS IN THE CRETACEOUS OF WEDDELLANIA

JUAREZ VALIERI, Ruben, Centro Paleontologico Lago Barreales, Cordoba, Argentina

Weddellania, the Cretaceous biogeographic province composed of South America, Antarctica and Australia has the best non-avian theropod fossil record from the Cretaceous of the Southern Hemisphere. In difference to other areas, such as the African or the Indo-Malagasy provinces, the theropod faunas from Weddellania represent almost the entire Cretaceous period, from the Hauterivian to the Maastrichtian. All the theropod clades that inhabited Gondwana are found in Weddellania (i.e. Abelisauroids, Carcharodontosauridae) and some of them are only registered in this province (i.e. Oviraptorosauroids, Alvarezsaurids). The Abelisauroidea are represented here from the Hauterivian, with two families, Noasauridae and Abelisauridae, and they survive to the Maastrichtian; they were found in South America. The Spinosauroidea are represented from the Albian to the Santonian from Brazil and Antarctica. The Carcharodontosauridae are found in the Cenomanian to the Turonian from Brazil and Argentina, but its biochron could extend to the Maastrichtian. Other carnosaurians of dubious phylogenetic position are represented in the Early Cretaceous of Australia. The coelurosaurian theropods are known throughout this period; basal forms like *Santanaraptor* from the Albian of Brazil and unnamed forms of the Turonian of Argentina. Ornithomimosaurids are located in the Albian of Australia. The Alvarezsaurids are located in the Turonian to Santonian of Patagonia and possibly in the Albian of Australia. The maniraptorans are represented by Oviraptorosauroidea from the Aptian to the Campanian of Australia, Brazil and Argentina. Troodontids are reported in the Turonian to the Maastrichtian of

Argentina and Brazil. Dromaeosaurids are registered in the middle Cretaceous to the Maastrichtian of Australia, Argentina and Brazil. Other maniraptorans are found in the Coniacian and Maastrichtian of Argentina. Theropods of indeterminate systematic position are found in several places along Weddellia. The differences in the fossil record between the Australian and South American clades are principally based in the diachronism of the geologic units containing the remains, although some kind of provincialism could exist and be based on latitudinal or geographic barriers.

99. **Ksepka, D.:** A SAUROPOD FROM BUR GOVE, MONGOLIA

KSEPKA, Daniel, American Museum of Natural History Division of Vertebrate Paleontology, New York, NY

A partial skeleton of a sauropod was discovered at Bur Gove, a locality in Dornogov Aimag, Mongolia in 2003. Bur Gove is a small locality of interbedded silts and sand channels that has produced a fauna of turtles and sauropod and theropod dinosaurs. Stratigraphically, it lies below the ?Lower Cretaceous Tsaagan Tsav beds and above the Lower Cretaceous Khara Khuutul beds. Six extremely well-preserved and articulated cervical vertebrae and an articulated partial hindlimb were collected, in addition to a sternal plate. The Bur Gove specimen represents a sauropod of modest size (tibial maximum length approximately 73.5cm).

The crescentic atlantal intercentrum is preserved in articulation with the axis via the wing-like neuropophyses. In the axis and succeeding vertebrae, the lateral surface of the centrum is marked by a well-developed pneumatic fossa that is subdivided by bony septae. The distribution of excavations within the pneumatic fossa and elsewhere on the centrum and neural spine is variable, even within a single element. A large excavation is present on the dorsal side of the diapophysis of the fourth and fifth cervicals. In the fourth and succeeding vertebrae, the neural spine is bifurcated. The elongate cervical ribs extend posteriorly to overlap the succeeding centra. The sternal plate preserves a thin, sharp, concave lateral border. The tibia has a subcircular proximal condyle and a mediolaterally expanded distal end. The lateral trochanter of the fibula is anterodistally oriented and has a slight posterodistal slant. The distal condyle is unexpanded. In anterior view, the astragalus exhibits the wedge-like shape typical of neosauropods, though tight articulation to the tibia prevents more detailed observation of its morphology. A small, globular, ossified calcaneum is present.

Characters including the shape of the sternal plate and expansion of the distal end of the tibia suggest this specimen represents a member of the Titanosauria. The exact phylogenetic position of the Bur Gove sauropod is uncertain. Preparation of additional material and more detailed comparison will shed light on this problem.

100. **Lancaster, T.:** THE SEARCH FOR BODY MASS MODELS FOR EOCENE CETACEANS

LANCASTER, Terry, Kent State Univ., Rootstown, OH

The body mass of an animal is important in the physiological study of fossil mammals; however, estimating the body mass of transitional fossil species, such as the Eocene archaeocetes, is difficult. Selecting an extant mammalian model for the Eocene archaeocetes is problematic for several reasons. Not only are Eocene archaeocetes morphologically different from modern cetaceans, but also the size range of the Eocene whales is large in magnitude and there is great variation in body shape. Finally, many archaeocete skeletons are incomplete. In the absence of a complete skeleton, simple regression equations can still be used to estimate body mass from the available material. I estimated body mass for representatives of each of the following families of archaeocetes: Pakicetidae, Ambulocetidae, Remingtonocetidae, Protocetidae, Dorudontidae, and Basilosauridae. I used simple and multivariable statistical body mass models of terrestrial, semi-aquatic, and aquatic mammals.

I measured the skeletons of extant carnivores, artiodactyls, and cetaceans. The variables included cranial, axial, and appendicular skeletal measurements, and body weight. I used Principal Component Analysis (PCA) to (1) eliminate repetitive variables and variables unrelated to body mass and (2) categorize the groups of extant mammals. By placing the same measurements for each archaeocete skeleton into the calculated PCA, I matched each Eocene whale specimen to an extant mammal model. From the remaining variables, I formulated a series of multivariable and simple linear regression equations for each Eocene whale derived from its extant model and predicted its body mass.

101. **Lee, A.:** ONTOGENETIC HISTOLOGY OF *CENTROSAURUS*: TESTING THE RELATIONSHIP BETWEEN LIMB BONE FORM AND FUNCTION

LEE, Andrew, Univ. of California, Berkeley, Berkeley, CA

Within Dinosauria, quadrupedal locomotion independently evolved at least four times. Basal sauropodomorphs, thyreophorans, ornithopods, and ceratopsians have relatively gracile forelimb bones whereas derived taxa from those clades have robust and often elephantine forelimb bones. Less clear is whether weight-bearing adaptations also occur at the microstructural level of bone, particularly because mechanics is only one of the factors responsible for bone microstructural variation. That microstructural variation is also a product of ontogeny and phylogeny.

The current study reports the ontogenetic variation in bone microstructure among the limb bones of the quadrupedal *Centrosaurus* (Dinosauria: Neoceratopsia). Primary fibrolamellar bony tissue occurs in the limb bones. During early ontogeny, radially oriented vascular canals are deposited, particularly in the humerus. Later in ontogeny, vascular canals are oriented circumferentially. Although cortical thickness generally decreases during ontogeny, a medullary cavity is not produced; cancellous bone occurs internal to the cortical shell. Secondary remodeling becomes prominent only in late ontogeny. The limb bone microstructure of *Centrosaurus* suggests that growth was sustained and rapid in both limbs for most of ontogeny. Furthermore, preliminary comparisons between the limb bone microstructure of *Centrosaurus* and bipedal theropods suggest that phylogenetic differences in limb growth strategy might account for much of the variation in microstructure.

102. **Liu, J.:** PHYLOGENY OF ORNITHISCHIA

LIU, Jun, Columbia Univ., Palisades, NY

Forty-four species and 326 characters are used to study the phylogenetic relationships among different groups of Ornithischia. The long recognized Stegosauria, Ankylosauria, Iguanodontia, Marginocephalia, Ceratopsia are corroborated by this study. In contrast, the often recognized Fabrosauridae and Hypsilophodontidae are not monophyletic groups in my analysis. Perhaps surprisingly, *Lesothosaurus* is the sister taxon of Thyreophora, *Agilisaurus* is the basal member of Neornithischia, and the monophyletic Marginocephalia clusters with Iguanodontia.

This data set also suggests that the degree of missing data should not be used as an inclusion or exclusion criterion for taxa. The method of using most primitive species of higher monophyletic group, accompanying by another more complete taxon when the percent of missing characters are high in primitive species, is suggested to analyze the phylogenetic relationships of higher groups.

Based on the results of my phylogenetic analysis, the most basal ornithischians is predicted to have maxillary shelf, cheek teeth with distinct crown and root, subtriangular tooth crown and marginal denticles. All these characters appeared on the earliest ornithischians, it indicates ornithischians adapted to herbivorous diet from the earliest known records.

103. **Martin, J.:** 3D RECONSTRUCTION AND COMPARATIVE ANATOMY OF THE SHOULDER GIRDLE OF *GRIPPIA LONGIROSTRIS* (ICHTHYOPTERYGIA)

MARTIN, Jeremy, Macon, FRANCE M

Most specimens of the Early Triassic (Spathian) ichthyosaur *Grippia longirostris* are found as natural molds in weathered nodular concretions. Impression of only one side of the bone is usually preserved, showing detailed structures. Due to preservation, the shoulder girdle of *Grippia* is poorly known and interpretation of the elements has been controversial.

To give a precise description of the shoulder elements, casts of the molds were digitized with a 3D laser scanner. Counterparts of the same bone element of two different specimens were stitched together in a computer, following a set of objective criteria. This method is less subjective than manual reconstruction. Reconstructed elements were then articulated.

Shoulder elements can be identified as follows: asymmetric shape and mediolaterally compressed glenoid shaft for the scapula, and symmetric shape for the coracoid. Among terrestrial reptiles it is commonly observed that scapula and coracoid are perpendicular to each other. However, in *Grippia*, they form a nearly even plane, resulting in a broad pectoral region. This feature is more accentuated in *Grippia* than in derived ichthyopterygians. Judging from 3D reconstruction of the bony shoulder joint in *Grippia*, the range of motion of the humerus has two degrees of freedom: 45 degrees dorso-ventrally and 120 degrees antero-posteriorly. Furthermore, the anterior expansion of the humerus sets a limit for upward rotation about the mediolateral axis. For comparison, the same method is applied to *Ichthyosaurus communis*. This derived ichthyosaur is well adapted for cruising, as suggested from its steep tailbend. The 3D reconstruction of the pectoral girdle allows for determining preferred movement of the humerus, which is distinguished by a well-rounded head. This feature indicates a high range of rotation although soft tissues may limit the range of motion. The model provides insights on forefin use in these two genera: *Grippia* shows more antero-posterior movement indicative of possible rowing, and *Ichthyosaurus* shows dorso-ventral and rotational movement suggesting rudders.

104. **Murray, L.:** TAXONOMIC SUCCESSION IN BLANCAN - IRVINGTONIAN CANIS FROM THE ANZA-BORREGO DESERT STATE PARK, SAN DIEGO COUNTY, CALIFORNIA

MURRAY, Lyndon, Univ. of Texas Austin, Austin, TX

Approximately 300 carnivoran specimens are listed among over 13,000 catalogued specimens in the Anza-Borrego Desert State Park (ABDSP) fossil vertebrate catalogue. About 60 of these are assigned to the genus *Canis*. There are three visibly distinct sizes of *Canis*. Both cranial and postcranial elements compared to modern canid material fall out either near *C. lupus* (large) near *C. latrans* (small) or at an intermediate size between the two modern species.

The Vallecito Creek and Fish Creek Basin (VFCB) fossil beds in the southern part of Anza-Borrego are correlated to the Global Polarity Time Scale (GPTS), and range in age from about 4.3 to 0.9 million years ago (MYA). Of the ABDSP localities that produced *Canis* material, 18 (these have only small and intermediate sized *Canis*) are within the VFCB and can be dated by the known age ranges of the paleomagnetic normal and reversed chrons and subchrons in which they lie. The *C. lupus*-sized specimens (1 dentary and 2 postcranial elements) are from areas of the park that are still stratigraphically ambiguous, although the localities appear to be in Irvingtonian age sediments.

Sorting the datable *Canis* specimens by stratigraphy and paleomagnetic age shows that all coyote-sized specimens are older than all intermediate-sized specimens and that the transition between the two size groups occurred during the first half of the Matuyama reversed chron, 2.58 to 1.95 MYA.

Evaluation of the sedimentation rate during deposition of the VFCB (a steady reduction from a high of 5.5 m/1,000 years at 4.3 MYA to a low of 0.5 m/1,000 years at 0.9 MYA) and the stratigraphic

separation (about 43 meters) between the highest (most recent) small *Canis* and the lowest (earliest) intermediate *Canis* shows a minimum possible age difference of 17,200 years and a maximum possible age difference of 86,000 years. This is the amount of time it took for the small *Canis* to be completely replaced by the intermediate *Canis*.

105. **Noto, C.:** IMPACT OF CLIMATE ON DINOSAUR DIVERSITY AND DISTRIBUTION OVER TIME

NOTO, Christopher, SUNY Stony Brook, Stony Brook, NY

A great deal of work over the past several years has offered many insights into dinosaur biogeography, leading to a better understanding of dinosaur evolution. However, the biogeographic paradigm has resulted in a heavy reliance upon historical or geophysical explanations for dinosaur distribution, while ignoring possible climatic or ecological causes. Such interactions may be just as important, if not more so, in determining the nature of dinosaur communities, and these interactions must be considered in concert with biogeographic processes. By including lithological and paleobotanical data, a more complete picture of the paleoenvironment inhabited by the dinosaur faunas can be drawn and the formation of dinosaur assemblages better understood.

Previous work on global dinosaur paleodistribution shows that it is markedly different from the equatorially-centered pattern observed today. Dinosaur diversity during the Jurassic peaks in the mid-latitudes, creating a roughly symmetrical bimodal distribution, which is maintained throughout this time. Global plant diversity also demonstrates this pattern, though the peak occurs at a slightly higher latitude than that of dinosaurs. Evidence suggests that this phenomenon is not simply the result of taphonomic or collection bias.

This study examines the possible impact of climate on patterns of dinosaur distribution over time, focusing on three regions: western North America, Europe, and southern Africa. All were connected during the Triassic, allowing for cosmopolitanism of dinosaur faunas, but by the end of the Jurassic the opening of the Atlantic fully separated Laurasia and Gondwana. Through this time span, each study area separated geographically and moved through different climatic regimes, allowing one to trace changes occurring in the dinosaur faunas. European and North American faunas shared more related taxa by the end of the Jurassic, yet African and North American faunas appear more ecologically similar. Similar climate caused African and North American communities to converge ecologically, and European and North American faunas, while related, evolved under diverging climatic regimes.

106. **Peyer, K.:** THE PHYLOGENETIC RELATIONSHIP OF THE FRENCH *COMPSOGNATHUS* WITHIN THE COMPSOGNATHIDAE AND COELUROSAURS

PEYER, Karin, Museum National D'Histoire Naturelle, Paris, Cedex 05, France

Compsognathids are represented in Upper Jurassic and Lower Cretaceous sediments of Europe, China, and South America. The genus *Compsognathus* presently includes *C. longipes* and *C. corallestris*. Previous phylogenetic analysis of coelurosaurs only included the well known German specimen. A reevaluation of the French *Compsognathus* from the Tithonian of Southern France provides us with new cranial and postcranial information crucial for a better understanding of the genus *Compsognathus* and the phylogenetic assessment of basal Maniraptoriformes and Compsognathidae.

The data matrix is based on our own observation and previously published data of 30 terminal taxa and 350 characters. Rooting was done by outgroup comparisons with *Herrerasaurus* and *Coelophysis*. The species-level phylogenetic analysis shows that the Compsognathidae (consisting of five genera and six species) is a monophyletic group. The phylogenetic analysis resulting in two most parsimonious trees shows the Compsognathidae near the base of the Maniraptoriformes. *Scipionyx* falls out at the base



of the Compsognathidae followed by *Sinosauropteryx*, *Huaxiagnathus*, and SMNK 2349 PAL, the later being the sister taxa to the clade including the German and French *Compsognathus*.

107. **Salton, J.:** INTERPRETING THE PLACENTALIAN CARPUS: EVOLUTIONARY MORPHOLOGY OF THE TENRECOIDEA (MAMMALIA) CARPAL COMPLEX

SALTON, Justine, City University of New York, Roslindale, MA

The carpal region of the mammalian postcranium can be difficult to interpret both functionally and phylogenetically. It is evolutionarily constrained in terms of functional morphology, yet there is considerable variation within and between many eutherian and metatherian taxa. Tenrecoids are useful models for morphological interpretation of the interplay between function and phylogenetic constraint. I present here an examination of skeletal elements from the wrist and hand of 13 tenrecoid, 2 macroscelidid, 1 solenodontid and 1 erinaceid species in order to test hypotheses regarding the functional interpretation of specific carpal, metacarpal and phalangeal characters. Qualitative comparisons, as well as bivariate and multivariate analyses of indices, illustrate that within Tenrecoidea, several aspects of the carpus are correlated with positional behavior. Convergences within Tenrecoidea, and between tenrecoids and non-tenrecoids with similar locomotor regimes, confirm a small number of carpal characters and a larger number of distal forearm, metacarpal and phalangeal characters that reliably correspond with functional expectations. In addition, several features of the carpus appear to be phylogenetically constrained and indicate specific affinities within Tenrecoidea. Finally, there are a significant number of carpal features that vary within and between the studied taxa and remain ambiguous in terms of phylogenetic and/or functional significance.

108. **Samman, T.:** ASSESSING CERVICAL RANGE OF MOTION IN THEROPODS

SAMMAN, Tanya, Univ. of Calgary, Calgary, AB, Canada

The assessment of the range of motion of the neck has potential implications for inferring aspects of the behaviour and ecology of theropods. Neck biomechanics are difficult to study because of the fragility of small bones (eg. from ornithomimids), and the unwieldy nature of larger vertebrae (eg. from tyrannosaurids). DinoMorph™ is being used, in collaboration with Dr. K. Stevens from the Department of Computer and Information Science, University of Oregon, to digitally model theropod vertebrae as complex three-dimensional surfaces. The models can be digitally manipulated, guided by the results of comparative studies of soft-tissue constraints, to assess cervical range of motion.

109. **Sandau, S.:** IMPORTANT NEW INFORMATION ON MID-EOCENE VERTEBRATES OF THE UINTA BASIN, UTAH

SANDAU, Stephen, Brigham Young Univ., Provo, UT

Late mid-Eocene time marks one of the most dynamic phases of the Paleogene in the western interior of North America. A new collection of vertebrates from the Pariette and Wells Draw area south, southwest of Myton, Utah has yielded a variety of taxa. Partially articulated *Lepisosteus* (garpike) specimens were recovered along with abundant skull elements and ganoid scales. These are found in channel sandstone within the study area along with hashes of scales, bones and crocodylian teeth in washed lag deposits. The anguid lizard *Glyptosaurus* is represented by several vertebrae. An exceptionally well-preserved skull and mandible of "*Crocodylus*" *affinis* is of particular importance, showing the shared dominance of this large basal crocodyloid with other more modern crocodylians within the Uinta Basin well into the late mid-Eocene. This is further substantiated by a number of isolated "*Crocodylus*" *affinis* teeth and postcranial elements found throughout the study area in many locations. An impressive variety of fossil turtles were collected including *Echmatemys callopyge*, *E.*

*uintensis*, *Hadrianus* sp., *Xerobates uintensis*, *Baena arenosa*, *Chisternon undatum*, *Apalone* (*Platypeltis*), and *Pseudanosteira pulchra*. They show surprisingly abundant pathological markers, most likely induced by bacterial or fungal infections and/or invertebrates, indicating possible environmental influences and prolonged postmortem exposure.

Uintan mammals are represented by *Mytonomys robustus?* (Rodentia), *Protoreodon petersoni*, and *P. pumilus* (oreodontid), *Poebrodon kayi?* (camelid), *Leptotragulus* sp. (protoceratid), *Epihippus* sp. (equid), and *Diplacodon?* (brontotheriid), as well as other unidentified Brontotheres represented by numerous postcranial elements. Harvesting (rodent gnawing), of turtle shell fragments (costals) and mammalian limb elements, again shows evidence of extended subaerial exposure and ecological interaction between fauna. Magnetostratigraphic work done within the Uinta Basin east and west of the study area tie in with Chrons C20n (43.5-42.5)-C19r (42.0-42.5) indicating late mid-Eocene time.

110. **Vavrek, M.:** PALAEOENVIRONMENTAL IMPLICATIONS OF FOSSIL SALAMANDER TAXA FROM THE UPPER CRETACEOUS (MAASTRICHTIAN) FRENCHMAN FORMATION OF SOUTHWESTERN SASKATCHEWAN

VAVREK, Matthew, Univ. of Alberta, Edmonton, AB, Canada

Two microsites from a small valley near the town of Eastend in southwestern Saskatchewan, Canada, have yielded numerous fish, amphibian, lizard and dinosaur remains. From these microsites, located within the Maastrichtian aged Frenchman Formation, three different salamander taxa have been recovered: *Habrosaurus dilatus* Gilmore 1928; *Scapherpeton tectum* Cope 1876; and *Opisthotriton kayi* Auffenberg 1961. While *Scapherpeton* and *Opisthotriton* are both relatively common fossil species, being widespread across much of western North America, they have no close living relatives. *Habrosaurus*, on the other hand, a sirenid, has several closely related forms still found in the southeastern United States. It is also a much more geographically restricted species, making it the best candidate for an environmental indicator. Based on current studies of modern sirenid taxa, the area in southwestern Saskatchewan was probably much warmer than today, with little to no frost during even the coldest months. Also, precipitation was seasonal, with periods of heavy rainfall contrasted with periods of drought conditions, during which time *Habrosaurus* probably went into aestivation. Support for this hypothesis also comes from palaeobotanical surveys of the area, which indicate a similar climate. This radically different temperature and precipitation regime came during a time when the area was located near 60 degrees north latitude, meaning that the area would have experienced winters with very little light. This site adds both more questions and answers as to what sort of climate the areas near and above the Arctic Circle were experiencing during the Late Cretaceous.

**FRIDAY MORNING, NOVEMBER 5, 2004**

**TECHNICAL SESSION X  
PLAZA BALLROOM A/B**

**MODERATORS: CASEY HOLLIDAY AND SCOTT SAMPSON**

**8:00 Faul, S.: QUANTIFICATION OF MORPHOLOGICAL VARIATION IN A HADROSAURID FOSSIL SAMPLE FROM THE TWO MEDICINE FORMATION, MONTANA**

FAUL, Sean, Montana State Univ., Bozeman, MT

The presence of morphological variation among dinosaur taxa offers an opportunity for study via metric quantification. The purpose of this study is to provide a quantitative method for recognition of fossil morphospecies. Methods such as Resistant-Fit Theta-Rho-Analysis (RFTRA), bivariate and multivariate analysis, and statistical testing have been applied, allowing numerical data to be examined and tested mathematically. This study employs these applications in an attempt to explore variation in a set of cranial elements purportedly belonging to the lambeosaurine dinosaur *Hypacrosaurus stebingeri*. The model tests the null hypothesis that all designated specimens belong to a single morphospecies against the alternative that at least one specimen does not.

The analysis was carried out at the Museum of the Rockies and Montana State Univ. in Bozeman, Montana, using hadrosaurid specimens collected between 1988 and 1999 from the Two Medicine and Judith River Formations of Western and Central Montana, respectively. A set of positively identified *Brachylophosaurus canadensis* specimens, including one articulated skull, was used as a control for intraspecific variation in hadrosaurids. The test set was then evaluated. Outliers were recognized in each of the three phases of the analysis.

The use of three separate methods make statements concerning variation in this sample more robust than the application of only one. The detection of significant outliers in the sample provides evidence that morphological quantification may be a useful technique for examining inter- and intraspecific variation.

**8:15 Holliday, C. and Witmer, L.: ANATOMICAL DOMAINS WITHIN THE HEADS OF ARCHOSAURS AND THEIR RELEVANCE FOR FUNCTIONAL INTERPRETATION**

HOLLIDAY, Casey, WITMER, Lawrence, Ohio Univ. Dept of Biological Sciences, Athens, OH

Heads are busy places, involving the intersection of numerous vital systems comprised of, for example, muscular, respiratory, nervous, and sensory components, all of which share a limited amount of cephalic space. Individually, each of these components represents a 'functional domain' with specific roles and spatial limits. For example, the adductor chamber and tympanic cavity are the domains related to, respectively, the masticatory and auditory apparatuses. Other domains relating to the orbital, oropharyngeal, nasal, and antorbital cavities, etc., can be identified. Attributes of these domains provide functional, behavioral, and phylogenetic insight into an animal's biology. Although the ultimate goal may be the detailed reconstruction of the soft tissues within a domain, the first step is recognizing the domain and identifying its boundaries. A next step is determining how these domains interact and share space within the head. For example, paleontologists tend to think of the 'braincase' as a unit, perhaps with its major role being housing the brain. However, braincases themselves encompass the boundaries of several functional domains, such as, again, the eye, jaw muscles, and middle ear, but also the neck and pharynx. In fact, it may be these boundaries that provide as much if not more insight into morphological evolution than the regions themselves, highlighting spatial competition and constraints

among organ groups. We identify a number of bony interdomain boundaries (e.g., otosphenoidal, ototemporal, orbitotemporal crests) that cross various braincase bones. In most cases, the soft tissues that correspond to these boundaries can be identified (e.g., tensor periorbitae, middle ear sac), allowing the assessment of which components are contained within a domain (e.g., MAME superficialis) and which span multiple domains (e.g., nerves, vessels). Given that the broad functions of each domain are well understood, differences among taxa in the relative size and conformation of the domains can provide critical functional insight. For example, maniraptorans expanded the cerebral and ocular domains at the expense of the adductor domain.

8:30 **Apestegui, S.:** GONDWANAN DUCK-BILLED SAUROPODS

APESTEGUIA, Sebastian, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina

A new rather complete titanosaur from Upper Cretaceous beds of Patagonia combines squared lower jaws with anteriorly restricted narrow-crowned teeth arranged in comb like teeth batteries, definitively demonstrating that titanosaurs acquired a mandibular configuration similar to diplodocoids, as suggested by the controversial *Antarctosaurus*. Rebbachisaurid diplodocoids, the only other reported Late Cretaceous sauropods, could also have had a long square-snouted, spoon-shaped, hadrosaur-like head as that present in the remaining nemegtosaurids. The similarities in mouth configuration and corporal mobility (i.e. loss of hyposphene-hypantrum complex) among rebbachisaurids and derived titanosaurs suggest morphological constraints related to environmental stasis or resource particularities. The new sauropod, probably related to nemegtosaurids, also shows clear evidence of a sharp keratinous sheath over the non-dentigerous region that probably had a maxillary counterpart and worked to guillotine plant material. This teeth and beak oral configuration renders these sauropods partially comparable to the highly diverse Laurasian ornithischian dinosaurs, poorly represented in Gondwanan landmasses, and whose success was related to the rise and diversification of flowering plants. Gondwanan Cretaceous sauropods probably explored also the adaptive zones common to Laurasian ornithischians. Their unusual features may help to explain the persistence of sauropods into the latest Cretaceous of southern continents. The presence of a beak-like structure in sauropod dinosaurs also reduces the morphological gap between birds and non-theropod dinosaurs.

8:45 **Coulson, A., Barrick, R., Straight, W., Decherd, S. and Bird, J.:** DESCRIPTION OF THE NEW BRACHIOSAURID (DINOSAURIA: SAUROPODA) FROM THE RUBY RANCH MEMBER (CRETACEOUS: ALBIAN) OF THE CEDAR MOUNTAIN FORMATION, UTAH

COULSON, Alan, Columbia, SC; BARRICK, Reese, College of Eastern Utah Prehistoric Museum, Price, UT; STRAIGHT, William, Duke Univ., Durham, NC; DECHERD, Sara, North Carolina State Univ., Raleigh, NC; BIRD, John, College of Eastern Utah Prehistoric Museum, Price, UT

Multiple elements from an unnamed brachiosaurid have been found in the Price River II Quarry near the top of the Ruby Ranch Member of the Cedar Mountain Formation. The quarry, opened in 1997, is southeast of Wellington, Utah, and has produced disarticulated remains from a minimum of seven individuals ranging from young adults to mature animals. Morphological comparisons among elements suggest a single taxon, though the presence of multiple taxa is possible given the non-diagnostic nature of some sauropod bones. Specimens prepared to date include 12 teeth, 2 cervicals, 14 dorsals, multiple partial ribs, 2 partial sacra, 36 caudals, and multiple examples of all limb and girdle elements except sternals.

Brachiosaurid affinities are based upon the presence of the following traits: long, slender metacarpals versus short, stout metatarsals; distal shaft of the ischium oriented 80 degrees down from horizontal; and the presence of a laterodistal process on metatarsal I. However, this taxon lacks the pubic

apron of *Brachiosaurus* and the caudal vertebrae are distinct from those of *Pleurocoelus*, *Cedarosaurus*, *Sonorosaurus* and *Venenosaurus*. Three autapomorphies have been identified that potentially distinguish this taxon as a new species. These include a coracoid foramen open to the scapulocoracoid border (even in mature individuals), a prespinodiapophyseal lamina running parallel to the spinodiapophyseal lamina in anterior-mid dorsal vertebrae, and a postspinal lamina on midcervical neural spines. The first two traits are unknown in other sauropods, and the latter is known only in *Isisaurus colberti*; research is continuing to affirm these traits as autapomorphic for this taxon.

9:00 **Myers, T.:** EVIDENCE FOR AGE SEGREGATION IN A HERD OF DIPLODOCID SAUROPODS  
MYERS, Timothy, Univ. of Cincinnati, Cincinnati, OH

The Mother's Day Quarry, located in the Salt Wash member of the Morrison Formation of south-central Montana, contains the remains of numerous *Diplodocus*. The bonebed is laterally extensive and contains both semi-articulated and disarticulated specimens. The assemblage is interpreted as an allochthonous, paucispecific accumulation resulting from a drought mortality of a herd group of sauropods. Time-averaging at the site appears to be minimal, and sauropod elements comprise the overwhelming majority of the recovered material. Transport from the initial site of death to the point of final burial appears to have been turbulent and short in terms of both distance and duration. Sedimentary indicators at the site suggest a mudflow was the agent of transport.

Significantly, all the sauropod material identified thus far belongs to juvenile or subadult individuals; no elements from fully-mature adults have been recovered. If the lack of adult specimens in the assemblage is not the result of taphonomic bias, this site represents only the second known body fossil assemblage indicating segregation of sauropod herd groups on the basis of age. Factors that could potentially distort the thanatocoenose in such a fashion as to produce the observed predominance of numerous immature individuals of a single taxon include a selective agent of mortality or extensive time-averaging due to attritional accumulation. A taphonomic investigation of the Mother's Day Quarry -- involving analysis of bone modification features, element ratios, element position and orientation, and the depositional setting of the quarry -- reveals no selective processes that could significantly bias the quarry assemblage. Therefore, the original herd group from which the death assemblage was derived must also have been devoid of adults, reflecting age segregation, a behavioral scenario previously postulated from trackway evidence, but never before noted in a taphonomically-constrained skeletal assemblage.

9:15 **Wilson, J.:** A REDESCRIPTION OF THE MONGOLIAN SAUROPOD *NEMEGTOSAURUS MONGOLIENSIS* NOWINSKI (DINOSAURIA: SAURISCHIA) AND COMMENTS ON LATE CRETACEOUS SAUROPOD DIVERSITY

WILSON, Jeffrey, Univ. of Michigan, Ann Arbor, MI

Restudy of the skull of the Late Cretaceous (Maastrichtian) sauropod *Nemegtosaurus* identifies features that link it and its closely related counterpart *Quaesitosaurus* to Titanosauria, a late-surviving clade that flourished on most continental landmasses until the end of the Maastrichtian. Titanosaur cranial synapomorphies include a posterolaterally oriented quadrate fossa, reduced quadrate flange of the pterygoid, relatively short supraoccipital, and a novel basisphenoid-quadrate contact. Features exclusive to *Nemegtosaurus* and *Quaesitosaurus* include the presence of a symphyseal eminence on the premaxillae, highly vascularized tooth bearing portion of the maxilla, enclosed maxillary canal, orbital ornamentation on the prefrontal and postorbital, exclusion of the squamosal from the supratemporal fenestra, and dentary teeth smaller in diameter than premaxillary and maxillary teeth.

Reevaluation of the phylogenetic affinities of Asian sauropods in light of these and other characters suggests (1) all Cretaceous Asian sauropods are titanosauriforms, (2) all Late Cretaceous Asian sauropods are titanosaurs, and (3) diplodocoids have not yet been recorded in Asia. Thus, a uniformly non-neosauropod Jurassic Asian fauna was replaced by titanosauriforms by the Early Cretaceous. The Middle Jurassic origin of Titanosauriformes implied by wide-gauge trackways suggests that the group originated outside Asia and later migrated to Asia. Although *Euhelopus*-like teeth and gobiconodontid mammals from the Early Cretaceous of Spain may suggest communication between Europe and Asia, the origin(s) of Asian titanosauriforms remain unknown.

By the latest Cretaceous, titanosaurs were the predominant sauropods in Asia and worldwide, where they are recorded on all landmasses but Antarctica. If connections between landmasses were severed by the Cenomanian, then latest Cretaceous survival and predominance of titanosaurs may have been independent on each landmass. Confirmation of this pattern will require further sampling of Cretaceous horizons, as well as a detailed framework of titanosaur interrelationships to evaluate their paleobiogeography.

9:30 **Martinez, R., Alcober, O., Fernandez, E., Trotteyn, M., Colombi, C. and Heredia, G.:** A NEW PROSAUROPOD DINOSAUR FROM THE QUEBRADA DEL BARRO FORMATION (UPPER TRIASSIC?), MARAYES BASIN, NORTHWESTERN ARGENTINA

MARTINEZ, Ricardo, ALCOBER, Oscar, FERNANDEZ, Eliana, TROTTEYN, Maria, COLOMBI, Carina, HEREDIA, Guillermo, Instituto y Museo de Ciencias Naturales, San Juan, Argentina

A new prosauropod was recovered from braided paleochannel deposits of the Quebrada del Barro Formation. Despite the high energy environment where the remains were buried, the remains show a good degree of preservation. The specimen consists of a complete skull with an articulated lower jaw, the first seven cervical vertebra, left scapula and coracoid, proximal end of both ischiums, left metatarsals III, IV and V and distal tarsals III and IV.

The new prosauropod is a plateosaurid closely related to *Massospondylus*, but with a posteriorly oriented dorsal process and well developed medial lamina of the maxilla, bigger orbital fenestra, wider external naris and very elongated cervical vertebra.

Including this new one, eight different genera of prosauropods from the Upper Triassic-Lower Jurassic outcrops in western Argentina have been reported, showing the high degree of diversification of sauropodomorphs during this part of the Mesozoic.

The age of the new taxa, due to the affinities with *Massospondylus*, can be assigned as Upper Triassic to Lower Jurassic, questioning the previous assigned age to the Quebrada del Barro Formation, usually considered as strictly Upper Triassic.

9:45 **Kellner, A., Azevedo, S., Carvalho, L., Henriques, D. and Costa, T.:** BONES OUT OF THE JUNGLE: ON A DINOSAUR LOCALITY FROM MATO GROSSO, BRAZIL

KELLNER, Alexander, AZEVEDO, Sergio, CARVALHO, Luciana, HENRIQUES, Deise, Museu Nacional / UFRJ DGP / Setor de Paleovertebra, Rio De Janeiro, RJ., Brazil; COSTA, Terezinha, Departamento Nacional de Producao Mineral, Cuiaba/Mato Grosso, Brazil; CAMPOS, Diogenes, Departamento Nacional de Producao Mineral, Rio de Janeiro/Rio de Janeiro, Brazil

Our knowledge of Brazilian dinosaurs is extremely poor due to the lack of good sites, a result at least in part explainable by the extensive vegetation that covers most of the territory. Recently an expedition to a remote region of Mato Grosso, close to the town Tesouro (in English = "treasure"), opened a new quarry near the Confusao creek. The outcrop is formed by conglomerates and sandstones that can be correlated with the lithostratigraphic units of the Bauru Group (Santonian-Maastrichtian). About 100

bones (plus 40 theropod and sauropod teeth) were collected totaling more than 2.5 tons. The excavated area of the outcrop is about 10 X 4 meters, with an overburden averaging one meter. Two distinct fossiliferous layers were found. The stratigraphically higher consists mainly of sandstones and showed the presence of several fragmentary bones and teeth. The second one, about 50 cm lower in the section, is composed essentially of conglomerates and yielded most of the specimens. Among the recovered elements is a sequence of dorsal and caudal vertebrae, found associated with long bones (still being prepared). Some of the anterior caudals are unfused and show a low and anteroposteriorly elongated neural spine. They are procoelic, a common feature of the Titanosauria. The centrum is depressed dorsoventrally but does not show the “heart-shaped” condition found in *Gondwanatitan*. The reduced size of the neural spine, combined with a marked lateral depression anterior to the postzygapophyses on the basal portion of the neural spine and its particular anteroposterior elongation differ from all previously collected sauropod caudals from Brazil. The dorsal vertebrae show a well developed large lateral pleurocoel. Among the long bones collected is an isolated femur that shows a developed lateral prominence, which is a diagnostic feature of the titanosauriformes. A small but marked lateral concavity, unknown in other sauropods, is present above this lateral prominence. Although still preliminary, the anatomical features of the titanosaurid sauropod bones collected at this site suggest that they belong to new taxa.

10:00 **BREAK**

10:15 **Fiorillo, A.:** DINOSAURS OF ALASKA AND THE ASSEMBLING OF BERINGIA

FIORILLO, Anthony, Dallas Museum of Natural History, Dallas, TX

Beringia is the name given to northeastern Asia, northwestern North America, and the surmised land connection between the two regions. Historically speculation on a connection between the two continents extends back to the late 16th century. Later work proposed a relationship between fluctuations in sea level and glacial advances and retreats inspired the concept of a dry land connection between Asia and North America. By the 1930s enough data had been gathered that Hulten proposed the name Beringia for the land bridge. By this definition, Beringia is a Pleistocene concept.

Hopkins extended the concept back in time to the mid- to early Tertiary based on floral similarity between Asia and North America, the lack of a seaway across the Bering Strait during this same time demonstrated by the presence of distinct Atlantic and Pacific mollusk and marine mammal fauna, and terrestrial faunal migration. Other workers have recognized the abundance and diversity of megaherbivores in the Beringian Pleistocene ecosystem, perhaps the result of a long growing season.

Based on recent tectonic reconstructions, the possibility that faunal migrations are not directly correlated with glacio-eustatic sea level changes, and new dinosaurian discoveries, the concept of Beringia can, and should be formally extended back in time to at least the Turonian and perhaps the Aptian/Albian. This implies that the concept of Beringia is rooted in its accretionary history rather than in a climatic history.

10:30 **Chapman, R., Deck, L., Varricchio, D. and Jackson, F.:** THE FAUNA OF THE LOWER CRETACEOUS WAYAN FORMATION OF IDAHO: A PRELIMINARY REPORT

CHAPMAN, Ralph, DECK, Linda, Idaho Museum of Natural History, Pocatello, ID;  
VARRICCHIO, David, JACKSON, Frankie, Montana State Univ., Bozeman, MT

Dinosaurs are relatively rare in Idaho. There is a paucity of terrestrial Mesozoic sediments and where such sediments do crop out, in southeastern Idaho, the complex stratigraphy and geologic structure has made reconnaissance for and extraction of fossils difficult. As a result, paleontologists have spent

relatively little time exploring and studying the terrestrial Mesozoic of Idaho. Yet dinosaur material from Idaho is more common than is generally realized. A consortium of organizations (the Idaho Museum of Natural History (IMNH), Idaho State University, and Montana State University) has initiated the first detailed research program, the Idaho Dinosaur Project. This first detailed analysis was made in conjunction with an IMNH Museum exhibit on the Idaho Early Cretaceous, and also reflects the initial interpretation of significant material collected during the very successful field season of 2003.

The available vertebrate material from the Wayan Formation represents a typical Albian-age North American dinosaur fauna, similar to the slightly older Cloverly Formation of Montana and neighboring states, and parts of the Cedar Mountain Group of Utah. The most common dinosaur remains are from a small to medium-sized dromaeosaurid theropod. Next in abundance is material referable to a medium-sized, *Tenontosaurus*-like iguanodont. There is also significant material from an as yet unidentified basal neoceratopsian and limited, non-diagnostic remains from a larger theropod. Other remains include a very small ankylosaur tooth identifiable as a nodosaurid and a large number of unidentified and unprepared theropod fossils. Although neighboring faunas include sauropods like *Pleurocoelus*, we have yet to identify any sauropod material from the Wayan. Dinosaur eggshell is common in the Wayan. Preliminary study reveals two types of eggshell structure. Both have been previously associated with theropod dinosaurs. Additional components of the assemblage include invertebrates, petrified wood, and fish and crocodile teeth.

10:45 **Lovelace, D.:** TAPHONOMY AND PALEOENVIRONMENT OF A LATE JURASSIC DINOSAUR LOCALITY IN THE MORRISON FORMATION OF EAST-CENTRAL WYOMING

LOVELACE, David, Univ. of Wyoming, Laramie, WY

The Morrison Formation of east-central Wyoming has received less attention than Shirley, northern Powder River, and Bighorn basins. A new locality near Douglas, Wyoming, has yielded remains of a disarticulated sauropod skeleton (cf. *Supersaurus vivianae*) and the remains of a semi-articulated small theropod. Taphonomy of the site provides information on a unique depositional environment, and circumstances leading to the preservation of the largest, and smallest dinosaurs found in the state. The site is broken into two units with a weak soil horizon separating them. The lower unit consists of fine grained to clay-sized matrix containing skeletal remains of the sauropod, and incorporates rip-up clasts from the underlying scoured layer. Due to surface cover the lateral extent is not well known. Where the lake sediments of the upper unit outcrop (under 50m) the lower sandy unit is not present, suggesting limited lateral extent. The lower unit exhibits no structure or sorting other than slight mottling interpreted to be root traces of a weakly developed paleosol. The sauropod bones show signs of rotting and mechanical stress during deposition, including abrasion marks from bone-bone contact, non-orogenic plastic deformation, and rupturing. Abundant charcoalified plant remains are present, showing no preferred orientation. This unit is interpreted to be a high-energy deposition, comparable to a muddy debris flow. Immediately above the contact with the lower unit a small theropod skeleton was found. Sedimentology and micropaleontology of the upper unit indicate a shallow lake, or pond environment. Laterally extensive caliche layers with interfingering clay horizons suggest successive stages of raising and lowering of lake levels, possibly due to seasonal variability in precipitation and evaporation, with P/E ratios varying from <1 to >1. The high concentration of charcoal, found only in the lower unit, indicate fire. The removal of vegetation by fire may have caused destabilization of sediment, and a seasonal increase in precipitation saturating the sediment enough that shear stress overcame yield strength resulting in a debris flow.



11:00 **Sampson, S., Loewen, M., Roberts, E., Smith, J., Zanno, L. and Gates, T.:** PROVINCIALISM IN LATE CRETACEOUS TERRESTRIAL FAUNAS: NEW EVIDENCE FROM THE CAMPANIAN KAIPAROWITS FORMATION OF UTAH

AMPSON, Scott, LOEWEN, Mark, ROBERTS, Eric, SMITH, Joshua, ZANNO, Lindsay, GATES, Terry, Univ. of Utah, Salt Lake City, UT

Recent work in the Late Campanian-aged (Judithian) Kaiparowits Formation, Grand Staircase-Escalante National Monument, southern Utah, has yielded remains of several previously unknown taxa of dinosaurs and other vertebrates. The new dinosaur taxa include a caenagnathid theropod, the first recovered south of Montana, and a chasmosaurine ceratopsid allied with southern forms. High-resolution chronostratigraphic data from multiple ash layers indicate that the Kaiparowits Formation is contemporaneous with several dinosaur-rich formations to the north (Dinosaur Park, Judith River, and Two Medicine) and to the south (the Fruitland and portions of the Kirtland and Aguja). Previously, vertebrate assemblages from these Western Interior formations have been characterized as northern and southern faunas, respectively. A comprehensive comparison of known vertebrate taxa from these formations was undertaken, encompassing over 324 taxa across fishes, amphibians, lizards, turtles, crocodylians, dinosaurs, and mammals. Relative to the northern and southern biotas, the Kaiparowits Formation fauna consists of a diverse mixture of endemic, cosmopolitan, northern, and southern taxa. We tentatively interpret this pattern as representative of an intermediate zone of faunal mixing and endemism that directly parallels a contemporaneous, latitudinally equivalent marine fauna from the adjacent Late Cretaceous Interior seaway. In addition, given the considerable latitudinal variation in constituent vertebrate taxa within these coeval terrestrial ecosystems, the faunal distributions and chronostratigraphic data together provide strong support for the vertebrate provincialism hypothesis. The present study represents one of the few examples of subcontinental scale biogeography for this era, underlining the future potential for addressing key ecological and evolutionary questions.

11:15 **Britt, B., Eberth, D., Scheetz, R. and Greenhalgh, B.:** TAPHONOMY OF THE DALTON WELLS DINOSAUR QUARRY (CEDAR MOUNTAIN FORMATION, LOWER CRETACEOUS, UTAH)

BRITT, Brooks, Brigham Young Univ., Provo, UT; EBERTH, David, Royal Tyrrell Museum, Drumheller, AB, Canada; SCHEETZ, Rodney, GREENHALGH, Brent, Brigham Young Univ., Provo, UT

Dalton Wells, near Moab, Utah, has produced the most diverse dinosaurian fauna known from any Lower Cretaceous site, including nine dinosaur taxa: *Utahraptor* (MNI 7), *Nedcolbertia* (MNI 2), Ornithomimosauria indet. (MNI 3), titanosaurid (MNI 14), brachiosaurid (MNI 3), camarasaurid (MNI 2), *Gastonia* (MNI 9), and a tall-spined iguanodontid ornithopod (MNI 4).

The deposit has an extent of  $>4,000\text{m}^2$  and consists of 2-4 stacked bonebeds that rest unconformably on the Morrison Fm. The bonebeds are rare examples of assemblages deposited by subaerial debris flows. An array of harsh and varied taphonomic factors influenced the assemblage prior to and following deposition. Although the assemblage consists primarily of disarticulated bones, groups of individuals are also present: 8 of 9 *Gastonia* individuals are closely associated/partially articulated in a local area with a juvenile titanosaur. Bone fragments ( $<1\text{mm}$  -  $1\text{m}$ ) dominate the assemblage (77% of specimens), whereas complete bones are rare ( $<4\%$  of specimens). Voorhies Group analysis reveals a near total depletion of Groups I & II, indicating the assemblage was sorted hydraulically prior to entrainment in the debris flows. Tooth marks are present on 1% of the specimens indicating scavenging played a minor role in bone modification. Ubiquitous bone splinters, sets of subparallel scratches, and spiral fractured bone show that trampling of fresh bone was a major factor in bone reduction and loss. Bone cracking and flaking (39% of specimens) indicate that elements were exposed for months to years prior to final

interment. 40% of the bones are chemically etched on one side (flat) or on broken/articular ends (rounded). Etching is attributed to rotting on or in a wet substrate. Associated bone fragments and vertical displacement of bones of an associated *Utahraptor* skeleton, demonstrate a second episode of trampling occurred following interment by the debris flow. Invertebrate (insect larvae) burrows and furrows are preserved in the matrix and along surfaces of bones, respectively, indicating that the assemblage was not fossilized prior to burial.

11:30 **Gates, T.:** HADROSAURIAN DINOSAUR DIVERSITY FROM THE UPPER CAMPANIAN KAIPAROWITS FORMATION, SOUTHERN UTAH

GATES, Terry, Univ. of Utah/Utah Museum of Natural History, Salt Lake City, UT

Fieldwork undertaken over the past several years has resulted in a dramatic increase in our understanding of hadrosaurian dinosaurs from the Upper Cretaceous (Late Campanian) Kaiparowits Formation, which outcrops in southern Utah. Currently, two hadrosaur taxa are recognized, one hadrosaurine and one lambeosaurine. The relatively large-bodied hadrosaurine provisionally referred to *Kritosaurus navajovius* is represented by several specimens, including a largely articulated skeleton with partial skull. This species represents the first definitive occurrence of a hadrosaurine from the Kaiparowits Formation. The lambeosaurine can be confidently identified as *Parasaurolophus cyrtocristatus*, known from the Kaiparowits by two partial skulls and an isolated crest. A number of these hadrosaur specimens are remarkably preserved, some with large areas of fossilized skin impressions that reveal intricate details of the epidermis from various regions of the body.

*K. navajovius* has otherwise been identified from marginally younger deposits in the Fruitland and Kirtland formations (New Mexico), the mid-to-upper Campanian Aguja Formation (Texas), and the uppermost Campanian Cerro del Pueblo Formation (Coahuila, Mexico). Recent chronostratigraphic work indicates an approximate 5 million year span for these occurrences. If the identifications are correct, both the geographic and stratigraphic ranges of *K. navajovius* would greatly exceed those for any other known Campanian hadrosaur. Given the much more restricted distributions typical of species within this clade, this evidence suggests that a re-examination of *Kritosaurus* taxonomy is in order.

Nonetheless, *Kritosaurus* and *Parasaurolophus cyrtocristatus* are otherwise known only from Campanian-aged deposits in the southern region of the Western Interior. In combination with recent chronostratigraphic data demonstrating contemporaneity with several dinosaur-rich northern formations (Judith River, Two Medicine, Dinosaur Park), this evidence provides strong support for the notion of Late Cretaceous dinosaur provincialism.

11:45 **Sullivan, R. and Lucas, S.:** THE KIRTLANDIAN LAND-VERTEBRATE “AGE” AND THE END OF LATE CRETACEOUS DINOSAUR PROVINCIALISM IN THE NORTH AMERICAN WESTERN INTERIOR AS WE KNOW IT

SULLIVAN, Robert, State Museum of Pennsylvania, Harrisburg, PA; LUCAS, Spencer, New Mexico Museum of Natural History and Science, Albuquerque, NM

The Kirtlandian land-vertebrate “age” (LVA = faunachron) is between the Judithian and Edmontonian (74.9–72 Ma). The Kirtlandian LVA is characterized by the vertebrate fossil assemblages (Hunter Wash and Willow Wash local faunas) of the Fruitland and Kirtland formations, San Juan Basin, New Mexico. It is defined as the interval of time between the first appearance of *Pentaceratops sternbergii* (= end of the Judithian) and the first appearance of *Pachyrhinosaurus canadensis* (= beginning of the Edmontonian). Principal correlatives include the vertebrate faunas of the lower part of the Bearpaw Formation of Montana and Alberta, Canada; Williams Fork Formation, northwestern Colorado; Kaiparowits Formation, south-central Utah; Fort Crittenden Formation, southeastern Arizona,

Ringbone Formation, southwestern New Mexico; the Corral de Enmedio and Packard formations of the Cabullona Group, Sonora, Mexico; and the Cerro de Pueblo Formation, Coahuila, Mexico.

Recognition of the Kirtlandian undermines the concept of two paleogeographically distinct dinosaur paleocommunities in the Western Interior during the late Campanian. The previously perceived endemism of dinosaur faunas is largely due to temporal diachroneity, not to provinciality. The small geographic ranges of hadrosaurid and other dinosaur genera are artifacts of a combination of limited stratigraphic exposures and temporal isolation. Altitudinal and transcontinental life zones are not as distinct as previously claimed, and the supposed north-south provincialism in the faunas from the Judithian through Lancian are the result of poor resolution. Both the Judithian and Edmontonian LVAs have longer durations than the Kirtlandian LVA, so they display greater taxonomic diversity at both the genus and species levels.

12:00 **Heathcote, J.:** CRANIAL VARIATION IN THE ORNITHOPODA (DINOSAURIA): RECONCILING GEOMETRIC MORPHOMETRICS AND PHYLOGENY

HEATHCOTE, Julia, 1 Central Ave., Hucknall, Nottingham NG15 7JJ UK

Geometric morphometrics has been shown to be an extremely useful tool in palaeontology, but rarely has it been applied to dinosaurs. The Ornithopoda, and specifically the Hadrosauridae, exhibit a great deal of variation in their cranial anatomy, and as such allow a detailed morphometric analysis. Whilst much of the skull is conservative, the premaxilla and nasal bones form elaborate ornamentation in many hadrosaurian dinosaurs. The extent of this variation is tested here using standard Procrustes techniques.

Seven landmarks and 86 sliding semilandmarks delimiting the jugal bone of 46 ornithopod skulls are analysed, using freely available thin-plate spline software. The resulting distribution of shapes is compared with that from an analysis of 38 of these skulls with respect to 8 landmarks and 55 semilandmarks from the premaxilla and nasal bone. A relative warp analysis is performed, calculating the principal components of the distribution of each set of shapes. The jugal bone is found to be most useful in defining successive taxa within the base of the clade, and the variation within the first relative warp matches that suggested by an existing phylogeny. However, the variation in the nasal bone is of more use in the definition of derived hadrosaurs, specifically the Lambeosaurinae. The variation shown by the first three relative warps creates an opportunity for the assessment of a number of taxa currently believed to be juvenile lambeosaurines. Mapping the variation within the clade onto the ornithopod phylogeny allows an interpolation between existing taxa, thus facilitating an estimation of the shape of the skull in hypothetical ancestors.

12:15 **Motani, R.:** THREE-DIMENSIONAL RETRODEFORMATION OF THE NECK OF THE ELASMOSAUR *THALASSOMEDON HANINGTONI* (SAUROPTERYGIA: PLESIOSAURIA)

MOTANI, Ryosuke

MOTANI, Ryosuke, Univ. of Oregon, Eugene, OR

Many vertebrate fossils have undergone deformation, whether by tectonic causes or through simple compression from sedimentary overburden. Consideration of such distortion is important because it often prevents paleontologists from understanding the true shape of the animal. The original shape may be reconstructed through removing the deformation, a process called retrodeformation.

Retrodeformation is possible when the distortion is simple (i.e., approximately linear), whereas non-linear cases remain challenging. Many papers have been published on retrodeformation of flattened fossils along the bedding plane, but little progress has been reported for retrodeformation in all three dimensions. In principle, 3D linear retrodeformation can be described by a symmetric matrix, just as in

2D cases. Such a matrix can be found by assuming bilateral symmetry of the object before burial, and by finding at least five pairs of originally symmetrical landmarks. I briefly reported a successful test case based on a trilobite fossil last year, but a question remained whether the method was applicable to vertebrate fossils, which present unique sets of problems.

The holotype of the elasmosaur *Thalassomedon haningtoni*, whose cervical vertebrae show obvious deformation, was digitized by using a 3D laser scanner. A linear 3D retrodeformation technique was applied to these vertebrae, but the initial trials all failed. The problem laid in the violation of the assumption that the vertebrae were symmetrical in life. A brief survey of living vertebrates revealed that centra were approximately symmetrical whereas the neural spines and especially the zygapophyses were usually asymmetrical from right to left. Therefore, the assumption would approximately hold when deriving data from the centra only. This reduces the number of available landmarks, posing a problem in finding five landmark pairs. Only three pairs are required when the strain ellipsoid is an oblate spheroid (e.g., compression from overburden). Fortunately, the vertebrae in question seem to have such deformation, and it was possible to retrodeform them based on centra measurements alone.

**PALEOCENE/EOCENE BOUNDARY AND  
FAUNAL CHANGE IN RELATION TO CLIMATE  
PLAZA BALLROOM F  
CONVENORS: PHILIP GINGERICH AND SUYIN TING**

8:00 **Gingerich, P. and Ting, S.:** PALEOCENE-EOCENE BOUNDARY AND FAUNAL CHANGE IN RELATION TO CLIMATE

GINGERICH, Philip, Univ. of Michigan, Ann Arbor, MI; TING, Suyin, Louisiana State Univ., Baton Rouge, LA

Vertebrate paleontologists were the first to accept insertion of a new epoch (Paleocene, or 'Orthocene') between the Late Cretaceous with dinosaurs and the Eocene with horses. In 1914 W. D. Matthew summarized evidence that the Paleocene is represented by distinctive groups of archaic mammals, and henceforth vertebrate paleontologists recognized this as a distinct epoch. Fieldwork in the Clarks Fork and northern Bighorn basins of western North America in the 1970s and 1980s clarified the abrupt transition from the Clarkforkian to Wasatchian land-mammal ages (Paleocene-Eocene boundary), suggesting faunal immigration. Surprisingly the transitional earliest Wasatchian 'Wa-0' mammal fauna included dwarfed taxa.

In the 1990s a distinctive 'late Paleocene' carbon isotope excursion (CIE) was found in deep-sea sediments coincident with an oxygen isotope event reflecting abrupt warming, and the CIE was then found on land in the Wa-0 faunal interval. Discovery of the CIE led to a revised concept of the Paleocene-Eocene boundary in marine strata, correlative in time with the Clarkforkian-Wasatchian boundary on land (revision now ratified by the international ICS/ISPS). The CIE enables precise correlation of marine strata with terrestrial deposits in North America, Europe, and Asia. The warming peak coincident with the CIE, the Paleocene-Eocene thermal maximum or PETM, is now known to be global. The CIE and PETM are tied in different ways to mobilization of marine methane clathrates responsible for a 100 kyr natural greenhouse climate event, explaining both Wa-0 dwarfing and the holarctic cosmopolitanism of vertebrate faunas.

The distinctive Eocene vertebrate fauna with modern mammalian orders Artiodactyla, Perissodactyla, and Primates dispersed across high latitude land bridges connecting Asia, Europe, and

North America within the first 10 kyr or so of Eocene. PETM climatic warming had a transient effect on mammalian body size during Wa-0 time, but a profound and lasting effect on the composition of terrestrial vertebrate faunas on all three northern continents.

8:15 **Flynn, J. and Tauxe, L.: MAGNETOSTRATIGRAPHY OF UPPER PALEOCENE-LOWER EOCENE TERRESTRIAL AND MARINE SEQUENCES**

FLYNN, John, The Field Museum, Chicago, IL; TAUXE, Lisa, Scripps Institution of Oceanography, La Jolla, CA

We expand on our 1998 analysis of principal magnetostratigraphic data sets from marine and terrestrial strata spanning the Paleocene/Eocene (P/E) Series boundary. To assess data reliability we use 2 simple measures (polarity data histogram analysis; jackknife parameter measuring dependence of a polarity stratigraphy on sampling density). There still are only sporadic magneto-biostratigraphic data, of questionable reliability, across the boundary in NW European shallow marine/epicontinental sequences. Several long marine sequences span the boundary, but there is poor consistency among the ODP/DSDP sites, and results are difficult to interpret. The most complete and reliable magnetostratigraphies spanning the boundary appear to be those from terrestrial strata, especially mammal-bearing sequences in Ellesmere Island and the San Juan, Northern Bighorn, and possibly Hengyang (China) Basins. Available data clearly indicate that the P/E Series boundary lies within Chron C24r. The poorly substantiated “Oldhaven normal event/subchron” probably results from overprinting and thus is not valid. A different short normal polarity interval, closely associated with the boundary, occurs in at least 1 marine and 2 terrestrial sequences and may be correlative with Cryptochron C24r.6. If this short event becomes better substantiated it would subdivide the long reversed magnetozone (Chron C24r) within which the boundary lies, and would have great potential to improve local and global temporal correlations. Although much progress remains to be made, studies integrating radioisotopic dating, magnetostratigraphy, biostratigraphy, and stable isotope stratigraphy (e.g., the now well-documented carbon isotopic excursion) have greatly improved chronostratigraphic correlations and insights into the relative timing and possible causes of biotic and physical events occurring near the P/E Epoch boundary.

8:30 **Bowen, G. and Koch, P.: STABLE ISOTOPES AND THE STUDY OF PALEOCENE/EOCENE BOUNDARY CLIMATIC AND BIOTIC CHANGE**

BOWEN, Gabriel, Univ. of Utah, Salt Lake City, UT; KOCH, Paul, Univ. of California, Santa Cruz, CA

Stable isotopes have been and continue to be an essential tool for the study of climate and biotic change across the Paleocene/Eocene boundary. Stable isotope analyses of terrestrial sedimentary rocks provide information for high-resolution correlation of fossiliferous strata. The carbon isotope excursion (CIE) marking the P/E boundary has now been identified at no fewer than 5 terrestrial sites on 3 continents, allowing correlation of widely dispersed fossil sites and analysis of biogeographic patterns of biotic turnover. Both paleosol carbonate nodules and concentrated and dispersed sedimentary organic carbon have been shown to successfully record the CIE in terrestrial basins, and correlation of nearshore marine sections using inorganic and organic isotope stratigraphy has provided additional insight into paleofloral change through the P/E boundary. High resolution  $\delta^{13}\text{C}$  records from terrestrial sections and marine  $\delta^{13}\text{C}$  records recalibrated using new age models show remarkable similarities over timescales of 10,000 years, implying that in some cases  $\delta^{13}\text{C}$  records may be used to partition time and correlate stratigraphic packages within the PETM. Comparison of terrestrial and marine  $\delta^{13}\text{C}$  records has provided evidence for a discrete switch in climate state during the PETM, during which the carbon and

nutrient dynamics of terrestrial ecosystems are likely to have changed dramatically. Oxygen isotope paleothermometry using endotherm/ectotherm pairs has provided the first estimates of PETM temperature change for the continental interiors, and there is significant potential for the use of oxygen and other isotope systems to reconstruct changes in atmospheric circulation, hydrology, and weathering during this geological global warming event.

8:45 **Wing, S.:** IMPLICATIONS OF PALEOCENE-EOCENE FLORAL CHANGE FOR MAMMALS

WING, Scott, Smithsonian, Washington, DC

The Paleocene-Eocene Boundary (PEB) was a time of rapid global warming and major shifts in mammalian faunal composition, body size, trophic adaptations and diversity. Changes in the taxonomic composition of the fauna have been attributed to migration across high latitude land bridges, whereas the other faunal changes more likely represent responses to climate, vegetation, or ecological interactions among immigrants and natives. If ecological changes in the fauna reflect modifications in the type or seasonality of food resources or the 3D structure of vegetation, this should be apparent in the plant fossil record.

Data from >200 fossil leaf sites and >60 palynological samples from the PEB interval in Wyoming show that changes in floral composition and diversity were not dramatic. About 15% of common megafossil plants last appeared in the ~500 ky prior to the PEB, and 12% first appeared in the ~500 ky following. Megafloral richness declined by about 20% during the ~1 my interval including the PEB, largely because of decreased sampling. Three of four taxa that appeared immediately after the PEB were highly dispersible ferns. There were no last appearances of common palynomorphs in the ~250 ky prior to the PEB, and only two moderately common taxa had first appearances in the ~250 ky following. There were major shifts in relative abundances of pollen taxa; formerly dominant walnut family pollen types decreased markedly, and elm, alder, and linden relatives increased. Within sample richness of palynofloras increased slightly across the PEB.

Modest changes in floral composition and diversity across the PEB contrast with major changes in mammalian faunas from the same region. Subdued floral change probably reflects the failure of plant populations to expand northward during the short warming, possibly because seeds could not establish themselves under pre-existing forest cover. The complacency of the flora suggests that changes in the fauna were not responses to shifts in the types of food plants available, or in the structure of the vegetation, but more likely reflect interactions among mammalian species.

9:00 **Rose, K. and Zack, S.:** NEW EARLIEST EOCENE MAMMALIAN FAUNA FROM THE CENTRAL BIGHORN BASIN, WYOMING

ROSE, Kenneth, ZACK, Shawn, Johns Hopkins Univ. Sch. of Medicine, Baltimore, MD

A significant new vertebrate fauna from the basal Eocene (Wa-0) has been collected over the past four field seasons from an area of the Bighorn Basin (Sand Creek Divide) 10 miles north of Worland and geographically between the two principal sites for Wa-0 faunas. Although the Bighorn Basin contains extensive exposures of Wasatchian age, the narrow stratigraphic interval yielding Wa-0 faunas is exposed in only a few localized areas on the periphery of the basin, which are much less fossiliferous than typical Wasatchian strata. The Sand Creek Divide area is of interest because it is relatively rich and has multiple productive zones within this >20 m interval spanning <100K yrs. Analysis of  $\delta^{13}\text{C}$  verifies that the sequence is entirely within the CIE, which is situated just above the Paleocene/Eocene boundary. At least 45 mammal species representing at least 15 orders have been identified based on more than 50 jaws, 700 isolated teeth, and a few postcranial associations, obtained from both surface prospecting and screen-washing. The fauna is dominated by mammals of small body size (<1 kg) which

are typically smaller than their later Wasatchian descendants; except for the taeniodont *Ectoganus* and the condylarth *Phenacodus*, larger mammals are rare. The microfauna, obtained mainly by screen-washing, is diverse and includes several marsupials and lipotyphlans, among them three nyctitheres.

The fauna contains microfaunal elements not yet known from Gingerich's Wa-0 fauna at the northern end of the basin. Like the latter, however, the new fauna contains several diagnostic Wa-0 elements (*Cantius torresi*, *Diacodexis ilicis*, *Hyracotherium sandrae*, and hyaenodontid creodonts) which are absent or rare in Strait's Wa-0 fauna from the southeastern part of the basin. Among the most significant species, also found at new Wa-0 sites in the southeastern part of the basin, is the omomyid primate *Teilhardina brandti*. It is intermediate between *T. belgica* from the base of the Eocene in Europe and *T. americana* from overlying Wa-1 strata, but is closer to the European species in several key morphologic traits.

9:15 **Meng, J.:** DIVERSITY AND PHYLOGENY OF BASAL GLIRES ACROSS THE PALEOCENE-EOCENE BOUNDARY IN ASIA

MENG, Jin, American Museum of Natural History, New York, NY

Paleocene-Eocene transitional sediments are known from the Naran Bulak Fm., Nemegt Basin, Mongolia, in which the Naran-Bumban transition is currently considered the Asian terrestrial P/E boundary. P/E transitional sediments correlative to those of the Naran Bulak Fm. are probably present in Hengdong Basin and in Bayan Ulan and Huheboerhe sections of Erlian Basin, China. In the three sections, basal Glires are the common mammals; new species continue to be discovered therefrom. Among Asian Paleocene and Eocene mammals the best fossil records (in terms of species and specimen numbers and distributional density) that extend across the boundary are from Glires. Eurymylids and mimotonids are most diverse in the late Paleocene and early Eocene. The first appearance of rodents in the early Eocene Bumban beds may be associated with the P/E boundary, but the earliest record of lagomorphs is much later in the middle Eocene of Asia. Whether the crown Rodentia and Lagomorpha made their first appearances simultaneously in the Paleogene is uncertain because of unstable relationships of the early Glires. However, the split of the clades leading to rodents and lagomorphs, respectively, can be dated back to the Paleocene. Phylogeny, tooth morphology and body size of species within the lineage of Glires do not show distinctive pattern that can be associated with the warming event at the P/E boundary, accepting the conventional P/E boundary at the Naran-Bumban transition in Asia.

9:30 **Smith, T.:** MAMMALIAN EVOLUTION AND MIGRATIONS BETWEEN EUROPE AND NORTH AMERICA AT THE PALEOCENE-EOCENE THERMAL MAXIMUM

SMITH, Thierry, Institut Royal des Science Naturelles de Belgique, Bruxelles, Belgium

The Belgian faunas of Dormaal and Erquelinnes, representing the earliest Eocene mammal faunas of Europe (reference-level MP7), are characterised by the first occurrence of modern placentals, which co-occur with persisting archaic mammals. Among the 37 encountered genera, 25 are also present in other MP7 localities of northern Europe, while only 12 are known from southern Europe. Most of the modern species from northern and southern Europe belong to different lineages. Paradoxically, at least 22 genera are common with North America. The Belgian faunas present the best correlations with the faunas from the basal Wasatchian (Wa0) of the Willwood Formation in the Bighorn Basin (Wyoming). Several species from Dormaal and from the Wa0 belong to the same lineages, such as species from the genera *Diacodexis* (artiodactyl), *Microparamys* (rodent), *Miacis* (miacid carnivore), *Prototomus* and *Arfia* (hyaenodontid creodonts), *Teilhardina* (euprimate), and *Macrocranion* (Erinaceomorph insectivore). Among the archaic mammals, a few are persisting from MP6 faunas and are thus endemic to Europe

such as the genera *Paschatherium* (hyopsodontid condylarth), *Landenodon* (Arctocyoniid), and *Bustylus* (adapisoriculid insectivore), while others have a North American origin such as *Phenacodus* (phenacodontid condylarth), *Apatemys* (apatotherid), *Palaeosinopa* (pantolestid), and *Leptacodon* (nyctitheriid insectivore). Hence, mammal taxa from the Belgian sites belong to lineages from different geographic origins with some closely related modern immigrants from Dormaal and from Wa0 indicating a common geographic origin. New discoveries and studies of lineages based on teeth morphology argue for an initial migration of several modern groups from Asia to Europe and then to North America via Greenland at the P/E boundary. Moreover, the Paleocene-Eocene thermal maximum has been recently identified by organic carbon isotopic analyses within Belgian boreholes and a well-calibrated section in Wyoming. This enables to precise the timing of faunal exchanges between continents of the Northern Hemisphere.

9:45 **Strait, S.: SMALL, SMALLER, SMALLEST: A CASE FOR DWARFING IN SMALL-BODIED WA-0 MAMMALS**

STRAIT, Suzanne, Marshall University, Huntington, WV

The Paleocene-Eocene boundary and the Wa-0 biozone coincide with a brief interval of dramatic global warming. Some studies have suggested that there is an inverse relationship between mean body size and paleotemperature within some mammalian lineages. In North America, a distinctive Wa-0 mammalian fauna includes many lineages with dwarfed species. In the Clarks Fork Basin Gingerich found 28% of Wa-0 species were about 15% smaller than their close Clarkforkian or Wasatchian relatives. However, all taxa previously reported as dwarfed are medium to large sized. This size bias is probably an artifact of these samples being almost exclusively surface-collected.

In the southeastern Bighorn Basin >1000 Wa-0 specimens, representing 41 species, have been collected. In areas with a high density of fossils, where surface collecting can be efficiently done in a prone position, it is typical to recover taxa in the 250-500 gram range. However, smaller taxa (<100 grams) are normally only recovered from fine mesh screen-washing. Due to intensive screen-washing and surface collecting, a large number of Wa-0 small-bodied mammals have now been identified. Forty-eight percent of species and 56% of the total specimens have estimated body masses <500 grams and 32% of species and 45% of specimens represent animals <100 grams. Therefore, it is now possible to consider the phenomena of dwarfing in smaller-bodied taxa as well.

This study investigated the extent of dwarfing in the dominant small-bodied lineages. The multituberculates, marsupials, and rodents do not demonstrate any indication of dwarfing. However, a proteutherian (*Prodiacodon*), three lipotyphlans (*Macrocranion*, *Leptacodon*, and *Wyonycteris*), and a primate (*Niptomomys*) all are represented by smaller forms during Wa-0. In summary, five of the twelve species (or 42%) belonging to small-bodied orders exhibit dwarfing during the earliest Wasatchian. This study provides further support for evolutionary dwarfing at the Paleocene-Eocene boundary.

10:00 **BREAK**

10:15 **Clyde, W., Khan, I. and Gingerich, P.: MAMMALIAN DISPERSAL AND THE INDIA-ASIA COLLISION**

CLYDE, William, Univ. of New Hampshire, Durham, NH; KHAN, Intizar, Univ. of New Hampshire, Durham, NH; GINGERICH, Philip, Univ. of Michigan, Ann Arbor, MI

Perissodactyls, primates, and artiodactyls appeared abruptly on northern continents coincident with the Paleocene-Eocene boundary. These groups are hypothesized to have originated on the Indian subcontinent, but no relevant paleontological information has been available to test this idea. We present



sedimentologic and paleomagnetic evidence to show that the lower Eocene Ghazij Formation of western Pakistan records continental sedimentation associated with initial India-Asia collision. Fossil mammals have been recovered from three intervals of the middle and upper Ghazij Formation. These assemblages show significant stratigraphic change in composition. The middle Ghazij fauna associated with coal deposits is dominated by an endemic family of archaic mammals, Quettacyonidae, which has not been observed elsewhere in the world. The fauna from the lower part of the upper Ghazij has a mixture of endemic quettacyonids and cosmopolitan taxa known elsewhere on northern continents (e.g., tillodonts and perissodactyls). The uppermost Ghazij fauna is dominated by modern, cosmopolitan taxa found on northern continents (e.g., perissodactyls, primates, and artiodactyls). Ghazij mammal faunas exhibit a pattern of decreasing endemism and increasing Holarctic affiliation and a pattern of increasing modernity through time. Our results are consistent with initial India-Asia collision occurring near the Paleocene-Eocene boundary, but modern orders of mammals appeared later in Indo-Pakistan and thus did not likely originate on the Indian subcontinent. It appears that during initial collision, modern orders of mammals dispersed into India rather than out of it. The Kuldana and Kalakot faunas of early middle Eocene age show an endemic diversification within some Holarctic groups that first appeared during Ghazij time (e.g., artiodactyls). Thus, early dispersal corridors were probably temporary, and endemism was initiated anew when the subcontinent was again partially isolated by marine incursions during early middle Eocene time.

10:30 **Godinot, M. and Gheerbrant, E.:** PALEOCENE-EOCENE MAMMALIAN TURNOVER IN EUROPE: COMPLETED PERSPECTIVE FROM LE QUESNOY FAUNA

GODINOT, Marc, EPHE, Paris, France; GHEERBRANT, Emmanuel, CNRS, Paris, France

Work in progress on the mammalian fauna from Le Quesnoy (Oise, France) contributes complementary information on the Paleocene-Eocene mammalian turnover in Europe. In comparison with the first mammalian reference-fauna of the European Eocene, the Belgian fauna of Dormaal, the Le Quesnoy fauna shows:

Among the small and middle-sized species, the presence of multituberculates, a paromomyid, *Hyopsodus* and *Cantius*, all taxa unknown in Dormaal. The rarity of *Paschatherium* in the Le Quesnoy fauna contrasts with its dominance in Dormaal. These marked differences must be due to a taphonomical bias in Dormaal and possibly also a biochronological difference.

Among the small and middle-sized species, a number are recorded for the first time in a fauna close to the Dormaal reference-level, increasing the number of probable North American immigrants in the European earliest Eocene. These include the paromomyid, a palaeonodont, and *Esthonyx*. A second perissodactyl larger than *Cymbalophus cuniculus* is also present, which, added to *Esthonyx*, diminishes the support for a PE III zone as defined by Hooker.

Among the middle-sized and large species, the presence of a large arctocyonid close to *Arctocyon* and the dominance of the *Plesiadapis* species increase the continuity with the Paleocene fauna of Berru. Dispersals dramatically changed the faunal composition. However, in contrast to the North American Interior, environments suitable for plesiadapids persisted in Europe after the Paleocene-Eocene boundary.

10:45 **Holroyd, P. and Huchison, J. H.:** DIVERSE DISPERSAL ROUTES FOR TURTLES IN THE PALEOCENE/EOCENE BOUNDARY INTERVAL

HOLROYD, Pat, HUTCHISON, J. Howard, Univ. of California Berkeley, Berkeley, CA

Most work on dispersal at the P-E boundary has focused on mammalian migration via high latitude corridors. However, this interval of global warming set the stage for more complex biogeographic

interchanges in other vertebrates. One of best records of significant dispersal is turtles. Within the earliest Eocene, a significant number of new taxa appear in both N. America (Wa0-Wa1) and Europe (MP7). Their phylogenetic relationships suggest multiple areas of origin.

The most detailed record of early Eocene turtles comes from the lowermost Willwood Formation in the Bighorn Basin of Wyoming. Here the Wa0 or boundary interval is marked by the appearance and geologically instantaneous dominance of the testudinoid *Echmatemys*. Additional immigrants appear within the first 120ka of the Wasatchian and include an additional, a rarer testudinoid and the kinosternid *Baltemys*. The detailed stratigraphic record available for the Bighorn Basin suggests that these migration events were comparatively rapid and concentrated in the earliest part of the Eocene. In Europe at least five immigrant taxa appear within MP7. These include the testudinoids *Francellia* and *Owenemys*, the carettochelyid *Allaeochelys*, the trionychid *Axestemys* (= *Palaeotrionyx*) and the podocnemidid *Neochelys*.

These dispersals occurred via diverse routes. Prior to the Eocene, testudinoids and carettochelyids are known only from Asia. Migration to Europe could have taken place via a number of routes, but the testudinoids in N. America must have arrived via a high-latitude corridor. Kinosternids are part of an exclusively N. American clade whose closest relatives are found in the Paleocene of the SE US. Their appearance in the Rocky Mountain Interior at the beginning of the Eocene represents a northern and/or western range expansion along continental waterways. The closest relatives of *Neochelys* are African, suggesting trans-Tethyan dispersal for this taxon. *Axestemys* is known from the earliest Paleocene in N. America and appears to be the sole immigrant from N. America to Europe.

11:00 **Kondrashov, P., Lopatin, A. and Lucas, S.:** MAMMALIAN FAUNAL CHANGE ACROSS THE PALEOCENE-EOCENE BOUNDARY AT THE TSAGAN KHUSHU AND NARAN BULAK LOCALITIES, MONGOLIA

KONDRASHOV, Peter, Northwest Missouri State Univ., Maryville, MO; LOPATIN, Alexey, Paleontological Institute of RAS, Moscow, Russian Federation; LUCAS, Spencer, New Mexico Museum of Natural History & Science, Albuquerque, NM

The Tsagan Khushu and Naran Bulak localities offer the most complete superposed assemblages of Gashatan and Bumbanian land mammal “ages” (lma) in Asia. As the Paleocene-Eocene (P/E) boundary is between these 2 lmas, these localities can be used to study faunal change at this time. The section includes three members: Zhigden, Naran (Gashatan lma, latest Paleocene), and Bumban (Bumbanian lma, earliest Eocene). There is an abrupt change in the mammalian fauna between the Gashatan members and the Bumban. None of the species cross the P/E boundary. The Gashatan fauna is endemic to Asia; the most common mammals are arctostylopids, mixodonts and pseudictopids. Rare Gashatan taxa include multituberculates; nyctitheriids *Praolestes nanus*, *P. maximus*, and *Jarveia erronea*; micropternodontids *Sarcodon pygmaeus* and *Hyracolestes ermineus*; a new geolabidid; didymoconid *Archaeoryctes euryalis*, rodentiaform *Tribosphenomys secundus* and mesonychian *Hapalodectes dux*. The Bumban fauna is very different. Besides typical Asian groups, such as mixodonts, it contains numerous foreign elements, such as condylarths (*Hyopsodus orientalis* and *Midiagnus gracilis*), primates (*Altanius orlovi*), creodonts (*Arfia* and ? *Prototomus*), perissodactyls (*Homogalax namadicus* and *Hyracotherium gabuniaii*) and artiodactyls (*Tsaganohyus pecus*). The fauna also includes numerous insectivores (Nyctitheriidae, Palaeoryctidae and Micropternodontidae) and rodents (Alagomyidae, Ivanantoniidae, Chapattimyidae). In Mongolia, the change in the mammalian fauna across the P/E boundary suggests that the main immigration event occurred at that time, and North American taxa, such as condylarths, perissodactyls and artiodactyls, quickly dispersed in the Asian biota. The appearance of these taxa in Asia is thus likely the result of immigration, which is confirmed by the total absence of

archaic ungulates in the Paleocene of Asia, while they are abundant in North America during this epoch. This contradicts the theory of Asia being the place of origin for Perissodactyla, Artiodactyla, and some other orders.

11:15 **Dawson, M.:** EARLY WASATCHIAN CYLINDRODONTID RODENTS: EVOLUTION IN THE GULF COASTAL PLAIN

DAWSON, Mary, Carnegie Museum-Vertebrate Paleontology, Pittsburgh, PA

Understanding of North American mammalian evolution at the Paleocene-Eocene boundary is skewed by the preponderance of localities of this age in the Rocky Mountain region and paucity of their record elsewhere. Those mammalian taxa that evolved under the various environmental conditions documented in the western Interior may thus be well known, whereas other lineages must be postulated only as gaps in the record. Such is the case for the cylindrodontid rodents, which are absent in Wasatchian faunas of the Rocky Mountain region. They became common components in many middle and late Eocene faunas of the Rocky Mountain region and experienced a radiation in the later Eocene of western Texas. This gap in cylindrodontid evolution is now being filled by the Red Hot local fauna of central Mississippi. The fossils of this fauna occur in estuarine sediments of the Tusahoma Formation, in the T4 sands. Correlation using marine taxa equates these sands with calcareous nannoplankton zone NP9. In turn the Red Hot local fauna appears to be older than the Dormaal fauna, one of the oldest Sparnacian faunas, MP7, of western Europe. The rodent record from the Red Hot local fauna indicates that at least some faunal provincialism, related to both geographic and environmental conditions, can be postulated to characterize the early Wasatchian within North America.

11:30 **Hooker, J.:** A NEW OMOMYID PRIMATE FROM THE UK EARLY EOCENE: ITS PHYLOGENETIC AND PALAEOBIOGEOGRAPHIC IMPLICATIONS

HOOKE, Jeremy, Natural History Museum, London, United Kingdom

A new genus and species of omomyid is described from the early early Eocene (Ypresian, c.54.5ma) Blackheath Beds of Abbey Wood, London, UK. Cladistic analysis of this taxon in combination with a diversity of other early omomyids shows it to be clearly a stem member of the endemic European subfamily Microchoerinae. This is in significant contrast to certain close resemblances between the Abbey Wood mammal fauna and penecontemporaneous ones from western North America. These resemblances extend to sibling species within genera (e.g. the dawn horses *Pliolophus vulpiceps* and *P. pernix* and the 'condylarths' *Hyopsodus wardi* and *H. loomisi*) and even to species shared by the two continents (e.g. the creodont *Oxyaena gulo* and the multituberculate *Ectypodus childei*).

The higher relationships of the Abbey Wood microchoerine within the family Omomyidae are less resolved, although it shares more derived character states with omomyines than with anaptomorphines. The implication of its subfamily affinity is that by the time of deposition of the Blackheath Beds, there was no longer any interchange of omomyids between Europe and North America. This contrasts with the time of the Mammalian Dispersal Event (MDE) at 55.5ma, when closely related species of *Teilhardina* inhabited both continents.

The Abbey Wood taxa that show closest taxonomic similarity to those of western North America are terrestrial or semiterrestrial animals. The arboreal primates, Microchoerinae gen. et sp. nov. and *Cantius eppsi*, and the scansorial paromomyid *Arcius* diverge more from their American cousins. This suggests that what had been a full land bridge linking North America and Europe through Greenland at the dawn of the Eocene had, by 1my later, become a filter that allowed terrestrial mammals to cross, but prevented tree-dwellers. One possible cause is that outpourings of Greenland and Hebridean lavas broke the continuity of the high latitude forest belt that must have existed to facilitate the MDE.

11:45 **Secord, R. and Gingerich, P.:** REVISED MAMMALIAN BIOSTRATIGRAPHY FOR THE TIFFANIAN AND CLARKFORKIAN LAND-MAMMAL AGES (LATE PALEOCENE) OF THE BIGHORN BASIN, WYOMING

SECORD, Ross, GINGERICH, Philip, Univ. of Michigan, Ann Arbor, MI

The northern Bighorn Basin preserves one of the richest sequences of superposed mammalian faunas of late Paleocene age in the world. These faunas have been widely used as a basis for regional biostratigraphic zonation. New stratigraphic sections, new collections, and further study of preexisting Tiffanian land mammal age faunas, has resulted in a revision of the zonation and a downward shift of several zonal boundaries. Biozonation for most of the late Paleocene is based on evolutionary lineages of *Plesiadapis*. We recognize a new zone (Ti-4b), based on the first occurrence of the plesiadapiform *Phenacolemur*, that includes faunas previously placed in the *Plesiadapis churchilli* and *Plesiadapis fodinatus* zones (Ti-4a and Ti-5a, respectively). Ambiguities in recognition of the first occurrence of *Plesiadapis fodinatus* lead us to abandon the *P. fodinatus* zone and recognize a new zone (Ti-5a revised) based on the first occurrence of the uinthere *Probathyopsis*. Finally, we abandon the late Clarkforkian *Phenacodus-Ectocion* acme zone (Cf-3) and recognize a new zone (Cf-3 revised) based on the first occurrence of the phenacodontid *Copecion*.

The lower and upper boundaries of the *P. churchilli* zone were previously placed in Chron C26N and C25R, respectively. Based on the occurrences of characteristic Ti-4 zone taxa at lower levels in the Polecat Bench sequence, however, and on the recognition of Ti-4b, both boundaries are moved downward into Chron C26R. The principal fauna known from the “type” Tiffanian in Colorado is from Mason Pocket, which lies near the base of an interval of reversed polarity about 140 meters thick. It was previously considered a correlative of the *P. churchilli* zone and correlated to Chron C25R. We agree with the faunal correlation, but based on the temporal ranges of taxa from Mason Pocket in the Bighorn Basin, conclude that it lies in Chron C26R, making it substantially older.

Refinement of the biozonation and documentation of stratigraphic ranges of all late Paleocene mammalian taxa will facilitate the regional correlation of other faunas.

12:00 **Wang, Y. and Jin, X.:** REVIEW OF CHINESE PALEOCENE TILLODONTS (TILLODONTIA, MAMMALIA)

WANG, Yuanqing, JIN, Xun, Inst. of Vert. Paleontol. & Paleoanthropol., Beijing, Peoples Republic of China

Discovery of Chinese Paleocene tillodonts has been considered as indicative of their Asian origin. Ten Chinese Paleocene mammal species were originally assigned or later reallocated to the order Tillodontia. However, the systematic position of some taxa has been questioned for many years. The primary reason for the situation is that the primitive tillodonts shared some dental morphological features with primitive pantodonts. Based on the observation of typical tillodonts and comparison of tillodonts with pantodonts, we can distinguish tillodonts from pantodonts by the combination of the following dental characters: enlarged I2/2, conical paracone and metacone, paracrista and metacrista adducted at their labial ends, anteroposteriorly compressed and U-shaped trigonid, and M<sub>3</sub> with hypoconulid lobe (trilobite). Review of all Chinese Paleocene tillodonts and phylogenetic analysis suggest that, of 10 genera and species, *Lofochaius*, *Meiostylodon*, *Interogale*, *Plethorodon*, *Simplodon*, and newly named *Benaius* have affinities to the order Tillodontia, whereas *Anchilestes*, *Dysnoetodon*, *Huananius*, and *Yuesthonyx* do not have close relationships to tillodonts. Fossil record of tillodonts in the Paleogene of Asia, North America, and Europe denotes that the Asian originated tillodonts

immigrated to North America in late Paleocene together with *Alagomys* and other animals and have a Holarctic distribution at the beginning of Eocene.

12:15 **Miyata, K. and Tomida, Y.:** EARLIEST KNOWN EOCENE MAMMAL FAUNAS FROM JAPAN: DIVERSITY AND CORRELATION WITH ASIAN LAND MAMMAL AGES

MIYATA, Kazunori, Fukui Prefectural Dinosaur Museum, Fukui, Japan; TOMIDA, Yukimitsu, National Science Museum, Tokyo, Japan

The earliest known Eocene mammal fauna from Japan is represented by three trogosine tillodonts, two coryphodontid pantodonts, an isctolophid perissodactyl, and an unidentified rodent, from the Akasaki Formation, Kumamoto Prefecture. The Akasaki fauna is chronologically significant because it is placed near the early / middle Eocene boundary, based on preliminary paleomagnetic data and stratigraphic correlations with the overlaying marine strata bearing nannofossils.

Recent fieldwork not only has led to discoveries of new material documenting greater diversity of the Akasaki fauna, but also has revealed the occurrence of another contemporaneous mammal fauna from the Nakakoshiki Formation in Kagoshima Prefecture, which is stratigraphically correlated with the Akasaki Formation. The latest specimens from the Akasaki Formation include new artiodactyls and a hyopsodontid condylarth. One of the artiodactyl specimens preserves a left mandible with a nearly complete dentition and long diastemata between canine and P<sub>3</sub>, as in the Irдинmanhan *Gobiohyus*, but the likely associated upper molars show homacodontid-like cusp patterns with sharp hypocones. The Akasaki hyopsodontid, represented by a right mandible with P<sub>3</sub>-M<sub>2</sub>, is referable to a large species of *Hyopsodus*, differing from the Bumbanian *Hyopsodus orientalis*. The Nakakoshiki Formation, in addition to two early brontotheriid perissodactyls reported on last year, yielded new specimens of two hyopsodontids, a coryphodontid, and a miacid carnivoran. The Nakakoshiki hyopsodontids are also possible *Hyopsodus* species with large lower molars.

Given the occurrences of trogosines and brontotheriids, the Akasaki and Nakakoshiki faunas are correlated with Arshantan rather than Bumbanian faunas on the Asian mainland. These new specimens from Japan indicate that hyopsodontid and artiodactyl distributions differed from those recorded from mainland Asia where both were rare elements in Arshantan assemblages. On the mainland hyopsodontids were mostly restricted to the Bumbanian while artiodactyls did not become abundant until the Irдинmanhan.



3. **Smith, J., Hasiotis, S. and Kraus, M.:** PRELIMINARY STUDY ON THE OCCURENCE AND DISTRIBUTION OF TRACE FOSSILS IN PALEOSOLS ACROSS THE PALEOCENE-EOCENE THERMAL MAXIMUM (PETM) IN THE BIGHORN BASIN, WYOMING

SMITH, Jon, HASIOTIS, Stephen, Univ. of Kansas, Lawrence, KS; KRAUS, Mary, Univ. of Colorado, Boulder, CO

The Paleocene-Eocene Thermal Maximum (PETM) is recorded in strata of the lower Eocene Willwood Formation in the Bighorn Basin, Wyoming. This abrupt global warming event coincides with a significant change in fossil mammal assemblages and anomalous isotopic carbon values from pedogenic carbonates. Soil biota, as represented by their fossil traces, may have also responded to the PETM warming event. Preliminary work has focused on the occurrence and distribution of ichnofossils in paleosols of the Willwood Formation. A diverse and abundant ichnofossil assemblage occurs in fine-grained mudstones and heterolithic avulsion deposits showing varying degrees of pedogenic modification. Trace fossils include root traces and a wide variety of invertebrate and vertebrate burrows. Ichnotaxa are largely restricted to specific paleosols depending on the relative degree of pedogenic modification. Mature, variegated mudstones of the distal floodplain contain the most numerous and diverse ichnofossil assemblage, while heterolithic units have a lower occurrence and diversity of trace fossils. This preliminary work provides a framework for comparing ichnologic assemblages between similar paleopedologic units occurring before, during, and after the PETM interval.

4. **White, P. and Schiebout, J.:** THE STABLE ISOTOPE STRATIGRAPHY AND PALEOSOLS OF NORTH AMERICA'S MOST SOUTHERN EXPOSURE OF LATE PALEOCENE/EARLY EOCENE FOSSILIFEROUS CONTINENTAL DEPOSITS: DOCUMENTING THE INITIAL EOCENE THERMAL MAXIMUM IN BIG BEND NATIONAL PARK TEXAS

WHITE, Paul, Baton Rouge, LA; SCHIEBOUT, Judith, Louisiana State Univ., Baton Rouge, LA

Outcrops in Big Bend National Park, Texas are North America's most southern exposure of early Paleogene continental deposits in which the Paleocene/Eocene transition is constrained by the occurrence of fossil mammals. A chemostratigraphic section using the stable isotopes of carbon and oxygen has been developed. A negative carbon excursion has been identified within C24r and is bracketed by a late Tiffanian or Clarkforkian fossil site and an early Wasatchian (Wa-1) site, which is the oldest Eocene terrestrial vertebrate site recognized in Big Bend and has yielded the stratigraphically lowest *Hyracotherium* in the Big Bend region. The range in  $\delta^{13}\text{C}$  values is from -8.1 to -13.2 per mil. Because of the condensed nature of the section and pedogenic overprinting, the interpretation of the negative carbon excursion is complex, as are its effects on pedogenic processes. Changes in pedogenesis did occur during this global warming event, and resulted in an increase in the translocation of clays and the leaching of calcite and plagioclase. To further examine the possible effects of the IETM on pedogenesis in the study area, the chemical index of alteration (CIA) was calculated for pre IETM paleosols and paleosols that occur within the negative carbon excursion. Pre IETM paleosol B horizons have an average CIA of approximately 70, and IETM paleosol B horizons have an average CIA of 69. The small difference between the CIA's of these two groupings of paleosols suggests that during the IETM, climatic conditions did not change enough to cause an increase in weathering. The clay mineralogy of Pre IETM paleosols is dominated by smectite, and it is only within the carbon excursion that there is a change. There is a notable increase in the amount of kaolinite in one paleosol horizon that is associated with the carbon excursion. Although the CIA data do not suggest any change in chemical weathering during the IETM, the increase in kaolinite, translocation of clays and an increase in the leaching of calcite and plagioclase suggests that there was a change in pedogenesis associated with this ancient global warming event.

**TECHNICAL SESSION XI**  
**GOVERNOR'S SQUARE 14**  
**MODERATORS: PER AHLBERG AND MICHAEL NEWBREY**

8:00 **Schoch, R. and Milner, A.:** INTRARELATIONSHIPS, MONOPHYLY AND EVOLUTION OF THE BRANCHIOSAURIDAE

SCHOCH, Rainer, Staatliches Museum fuer Naturkunde Stuttgart, Stuttgart, Germany; MILNER, Andrew, Birkbeck College, London, United Kingdom

Branchiosauridae are small gill-bearing temnospondyl amphibians. Most are from the Permo-Carboniferous limnic deposits of Central Europe. They appear to represent a single clade of dissorophoids related to the more terrestrial Amphibamidae. A cladistic analysis was undertaken based on 39 characters of 11 well-characterised species belonging to 4 genera of branchiosaurid, together with the dissorophoids *Amphibamus*, *Platyrhinops*, *Micromelerpeton*, *Micropholis* and *Ecolsonia*. Outgroups were the primitive temnospondyl *Balanerpeton* and the stem-stereospondyl *Sclerocephalus*.

Branchiosauridae appears to be monophyletic in this analysis, with Amphibamidae as its sister-taxon. Within the Branchiosauridae, *Branchiosaurus* is the basal genus with the remaining species forming two clades, one comprising *Apateon* species and the other comprising *Melanerpeton* and *Schoenfelderpeton*. *Apateon* includes *A. gracilis*, a species previously referred to *Melanerpeton*. *Melanerpeton* is paraphyletic with respect to *Schoenfelderpeton*. *A. gracilis* is the only species which appears to metamorphose into a terrestrial adult.

Most known Branchiosauridae appear to have been neotenus animals feeding on plankton, and the key family characteristic is the branchial ossicles with brush-like denticles. Other dissorophoid larvae have simpler single-spiked gill-rakers. Much of the diversification of the family appears to have been based on variation in feeding mechanisms involving suction-gulping and prey-processing in the mouth. Either neoteny was obligate in the family and reversed in *A. gracilis*, or it was facultative in the family but only expressed in lowland species.

8:15 **Robinson, J. and Ahlberg, P.:** THE IMPEDANCE MATCHING EAR AND BRAINCASE OF THE EARLY TEMNOSPONDYL *DENDRERPETON ACADIANUM*

ROBINSON, Jamie, The Natural History Museum, London, United Kingdom; AHLBERG, Per, Uppsala Univ., Uppsala, Sweden

*Dendrerpeton acadianum* from the Westphalian A of Joggins, Nova Scotia, is one of the earliest and phylogenetically most basal temnospondyls. Its external cranial anatomy has been used previously to suggest the presence of a tympanic membrane and an impedance matching ear. However supporting evidence for this from stapedial and braincase morphology has so far been wanting. The only known stapes, from the Natural History Museum specimen BMNH R.436, is only partially exposed but was reconstructed by Clack (1983) as having a unique morphology, intermediate between a typical temnospondyl stapes and a more primitive tetrapod pattern such as that in *Pholiderpeton*. The braincase has remained almost wholly unknown.

CT scanning and 3D computer reconstruction of BMNH R.436 has been used to shed light on these important areas in *Dendrerpeton acadianum*. Both stapes prove to be present in the specimen; the right stapes (described by Clack) is somewhat compressed, but the left stapes lies inside the cranial cavity and



is perfectly preserved. It proves to be of a normal temnospondyl shape, quite similar to *Doleserpeton*. The morphology and orientation of the stapes provide strong evidence for the presence of an impedance matching ear with similarities to the extant amphibian condition. The reconstructed braincase shows a high degree of similarity to that of other basal temnospondyls. This gives supporting evidence that *Dendrerpeton acadianum* is correctly placed in the temnospondyl phylogeny and thus demonstrates one of the earliest impedance matching hearing systems that can be homologised with the extant amphibian condition.

8:30 **Retallack, G.:** PALEOENVIRONMENTS OF LATE DEVONIAN TETRAPODS FROM PENNSYLVANIA

RETALLACK, Gregory, Univ. of Oregon, Eugene, OR; HUNT, Russell, Eugene, OR

The Upper Devonian (Famennian-Fa2c), Duncannon Member, Catskill Formation near Hyner, has yielded two tetrapods (*Hynerpeton basseti* and *Densignathus rowei*), and a humerus that may belong to a third species (ANSP21350). We studied 41 successive paleosols of 6 different kinds there. Fossil Aridisols have root traces of progymnosperm shrubland and formed under 686+/-141 mm mean annual precipitation, estimated from a transfer function for depth to calcic horizon in modern soils after correcting for compaction by 7.5 km of overburden. Fossil Vertisols formed under 821+/-141 mm per annum, with pronounced dry season, and open woodland of *Archaeopteris*, were similar to soils along the Barwon River near Walgett, Australia. Vertisols and Aridisols alternate at Hyner, like other Catskill cycles attributed to Milankovitch-eccentricity cycles (100 kyr). Tetrapods were found in Entisols of the wet part of the climate cycle, not the dry part. They lived in vegetation-choked streamside swales and anabranches, which were seasonally dry, as indicated by oxidized red Entisols with large burrows like those used for aestivation, and by charcoal in gleyed Inceptisols of Rhacophyton swamps. Tetrapods of vegetation-choked streamside swales during the wet season avoided 3-4-m-long predatory fish (*Hyneria lindae*) of open water. Tetrapod bones are cracked and disarticulated in red Entisols, as if victims of dry-season death, decay, and weathering. How large (0.8-1 m) and long-lived tetrapods survived the dry season is unclear, because none were found in aestivation burrows or paleochannels. They may have migrated to wetter regions during climatic drying every 100 kyr, and to local ponds in rivers during dry seasons. Thus we regard tetrapod limbs from Hyner as adaptations for climbing through vegetation-choked shallow water with food of small fish, arachnids, myriapods and scorpions. Classical scenarios of tetrapod limbs as adaptations to overland escaping or relocating shrinking ponds in dry climates or seasons are unlikely. If they came out of water at all, it was during wet seasons of breeding and feeding, rather than fatally dry seasons.

8:45 **Garcia, W.:** EARLY TETRAPOD MATERIAL FROM A PALEOSOL IN THE BUFFALO WALLOW FORMATION (MISSISSIPPIAN, NAMURIAN A) OF WESTERN KENTUCKY, U.S.A.

GARCIA, William, Univ. of Cincinnati Geology Dept, Cincinnati, OH

The Hancock County locality in north-central Kentucky, U.S.A. preserves a diverse fish and tetrapod fauna from four distinct facies: marine limestone, sandstone channel deposits, freshwater ox-bow lake, and a floodplain paleosol. Facies are from the Buffalo Wallow Formation (Mississippian, Namurian A). The paleosol fauna is of particular interest because tetrapods have not been previously described from such a facies. Material collected to date indicates a minimum of two taxa within the fauna including an embolomere and a whatcheerid. The embolomere material is divided into at least three distinct size classes while the whatcheerid material comes from only a single size class. Additional material conforms to both whatcheerid and embolomere morphology and thus cannot be diagnosed further. Vertebrae from the facies are notable for the high degree of suturing and fusion among central elements.

The embolomeric vertebrae possess dorsally complete pleurocentra with large notochordal canals and are fused to their neural arches. Fusion is known to occur among some vertebrae in certain embolomeric taxa. A small section of whatcheerid vertebrae exhibit suturing of the inter- and pleurocentra as seen in *Whatcheeria*. Fusion and suturing of multipartite vertebrae has often been associated with increased support. Four ilia representing unknown taxa similar in morphology to material from Delta, Iowa are known from the paleosol. These bifurcate ilia are unique among early tetrapods in having a small ventrally oriented dorsal shelf on their acetabula. In the smallest of the ilia this orientation is ventro-lateral. Early tetrapod ilia lack ventrally facing lateral projections, having at most a small dorsal ridge marking the dorsal border of the acetabulum. Although not large enough to buttress the entire femoral head, this shelf would have transferred vertical forces received by the limb to the pelvic girdle. This transfer of forces would have been useful during locomotion on firm substrates and suggests a greater degree of terrestrial locomotory capability than is known for other Mississippian taxa.

9:00 **Gao, K.-Q., Fox, R., Li, D. and Zhang, J.:** A NEW VERTEBRATE FAUNA FROM THE EARLY TRIASSIC OF NORTHERN GANSU PROVINCE, CHINA

GAO, Ke-Qin, Peking Univ., Beijing, Peoples Republic of China; FOX, Richard, Univ. of Alberta, Edmonton, AB, Canada; LI, Daqing, Bureau of Geological Survey, Gansu Province, Lanzhou, China; ZHANG, Jianping, China Univ. of Geosciences, Beijing, China

The Beishan area in northern Gansu Province, China, is part of the "Black Gobi," probably visited by the Sino-Swedish Expeditions of 1927-1935. Recent fieldwork by a joint party from Peking University and the Geological Survey of Gansu Province has resulted in the discovery of an interesting vertebrate fauna from the Triassic beds in the Beishan area. The vertebrate fauna shows considerable taxonomic diversity, containing a freshwater shark, a coelacanth, actinopterygian fishes, two kinds of amphibians, a lizard-like diapsid, and a eucynodont therapsid. The freshwater shark is hybodontid-like with two dorsal spines. Large coelacanths are known from several nearly complete skeletons, documenting a rare record of the group in China. Actinopterygians are the predominant fishes here, represented by several hundred specimens. The amphibians include a microsauro-like lepospondyl and a branchiosaurid-like temnospondyl, the first records of either group from Asia. The eucynodont therapsid is Sinognathus-like, with a short snout, laterally flaring zygomatic arches, and a well-developed sagittal crest. This taxon provides the most reliable evidence for the Early Triassic age of the fossil beds, as no known eucynodonts are older than Early Triassic. The fossil-bearing deposits mainly consist of dark silty shales, derived from a metamorphic rock source, as indicated by the strained quartz crystals. Most of the specimens are preserved in full articulation, showing little current disturbance or scavenging, and indicating a quiet water depositional environment for the Gansu fauna.

9:15 **Ahlberg, P. and Luksevics, E.:** NEW LIGHT ON THE DEVONIAN TETRAPOD *VENTASTEGA CURONICA*

AHLBERG, Per, Uppsala Univ., Uppsala, Sweden; LUKSEVICS, Ervins, Univ. of Latvia, Riga, Latvia

Only two of the 10 known Devonian tetrapod genera, *Ichthyostega* and *Acanthostega*, both from the Famennian of Greenland, are represented by extensive articulated material. Most are very fragmentary, with some known only from lower jaws. Here we present an overview of the material of the late Famennian tetrapod *Ventastega curonica*, collected from the Ketleri Formation of Latvia since 1991. *Ventastega* is represented by virtually the whole skull and lower jaw, most of the shoulder girdle, part of

the pelvis, and fragments of the axial skeleton (ribs and tail fin rays). This makes it the most complete Devonian tetrapod after *Ichthyostega* and *Acanthostega*.

Although contemporary with these genera, the lower jaw of *Ventastega* suggests that it is more primitive than either. However, its general morphology closely resembles *Acanthostega*. Shared characters include: paired median rostrals; a loosely attached dentary; an internasal fontanelle; the morphology of the otic capsule; a kite-shaped interclavicle; short, slender ribs; a slender ilium with a posterodorsally directed postiliac process and no iliac canal; and (probably) large caudal lepidotrichia. Large caudal lepidotrichia and small slender ribs are clearly symplesiomorphies. The internasal fontanelle is obviously derived, as it is absent in all non-tetrapod outgroups, but its distribution among tetrapods is patchy and does not seem to define a clade. Some of the *Acanthostega*-like features (braincase, ilium, shape of interclavicle) persist into more derived tetrapods, indicating that they are attributes of a segment of the tetrapod stem lineage rather than characters of an *Acanthostega*-*Ventastega* clade. Unique features of *Ventastega* include a fish-like orbitotemporal braincase region and the large size of the internasal fontanelle. Overall, *Ventastega* appears to be a less crownward tetrapod than *Acanthostega*; their shared characters are probably attributes of a segment of the tetrapod stem lineage.

9:30 **Jenkins, Jr., F., Shubin, N., Gatesy, S. and Warren, A.: GERROTHORAX PULCHERRIMUS FROM THE UPPER TRIASSIC FLEMING FJORD FORMATION OF EAST GREENLAND AND A REASSESSMENT OF THE CONTRIBUTION OF HEAD LIFTING TO FEEDING IN TEMNOSPONDYLS**

JENKINS, Farish, Harvard Univ., Cambridge, MA; SHUBIN, Neil, Univ. of Chicago, Chicago, IL; GATESY, Stephen, Brown Univ., Providence, RI; WARREN, Anne, La Trobe Univ., Bundoora, Melbourne, Victoria, Australia

Well-preserved material of *Gerrothorax pulcherrimus* permits reassessment of the unusual feeding mechanism that has been proposed for plagiosaurs as well as for other temnospondyls. Aquatic temnospondyls, especially those with flat skulls, have been interpreted as having achieved a large gape by elevating the skull rather than by lowering the jaw. No corroborating anatomical evidence from the atlanto-occipital joint, however, has ever been adduced.

In *Gerrothorax pulcherrimus* the widths of the atlantal and condylar facets are comparable, but dorsoventrally the condylar facets are 45 percent longer than the comparable dimension of the atlantal facets. Elevation of the skull occurred by atlanto-occipital rotation, and was facilitated by a radius of curvature of the superior part of the occipital condylar facets that is shorter than that of the inferior part. From a resting, closed mouth position, *G. pulcherrimus* was capable of elevating the skull through an excursion of approximately 50°, a movement that rotated the quadrate forward and protruded the lower jaw.

Several features appear to be related to relieving the spinal medulla of the sharp angular deformation that head lifting might entail. Long condylar processes effectively lengthen the neural canal between the foramen magnum and the atlantal neural arch. The neural canal in this region is open dorsally (without a bony roof) by virtue of the anterior inclination of the occiput and the recessed anterior margins of the atlantal laminae. Bending of the medulla need not have been concentrated solely at the transverse plane of the atlanto-occipital joint, but could have been distributed along a greater length of the cord in the elongate, dorsally open neural canal between the foramen magnum and atlantal arch. Minimal deformation of the spinal medulla during head lifting occurs if the joint axis is positioned so as to pass through the spinal medulla. In *Gerrothorax pulcherrimus* and other plagiosaurs the condyles have

shifted dorsally to achieve this effect. This suite of features does not appear to be common in non-plagiosaurid temnospondyls.

9:45 **Sidor, C., Damiani, R., Larsson, H. C. E., O’Keefe, F. R., Smith, R. M. H. and Steyer, J.-S.:** LATE PERMIAN TETRAPOD BIOGEOGRAPHY: NEW INSIGHTS FROM WEST AFRICA

SIDOR, Christian, New York College of Osteopathic Medicine, Old Westbury, NY; DAMIANI, R., Univ. of the Witwatersrand, Johannesburg, South Africa; LARSSON, H.C.E., McGill Univ., Montreal, QB, Canada; O’KEEFE, F. R., NY College of Osteopathic Medicine, Old Westbury, NY; SMITH, R.M.H., South African Museum, Cape Town, South Africa; STEYER, J.-S., Paleontologie MNHN-CNRS, Paris, France

For over 150 years, Middle and Late Permian fossils from southern Africa have shaped our understanding of end-Paleozoic terrestrial ecosystems. The richness of these beds, particularly South Africa’s Karoo Basin, has provided fundamental insight into the origin of modern terrestrial trophic structure in addition to the early evolution of mammalian forebears. The composition of the Karoo fauna can be traced to coeval Gondwanan rocks in Brazil, India, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, as well as Laurasian strata in Germany, Scotland, and Russia. This broad geographic distribution provides compelling evidence for the unrestricted dispersal of tetrapods across a coalesced Pangean landscape and implies a relatively cosmopolitan end-Permian fauna.

Recent fieldwork in the Upper Permian Moradi Formation of northern Niger has yielded a fauna that is strikingly different from those known elsewhere on Africa. In addition to previously reported reptiles (i.e., the captorhinid *Moradisaurus grandis* and the pareiasaur *Bunostegos akokanensis*), three new temnospondyls are equally bizarre. The first taxon shares features with edopoids, a group previously known only from the Permo-Carboniferous of Euramerica. The second taxon is the first Permian dvinosaurian from Gondwana, possibly related to Russian or North American forms. The third taxon is the largest, but also the least complete. We tentatively identify this specimen as a brachyopoid, which would be the earliest record of an otherwise Triassic group.

Taxa recovered from the Moradi Formation counter longstanding biogeographic theories of faunal homogeneity. For example, the fauna of the Moradi Formation is clearly endemic. Moreover, preliminary phylogenetic research suggests that the Moradi taxa do not cluster with southern African forms. Ecologically, the Moradi fauna apparently lacks the dicynodonts that are so commonly preserved in other Upper Permian rocks. We hypothesize that faunal differences between West and southern Africa are due to biogeographic isolation caused by the desert-like conditions that prevailed in central Pangea during Late Permian times.

10:00 **BREAK**

10:15 **Anderson, P., Westneat, M. and Coates, M.:** FEEDING IN PLACODERMS: BUILDING A BIOMECHANICAL MODEL OF SKULL KINETICS IN DEVONIAN FOSSIL FISHES

ANDERSON, Philip, Univ. of Chicago, Chicago, IL; WESTNEAT, Mark, Field Museum, Chicago, IL; COATES, Mike, Univ. of Chicago, Chicago, IL

Biomechanical models illustrate how physical laws constrain function in organisms, allowing ecological inferences and predictions to be made based on the models. Morphological diversity does not necessarily correlate with functional diversity when complex systems are examined. Dynamic linkage and lever models of feeding in fishes predict function from morphology and have been used to quantify ecological disparity. Inferring aspects of ecology from morphology is a powerful tool for vertebrate paleontology, and allows for more quantitative paleoecological studies. In this paper, we offer an

example for the construction and use of a dynamic biomechanical linkage model in arthrodire placoderms. Placoderms are particularly appropriate fossils for biomechanical modeling, as they are frequently preserved three-dimensionally.

A study of muscle homology between representatives of Osteichthyes, Elasmobranchii and Holocephalii is used to determine a baseline muscle arrangement for lower vertebrates. This is the basis for a muscle reconstruction in the skull of *Dunkleosteus terrelli*. A four-bar linkage model for feeding in *Dunkleosteus* is then constructed. Model simulations including muscle reconstructions show that cranial elevation and jaw rotation are similar to extant fishes, ranging from 20-30 degrees for cranial rotation and 40-60 degrees for jaw rotation. We used a third-order lever model to describe lower jaw closing mechanics in six placoderm genera. We compared MA among species, for different possible inlevers and outlevers within jaws. Our results indicate a wide range of MA values among groups. The MA values are comparable to modern fish, with a larger range of values. A great deal of variation is also seen within jaws of a single group depending on the differences in dentition along a single jaw.

10:30 **Carr, R.:** RECOGNITION AND INTERPRETATION OF SNOUT ELONGATION AND THE ANTERIOR NEUROCRANIUM IN BRACHYTHORACID ARTHRODIRES (PLACODERMI)

CARR, Robert, Ohio Univ., Athens, OH

Among craniates, much attention is directed to understanding the skull: its origin, organization, and development, with increased emphasis on anatomical interpretation as a necessary component of phylogenetic systematics. The dermatocranium serves as a primary source of characters, with the less well-preserved neurocranium, splanchnocranium, and soft tissues gaining in importance. As systematic work considers new fossils, our understanding of the head becomes more critical.

The placoderms are the least known in terms of gnathostome cranial anatomy. A review of the snout in brachythoracid arthrodires (the dominant Late Devonian placoderm subgroup) demonstrates the independent origin of elongation at least six times. Only in *Carolowihelmina*, with its unique association of sensory lines, pits, and depressions on the rostrum may the elongation be correlated with a sensory function. A functional correlation, in other forms, is not clear.

The anterior neurocranium is a stable structure within Arthrodira. Only four variations from the plesiomorphic pattern are observed: (1) shift in the relative position of landmarks associated with enlargement of the orbits in *Tapinosteus* and *Pholidosteus*; (2) ectethmoid expansion in dunkleosteids associated with functional support of the enlarged anterior superognathal; (3) expansion of the rhinocapsular ossification in *Rolfosteus* associated with enlargement of the olfactory tracts and bulbs; and (4) rotation of the cribrosal from a ventral orientation to an anterior one. Current data suggest that these examples represent isolated variations on a generalized pattern for the arthrodiran neurocranium.

Despite gains, several research avenues will improve our anatomical knowledge base. These include a reanalysis of the 'neurocranial scraps' of previous research, a concerted effort to prepare material preserving components of the neurocranium, a review of unpublished data from the serial sections of Stensio, and promising new discoveries of arthrodiran taxa. Taken together these approaches offer great promise to advance the anatomical knowledge of the Arthrodira.

10:45 **Davis, M.:** THE HOMOLOGY OF THE PAIRED APPENDAGE ENDOSKELETON: RECONCILING EMBRYOLOGICAL AND PALEONTOLOGICAL DATA

DAVIS, Marcus, Univ. of California - San Francisco, San Francisco, CA

Discussions on the putative homology of the various elements of the fin/limb endoskeleton have a long and circuitous history. A central issue has been how to reconcile observations of process, such as embryological data, with the resultant morphology that derives from these processes. For example, fossil

evidence supports the hypothesis that a tribasal paired fin endoskeleton, consisting of pro-, meso-, and metapterygial elements, is the primitive condition for gnathostomes. This condition has been modified in sarcopterygians and derived actinopterygians (specifically teleosts), each of which are characterized by evolutionary loss of specific elements of the tribasal bauplan. Yet, despite sharing a common evolutionary origin, comparative embryological studies reveal that the mechanisms of endoskeletal development differ markedly in teleost and sarcopterygian appendages.

The study of pectoral fin development in basal actinopterygian and chondrichthyan taxa reveals that aspects of both sarcopterygian and teleost endochondral patterning mechanisms are present in basal gnathostomes. This suggests that the distinct ways by which teleost fins and sarcopterygian fin/limbs develop do not involve the acquisition of novel patterning mechanisms but, instead, are the result of correlative loss of patterning mechanisms specific to portions of the primitive gnathostome pectoral bauplan. Data also supports the interpretation that the metapterygium is an embryologically distinct structure, sharing more in common with the endochondral shoulder girdle in its mode of development than with the rest of the paired fin skeleton.

11:00 **Fierstine, H. and Weems, R.:** A FINE CATCH OF BILLFISH FROM THE OLIGOCENE OF SOUTH CAROLINA

FIERSTINE, Harry, California Polytechnic State Univ., San Luis Obispo, CA; WEEMS, Robert, Geological Survey, Reston, VA

The Ashley and Chandler Bridge Formations near Charleston, South Carolina, have yielded numerous billfish remains (Perciformes: Scombroidei: Palaeorhynchidae and Xiphidae) that represent three species of *Aglyptorhynchus*, two of which are new, and one species of *Xiphiorhynchus*.

Although no one specimen of *Aglyptorhynchus* is complete, the sum total of elements yields a morphological picture heretofore unknown or only surmised for the genus. The head is compressed and deep with the lower jaw equal to subequal in length to the rostrum. The rostrum could elevate and depress because of the joint structure between the maxillary and ethmoid; the suspensorium allowed only lateral and medial movements; the jaw joint is located at the level of the orbit, was weak, and only permitted limited opening and closing. There is a ball and socket joint between the head and first vertebra, a condition found in only one other teleost. The vertebral column has expanded neural spines and overlapping zygapophyses that probably functioned to stiffen the backbone. The hypural is a fused element that housed a stiff caudal fin with a high aspect ratio.

*Xiphiorhynchus rotundus* long was known only from the holotype (BMNH P8799), a stout, distal rostrum with a vague provenance (Tertiary phosphate beds, Cooper River, South Carolina). An additional specimen of *X. rotundus* now is known from the Chandler Bridge Formation. Based on recent stratigraphic work in the Charleston area, we conclude that the holotype originally came from a late Oligocene or early Miocene deposit. Large vertebral centra, up to 147 mm long and 109 mm in diameter, provide evidence that *Xiphiorhynchus* grew to become a giant fish.

11:15 **Newbrey, M., Ashworth, A. and Wilson, M.:** GEOGRAPHIC TRENDS IN NORTH AMERICAN FRESHWATER FISHES FROM THE CRETACEOUS TO THE PLIOCENE

NEWBREY, Michael, ASHWORTH, Allan, North Dakota State Univ., Fargo, ND; WILSON, Mark V. H., Univ. of Alberta, Edmonton, AB, Canada

The age - latitude relationships for 54 taxa within 37 families of freshwater fishes were examined from over 150 fossil localities from the Late Cretaceous to the Pliocene in North America. Within the data, 16 southerly linear trends were detected for which regression analyses indicate significant relationships. The results suggest that a common process might link the patterns. Processes that could

account for trends on a scale of millions of years include those associated with evolution, plate tectonics, and climate change. For any taxonomic grouping, a trend might have an evolutionary cause. However, it is improbable that evolution would result in geographically similar trends between several distantly related groups. Southerly trends could also result from transport of fossils by movement of the North American plate. However, the rates of movement measured from the trends are too high to be accounted for by plate tectonics. Also, the fossil trends are multidirectional, and not unidirectional as would be expected if they resulted from plate movement. To examine the long-term effects of climate, we compared the changes in latitudinal data with changes in paleotemperatures based on the oxygen isotope analyses of benthic foraminifera. We assumed that during warming and cooling trends, fish populations would shift to the north and south, respectively. A non-parametric t-test indicates that in a significant number of cases (i.e., 65%), the latitude distribution data were inversely correlated with trends in the paleotemperature curve. This relationship suggests that fish populations shifting in response to changing thermal conditions can explain many of the patterns in long-term fish dispersal. The southward component in the trends for the 16 fish taxa analyzed can be accounted for by the response of those taxa to the climatic cooling primarily of the Cenozoic Era.

11:30 **Mutter, R.:** EARLY TRIASSIC PERLEIDIDAE (ACTINOPTERYGII): PROTAGONISTS IN FAUNAL RECOVERY PROCESS

MUTTER, Raoul, Univ. of Alberta, Edmonton, AB, Canada

The family Perleididae (not synonym with Colobodontidae) had served as a wastebasket for Middle Triassic neopterygians showing a deepened posterior maxillary plate and well-developed molariform dentitions. Re-investigation of “*Perleidus*”-like species from the Eotriassic of Madagascar, East Greenland and Spitzbergen, and discovery of a new species in the Early Triassic of the Sulphur Mountain Formation in western Canada evoke redefinition of the family and re-interpretation of its evolutionary history. Early Triassic perleidids are evidenced in the northern and in the southern hemisphere, and they are present with both small-sized and relatively large-sized species. The few but nicely preserved specimens show interesting differences in the pattern of snout ossifications and in the caudal fin if compared to the type species *P. altolepis* from the Middle Triassic. Remarkably, greatest morphological variation of taxa in the Early Triassic are of intraspecific nature whereas the variation of Middle Triassic taxa is interspecific. Although known from few localities, several distinctive groups of perleidids and perleidid-like fishes can be distinguished by the Anisian (early Middle Triassic) and suggest their radiation in the middle-late Early Triassic. Interrelationships between these groups are still problematic but features in the squamation and in the dentition indicate both their close relationship and their successful adaptation during the faunal recovery process. It is concluded that their comparatively small yet fusiform body, their unspecialized dentition and the plate-like flank scales represent ideal prerequisites for adaptation and radiation in diversified marine environments such as lagoon-associated habitats or developing reef systems during the middle-late Early Triassic.

11:45 **Johnson, S. and Lucas, S.:** LATE CRETACEOUS SELACHIAN FAUNAS IN NEW MEXICO

JOHNSON, Sally, Univ. of New Mexico, Albuquerque, NM; LUCAS, Spencer, New Mexico Museum of Natural History and Science, Albuquerque, NM

The majority of the Cretaceous rocks in New Mexico are Late Cretaceous and are very fossiliferous marine strata deposited in the Interior Seaway. Selachians are some of the most abundant fossils found. Initially, during the Cenomanian, the selachians are not abundant: sparse localities are known from the Clay Mesa Member of the Mancos Shale, Cubero Member of the Dakota Formation and the Lincoln Member of the Greenhorn Limestone. These oldest sites are dominated by *Odontaspis* and *Ptychodus*

teeth. At the Cenomanian-Turonian boundary, *Scapanorhynchus* makes its first appearance locally. Starting in the middle Turonian, large selachian faunas appear. Sites in this interval typically yield 12 to 24 species of selachians, and, in a couple of square meters of outcrop, thousands of teeth can be found. This fauna is dominated *Scapanorhynchus raphiodon*, *Ptychotrygon triangularis*, *Pseudohypolophus mcnultyi*, *Squalicorax* spp., and *Ptychodus* spp. This fauna begins in the middle Turonian with the Carlile Shale and extends to the middle Campanian, ending at the Cliff House Sandstone. During this interval, deep water sites show much less diversity and abundance than shallow water sites. Thus, the deep water sites yield 3-4 species, whereas the shallow water sites have 15-20 species. A few of the species continue into the Late Campanian middle part of the Lewis Shale. By the end of the Campanian, there is a drastic change in the selachian fauna. The Pictured Cliffs fauna is dominated by six species of *Cretodus*, *Cretolamna*, and *Odontaspis*. The only species that remain from the earlier fauna are *Pseudohypolophus mcnultyi* and *Squalicorax pristodus*. *Scapanorhynchus* has locally become extinct, and several other lamniform sharks replace it. The Late Cretaceous selachians in NM thus go through three phases, *Odontaspis-Ptychodus* faunachron (Cenomanian-early Turonian) of low abundance and low diversity, *Scapanorhynchus* faunachron (early Turonian-middle Campanian), and the *Cretodus* faunachron (middle-late Campanian).

12:00 **Downs, J.:** HISTOLOGICAL EXAMINATION OF A *BOTHRIOLEPIS CANADENSIS* GROWTH SERIES: ONTOGENY OF A PROPOSED EXAMPLE OF SKELETAL SYSTEM FUSION

DOWNNS, Jason, Yale Univ., New Haven, CT

Advances in the technology of histological observation have renewed interest in the microanatomy of fossil tissues. Such advances present new opportunities to address the origins and relationships of the vertebrate skeletal systems. Paleontologists play an important role in this discussion as fossils provide physical evidence of evolutionary history.

A recent histological study of full-grown specimens of *Bothriolepis canadensis* proposes that the external skeletal elements include contributions from two different skeletal systems: the superficial dermal skeleton and the internal endoskeleton. Based on the results of this previous work, we hypothesized that the dermal skeletal and endoskeletal tissues of *Bothriolepis canadensis* originated independently of one another and subsequently fused during ontogeny. The present work, a histological examination of a *Bothriolepis canadensis* growth series, addresses the developmental mechanism behind this unique example of endoskeletal-dermal skeletal fusion.

The study material is comprised of specimens of *Bothriolepis canadensis* that represent multiple stages of maturity. Each was collected from the Escuminac Formation (Late Devonian, Frasnian Stage) near Miguasha, Quebec, Canada. For the purposes of this investigation, two complementary imaging methods were employed: thin-section microscopy using Nomarski interference optics and high-resolution SEM imaging of specimens etched with chromium (III) sulfate. Investigation on the optical microscope resolves internal biological structures including tissue layers, cell and cell process spaces, and vascular canals. Scanning electron micrographs enable examination of the physical texture of the mineral component of the tissues.

This paper reports on the variation in skeletal microanatomy between members in a growth series of *Bothriolepis canadensis* and uses these data to address the developmental mechanism responsible for the composite nature of the external skeletal elements.

12:15 **Bruner, J., Wood, D. and Wilson, M.:** FIRST REPORTED VERTEBRATE FROM THE SWAUK FORMATION (LOWER EOCENE), NEAR LIBERTY, KITTITAS COUNTY, WASHINGTON, IS A NEW SPECIES OF FRESHWATER PERCOMORPH FISH



BRUNER, John, Univ. of Alberta, Edmonton, AB, Canada; WOOD, Daniel, Univ. of Washington, Seattle, WA; WILSON, Mark, Univ. of Alberta, Edmonton, AB, Canada

The first reported vertebrate collected from the Swauk Formation is a fish 3.48 cm in standard length. The specimen was collected from the lower half of the Swauk Formation near Liberty, Washington. The fish locality is characterized by medium-grained sandstone, interbedded with shales and mudstones, deposited in a low-gradient fluvial system with channel and interchannel deposits. Palynology studies date the Swauk Formation as lower to middle Eocene. Fission-track dated zircon from interbedded volcanic tuffs from several localities in the Swauk Formation found ages ranging from 50.4 - 43.6 Ma. This early Eocene Ypresian freshwater fish is important because it occurs during the early- to mid- Eocene radiation of Percomorpha. Of the known 111 families of Percomorpha from the Ypresian and Lutetian Eocene stages, 84 families are marine, 27 families are, or have, freshwater members, 4 are marine families known from North America, and only 5 families are known to have freshwater members from the North American Eocene. This enigmatic Swauk Formation fish does not belong to any of the known North American Eocene genera of freshwater fishes. A description and preliminary classification of the fish will be presented.

**FRIDAY AFTERNOON, NOVEMBER 5, 2004**

**TECHNICAL SESSION XII  
PLAZA BALLROOM A/B  
MODERATOR: DAVID SMITH**

**1:30 Ridgely, R. and Witmer, L.: NEW APPLICATIONS OF CT SCANNING AND 3D MODELING FOR DINOSAUR VISUALIZATION**

RIDGELY, Ryan, Ohio Univ., Athens, OH; WITMER, Lawrence, Ohio Univ., Athens, OH

The benefits of x-ray CT for revealing internal anatomical features is now well known, as is the ability to reconstruct slices into 3D volumes and surfaces. Both of these will remain indispensable, but a burgeoning new area involves using the resulting 3D digital datasets in novel ways. CT scanning technology and 3D visualization software have developed to the extent that fossils can be “virtually” prepared, restored, manipulated, and interpreted with increasingly high fidelity. New tools allow regions of interest to be digitally extracted (i.e., segmented) based on morphological criteria. For example, matrix-filled spaces within skull bones (e.g., osseous labyrinth; pneumatic, endocranial, and nasal cavities) can be segmented, yielding 3D objects that can be manipulated, measured, and combined. Such segmentation simultaneously results in digital removal of matrix (virtual preparation). CT scanning of isolated elements of a disarticulated *Majungatholus* skull presented the opportunity to explore methods of reassembly. The separate datasets were loaded into the same 3D environment and then manipulated into articulation. Another method was to scan a previously articulated cast of the whole skull, and then use landmarks to align each element. In this way, anatomical structures segmented in isolated elements (e.g., sinuses, brain cavity) can be visualized together in the complete skull. Excellent scan data were obtained using a conventional medical scanner, but the ear region of the braincase required the increased resolution of microCT. The two datasets were combined and registered using landmarks common to both datasets. Thus, inexpensive medical CT datasets can be integrated with more costly, but anatomically targeted, microCT datasets. Digital methods for the amelioration of the effects of taphonomic distortion (e.g., crushing, plastic deformation) are being explored in a CT dataset of the skull of the giant Paleogene bird *Diatryma*. The possibility of the full restoration of anatomical relationships remains on the horizon, but landmark-based techniques as well as 3D-warping methods can improve symmetry and approximate the original conformation.

**1:45 Parsons, W.: POSTCRANIAL ONTOGENY OF *DEINONYCHUS ANTIRRHOPUS* (SAURISCHIA, THEROPODA)**

PARSONS, William, PARSONS, Kristen, East Aurora, NY

In 1982, an incomplete skeleton of a small dromaeosaurid (MCZ 8791) was recovered from Unit VI of the Himes Member, Cloverly Formation at the Wolf Creek site, Pryor Mountain field, south-central Montana. After factoring in the disparity between the limb proportions of adults and sub-adults of this species that was initially observed on MOR 1178, the comparison of the pes elements of MCZ 8791, with similar pes elements of the holotype (YPM 5205) confirms the identification of this specimen as *Deinonychus antirrhopus*. The unfused neural arches, as far back as a posterior dorsal vertebra, indicate that this specimen represents a younger growth stage than MOR 1178. Additional skeletal elements preserved with MCZ 8791 include multiple vertebrae, right and left coracoids, a right ulna, a left radius, a right manus II-2, a left fibula and left tibia. Both sub-adult specimens possess a proximal caudal vertebra which, after examining their qualitative morphology and the ratio of multiple linear

measurements, though dissimilar in size, are otherwise identical. The axial length of the centrum of this vertebra was used as an index to construct comparative growth ratios. Analysis of these ratios indicates that this MCZ juvenile possessed forelimbs that were even greater in relative length than the forelimbs found on MOR 1178. These juvenile limb to body proportions approach those possessed by some other smaller members of the Dromaeosauridae. The limb morphology of both sub-adult specimens indicates a pattern of exaggerated forelimb development at an very early stage of growth. These new data, along with the newly confirmed lateral position of the glenoid fossa of the scapula, permit a more accurate reconstruction of ontogenetic modifications in the limb morphology of *Deinonychus antirrhopus* and may add some possibilities to considerations regarding the use of the forelimb.

2:00 **Snively, E. and Henderson, D.:** NASAL FUSION REINFORCED THE ROSTRUM OF TYRANNOSAURIDS

SNIVELY, Eric, HENDERSON, Donald, Univ. of Calgary, Calgary, AB, Canada

Tyrannosaurids are characterized by nasal fusion throughout their phylogenetic history and across their ontogenetic size range. Computed tomographic (CT) scans of several tyrannosaurid specimens of different sizes confirm that the fusion extends fully through the nasals, rather than being isolated to ornamental fusion of the dorsal suture. In contrast, CT scans of *Allosaurus* specimens of a range of sizes confirmed no tendency towards fusion. The ankylosis in tyrannosaurid nasals proceeded ontogenetically, posteriorly and anteriorly, from the region over the largest maxillary teeth. Calculations of bending, torsional, and compressional strengths indicate that nasal fusion and thickening, and a staircase-style naso-maxillary joint in giant individuals, contributed to reinforcement of the snout. We hypothesize that nasal fusion in tyrannosaurids was part of a correlated progression towards crushing bone, and reducing prey by vigorous lateral flexion of the head and neck. Independent evolution of nasal fusion in spinosaurids and abelisaurids indicates the utility of mechanical reinforcement in the skulls of other large theropods.

2:15 **Sellers, W. and Paul, G.:** SPEED IN GIANT TYRANNOSAURS: EVOLUTIONARY COMPUTER SIMULATION

SELLERS, William, Loughborough Univ., Loughborough, United Kingdom; PAUL, Gregory, Baltimore, MD

One particularly promising technique for estimating the locomotor capabilities of fossil animals is evolutionary robotics. In this approach a biomimetic computer simulation of the musculoskeletal system of the animal is created and evolutionary algorithms are used to generate muscle activation patterns that produce realistic movements. The pattern generation is an optimisation process and by choosing a suitable fitness goal or goals the model can generate locomotion optimised for economy, performance or perhaps other desired outcomes such as stability. The reliability of the predictions depends on the sophistication of the model and the accuracy of the reconstruction of the fossil animal.

This paper demonstrates a model based on a reconstruction of *Tyrannosaurus rex* CM9380 using an estimated body mass of 5700kg. The linear dimensions are based directly on the reconstruction and the mass properties derived from a 3D extrusion CAD model. Muscles groups are modelled as point-to-point force generators acting around the hip, knee and ankle joints with physiological parameters derived from their estimated masses. The central pattern generator has 3 finite states per half gait cycle controlling the 6 muscle groups, and since the duration of each state is also variable this means that the locomotion of the model is completely specified by 21 parameters. Using body/leg extensor mass ratios and muscle burst power outputs normal for fast bipeds, this model is easily able to produce convincing-looking running gaits with speeds in excess of  $10\text{ms}^{-1}$ . However the precise values of these speeds

depend on the modelling parameters chosen and it is clear that the incorporation of further biorealism might considerably increase these estimates. One advantage of this technique is that the assumptions made are transparent and the nature of the simulation means that other useful data can be directly estimated such as metabolic energy consumption, ground reaction forces and skeletal loading as well as allowing the production of animated sequences.

2:30 **Smith, D., Kirkland, J., Sanders, K., Zanno, L. and Deblieux, D.:** A COMPARISON OF NORTH AMERICAN THERIZINOSAUR (THEROPODA: DINOSAURIA) BRAINCASES

SMITH, David, Brigham Young Univ., Provo, UT; KIRKLAND, James, Utah Geological Survey, Salt Lake City, UT; SANDERS, Kent, ZANNO, Lindsay, Univ. of Utah, Salt Lake City, UT; DEBLIEUX, Donald, Utah Geological Survey, Salt Lake City, UT

Extensive fossils of a new, primitive therizinosaur are being recovered from the Lower Cretaceous (Barremian) Crystal Geyser Quarry in the Cedar Mountain Formation of eastern Utah. Among the preserved elements are a number of partial braincases, one of which constitutes the holotype for the new taxon. These braincases are compared with *Nothronychus*, a more derived therizinosaur from the Turonian of New Mexico.

The Crystal Geyser braincase has more elongate, posteroventrally oriented paroccipital processes unlike the dorsoventrally inflated, laterally oriented condition in *Nothronychus* and other derived therizosaurs. Additionally, the Crystal Geyser taxon is conservative in that it retains the open basisphenoidal recess, and distinct basal tubera and basipterygoid processes of other theropods. Derived therizosaurs possess a ventrally hyperexpanded basisphenoid that obscures the latter structures. CT scans of the two taxa reveal that *Nothronychus* has a more foreshortened braincase with respect to the middle ear than does the Crystal Geyser taxon.

The Crystal Geyser therizinosaur exhibits the primitive condition for this clade, so its morphology can be used to suggest a developmental pathway for some of the more unusual structures observed in more derived taxa. Therizosaurs are striking in their development of basicranial pneumaticity, but this character is incompletely developed in the new species. Above the basisphenoidal recess, the basisphenoid, prootic, and opsthotic are extensively pneumatized as in other therizosaurs. However, the Crystal Geyser specimens retain an open basisphenoidal recess. A hypothesis for its enclosure would be the ossification of the ventral epithelium under the base of the recess, resulting in the large pneumatic chamber observed in derived therizosaurs.

2:45 **Lacovara, K., Harris, J., Lamanna, M., Novas, F., Martinez, R. and Ambrosio, A.:** AN ENORMOUS SAUROPOD FROM THE MAASTRICHTIAN PARI AIKE FORMATION OF SOUTHERNMOST PATAGONIA

LACOVARA, Kenneth, Drexel Univ., Philadelphia, PA; HARRIS, Jerald, LAMANNA, Matthew, Univ. of Pennsylvania, Philadelphia, PA; NOVAS, Fernando, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina; MARTINEZ, Ruben, Universidad Nacional de la Patagonia, Comodoro Rivadavia, Argentina; AMBROSIO, Alfredo, Museo Argentino de Ciencias Natural, Buenos Aires, Argentina

The Pari Aike Formation of west-central Santa Cruz Province, Argentina consists of lithified fluvial channel sand and overbank mud deposits and is assigned to the Maastrichtian stage of the Upper Cretaceous based on microfaunal assemblages. Although the represented streams were proximal to marine water, the complete absence of tidally influenced sediments suggests a relatively steep gradient down to the seacoast. Dinosaur fossils were first reported from the Pari Aike in 1929, but until recently the unit's fossil biota remained virtually unstudied. In the vicinity of the Rio Leona between Lago

Argentino and Lago Viedma we have collected or documented numerous and often enormous silicified conifer trunks, elasmobranch teeth, semionotiform scales, dipnoan tooth plates, turtle shells, a small theropod tooth, and abundant but disarticulated material of giant sauropods at several stratigraphic levels. One specimen consists of a titanosaurian femur 2.22 m in length.

The Pari Aike femur (MPM-PV-39) is exceptionally robust. Based on its minimum shaft circumference of 990 mm, we estimate the mass of the titanosaurian it represents at 58 metric tons, nearly twice that predicted for the largest previously known Campanian-Maastrichtian sauropod. The femoral head is “squared” and sharply angled dorsomedially, reminiscent of other titanosaurians, a derived feature that indicates that the animal maintained a “wide-gauge” stance. The proximolateral margin displays a lateral bulge, a diagnostic character of the Titanosauriformes.

Specimen MPM-PV-39 demonstrates that enormous dinosaurs survived until the end of the Cretaceous and enervates arguments for a general reduction in the size of the largest sauropods through the Late Cretaceous. Additionally, the occurrence of the gigantic Pari Aike sauropod is inconsistent with paleogeographic reconstructions of southern Patagonia as an areally restricted landmass isolated from other regions by epeiric seas.

### 3:00 **Hartman, S.:** STANCE AND CARRIAGE IN *BRACHYLOPHOSAURUS*: EVIDENCE FROM ARTICULATED SPECIMENS

HARTMAN, Scott, Univ. of Wyoming, Laramie, WY

Since the mid 19th century there have been multiple interpretations regarding the posture, gait, and carriage of hadrosaurid dinosaurs. Exquisite preservation of two new specimens of *Brachylophosaurus canadensis* provides evidence bearing on probable stance and mode of locomotion. The scapulae are preserved in three different specimens at roughly forty-five degrees from the horizontal, with nearly the entire scapular blade overlapping the ribcage. In each specimen the cranial thoracic ribs are swept strongly caudally. As a consequence, the glenoid fossa is situated cranial to the ribcage, precluding contact between ribs and the proximal end of the humerus, regardless of the degree of humeral eversion. Though compression from overburden has forced the forelimbs into a parasagittal planar orientation, glenoid orientation suggests a non-graviportal upright stance with 10-20 degrees of humeral eversion (from vertical). The ulna and radius do not strongly cross. In articulation, the proximal carpal sits firmly between the distal ends of the ulna and radius, preventing rotation around the long axis. The distal carpal is firmly affixed to the proximal carpal and the distal ends of the radius and ulna. The distal carpal protrudes distally beyond the forearm. When the manus is extended, the distal carpal forms a peg and socket joint with a notch in the metacarpal packet formed by the raised proximal ends of metacarpals two and four. Thus during manual extension the wrist and elbow are limited to movement in the parasagittal plane. The weight-bearing metacarpals (2-4) are tightly bound; as a result of the reduced carpus they would effectively transmit ground forces directly to the ulna and radius.

The specialization of the forelimbs to reduce the range of movement of the distal elements to within a parasagittal plane is reminiscent of ungulate forelimbs, which have a similar reduction in degrees of freedom of joint rotation. Combined with elongate distal forelimb elements and tightly bound metacarpals, it appears that *Brachylophosaurus* spent much of its time in a quadrupedal stance, perhaps even engaging in rapid quadrupedal locomotion.

**TECHNICAL SESSION XIII**  
**PLAZA BALLROOM F**  
**MODERATOR: JONATHAN BLOCH**

**1:30 Alroy, J.: CLIMATE, ENVIRONMENT, AND THE ECOMORPHOLOGY OF MAMMALS**

ALROY, John, University of California Santa Barbara, Santa Barbara, CA

Previous analyses established a dietary ecomorphospace for mammals that contrasts anisodonty (dissimilarity of upper and lower cheek tooth widths) with carnassialization (heterogeneity of cheek tooth lengths). Low anisodonty separates out small herbivores such as rodents and multituberculates. Carnassialization separates out hypercarnivores such as carnivorans and creodonts. Omnivores have intermediate anisodonty and low carnassialization. Ungulates and insectivores have generalized cheek tooth proportions but differ in size. Data on over 1100 North American mammal species show that anisodonty decreased slowly over the Cenozoic, whereas carnassialization increased abruptly around 40 Ma. No link to climate is apparent. Oxygen isotope values for benthic foraminiferans, which are a proxy for global temperature and ice sheet volume, are uncorrelated with the two measures. Furthermore, major Cenozoic transitions in mammalian diversity, taxonomic composition, and body mass show no simple connection to shifts in ecomorphology. For example, no changes are evident at the Paleocene-Eocene boundary. Data on Recent mammal communities from the Kruger National Park savannah in South Africa (490 mm/year precipitation), the Reserve de Campo rain forest of southwestern Cameroon (2680 mm/year), and the Thar Desert in northwestern India (320 mm/year) fail to demonstrate Tertiary analogs. The Kruger data are most similar to the middle to late Miocene, but carnassialization is more extreme. The Cameroon carnassialization data fall in the post-40 Ma range, but anisodonty is lower. In the Thar Desert, anisodonty and carnassialization are both high. Hence, attempts to interpret Tertiary habitat and climate on the basis of gross dietary ecomorphology are dangerous because modern analogs do not exist. Instead, Tertiary faunas were persistently generalized as a result of evolutionary lags. Nonetheless, the abrupt Eocene shift in carnassialization did come during a global cooling episode, and involved both carnivorans and creodonts. Therefore, the most likely explanation for this transition may be parallel evolutionary innovations triggered by environmental change.

**1:45 Sereno, P.: CHARACTERSEARCH: ONLINE DATABASE FOR CHARACTERS**

SERENO, Paul, Univ. of Chicago, Chicago, IL

Character data will always be central to phylogenetic analysis of extinct species or extant clades with many stem taxa. Here I present an online database, CharacterSearch, available at <http://www.charactersearch.com> and created for use with any set of morphological characters. The database permits immediate recall of individual characters or sets of characters by inputting any part or aspect of the character. Its output for a set of characters includes charts summarizing the following: character status, structure, type, authorship, and location. In addition, a data quality profile compares character location and missing data; a missing data profile allows one to assess missing data by taxon or character; and a data accumulation profile allows one to understand when data for a particular clade was first published. CharacterSearch allows one to assess, character by character an alternative data set and quickly locate shared character data, and ascertain which characters were rejected and for what reason.

**2:00 Wesley-Hunt, G.: COMPLEXITY AND PROBABILITY OF CHARACTER EVOLUTION: A TEST CASE IN MAMMALIAN EVOLUTION**

WESLEY-HUNT, Gina, Swedish Museum of Natural History, Stockholm, Sweden

The assumption that an intricate, organized, functional complex can only evolve once is evident in modern research and has influenced our understanding of morphological evolution and phylogenetics. The impact of this idea is clear in hypotheses of early mammalian evolution. As our understanding of mammalian phylogenetics currently stands, in order for Mammalia to be monophyletic, either the triossicular middle ear or the reversed-triangles molar pattern must have evolved multiple times. Traditionally multiple origins of the middle ear have been favored, while more recent studies propose the parallel evolution of reversed-triangle molars. Complexity has been used on both sides to substantiate the pattern of relationships supported by the character of choice evolving only once. But can the relative complexity of a character help us to choose between competing phylogenetic hypotheses?

By simulating the occurrence of rare events during stochastic evolution, I tested the hypothesis that a complex character will not evolve more times than a simple character during the evolution of a clade. I used the character evolution of the middle ear and reversed-triangle molars in Mammalia to construct the parameters for the model. The rate of occurrence of the simple character ranged from 1-5 events per 5000 Lineage million years (Lmy). The rate of the complex character was constrained to be less than the simple character and had a lower limit of 0.5 events per 5000 Lmy. Every combination within these ranges was examined. The program tabulated three results over 1000 iterations for each combination: 1) the simple character evolved more times than the complex character; 2) the complex character evolved more times than the simple character; and 3) ties.

The results did not support the hypothesis. In 82% of the combinations, the event of a complex character evolving more often than a simple character could not be statistically ruled out ( $p < .05$ ). Therefore, the complexity of a character alone should not be used to determine which phylogenetic hypothesis to accept.

2:15 **Gunnell, G. and Gingerich, P.:** EARLY EOCENE TILLODONTIA (MAMMALIA) FROM PAKISTAN: IMPLICATIONS FOR DIVERSITY AND PALEOBIOGEOGRAPHY

GUNNELL, Gregg, GINGERICH, Philip, Univ. of Michigan, Ann Arbor, MI

The lower Eocene Ghazij Formation of western Pakistan (Balochistan Province) consists of a lower marine facies, a middle paludal facies, and an upper fluvial facies. Three differing mammal assemblages have been recovered from the middle and upper units of the Ghazij Formation, suggesting some combination of evolutionary change, immigration, and differential sampling from distinctive paleohabitats. Middle Ghazij mammals consist of endemic quettacyonid condylarthrans and an anthracobunid (Proboscidea?). The upper unit contains two assemblages – a lower one with quettacyonids, archaic perissodactyls, and tillodonts, and an upper one with a cosmopolitan late early Eocene mammalian fauna including artiodactyls, perissodactyls, euprimates, andhyaenodontid creodonts.

Ghazij tillodonts include three taxa: a smaller, relatively primitive form, and two larger taxa. The small taxon retains three lower incisors and a large canine but is derived in having lost p2 and in having lower molar cristid obliquae that originate lingually. A larger form is derived in having lost P2, i1, i3, and p2, in lacking a sagittal crest, in having robust dentary flanges, strong upper molar mesostyles, large hypocone shelves, and enlarged lower molar metastylids, but is primitive in lacking upper molar lingual inflation. The largest form is poorly known but differs in having more bulbous teeth and cristid obliquae that originate more buccally. Ghazij tillodonts differ from *Basalina* (middle Eocene, Pakistan) in lacking p1-2 and in having anterior diastemata. They are most similar to Asian late Paleocene *Yuesthonyx* and North American early Eocene *Megalesthonyx* but differ from these taxa in having lost anterior teeth. The Ghazij tillodonts further differ from *Yuesthonyx* in having fused symphyses, lower molar metastylids

and in lacking a P4 metacone. They further differ from *Megalestonyx* in having enlarged upper and lower canines.

The presence of these distinctive tillodonts in the Ghazij Formation is consistent with other evidence suggesting faunal dispersal from Asia into Indo-Pakistan in the latest Paleocene or early Eocene.

2:30 **Lucas, S. and Kondrashov, P.:** EARLY EOCENE PERISSODACTYLS FROM MONGOLIA, CLADOTAXONOMY AND SUBDIVISION OF THE BUMBANIAN LMA

LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM; KONDRASHOV, Peter, Northwest Missouri State University, Maryville, MO

Basal perissodactyls are relatively common in Wasatchian deposits of North America, but rare in the lower Eocene (Bumbanian land-mammal “age” [lma]) of Asia, where only a few species and less than 20 specimens are known from that time interval. New specimens of *Homogalax namadicus* and *Hyracotherium gabuniai* from the early Eocene Bumban Member of the Naran-Bulak Formation at Tsagan-Khushu, Mongolia, support the conclusion that *Orientalophus hengdongensis* Ting is a junior subjective synonym of *H. gabuniai*. Cladotaxonomy is the recognition of cladotaxa, which are low-level taxa (genera and species) that correspond to clades in a cladistic analysis. *Hyracotherium* was long regarded as the only generic name for the oldest and most primitive perissodactyl, but recent cladotaxonomy has split *Hyracotherium* into several genera. This is supposedly justified by recognizing that *Hyracotherium* (traditional usage) is revealed to be paraphyletic by the cladistic analysis, so every strictly monophyletic taxon the analysis identifies merits a separate genus name. We reject this cladotaxonomy of basal perissodactyls as typological, oversplit, devoid of biological significance and premature. Taxonomic identity should be demonstrated by morphological similarity analyzed within the context of population variation. This approach, when applied to basal perissodactyls, long identified a single genus *Hyracotherium* composed of several species. It is preferable to the typology inherent to cladotaxonomy. Basal perissodactyls have been used to divide the Bumbanian lma into three “zones,” most recently termed (in ascending order) the *Orientalophus*, *Homogalax* and *Heptodon* interval zones. However, no stratigraphic superposition documents these Bumbanian subdivisions, and the evolutionary trajectories that supposedly support it are not documented. Clearly, subdivision of the Bumbanian lma should be possible, but the data provided by basal perissodactyls are as yet insufficient to do so.

2:45 **Bloch, J., Boyer, D., Silcox, M. and Houde, P.:** NEW SKELETONS OF PALEOCENE-EOCENE *LABIDOLEMUR KAYI* (MAMMALIA, APATEMYIDAE): ECOMORPHOLOGY AND RELATIONSHIP OF APATEMYIDS TO PRIMATES AND OTHER MAMMALS

BLOCH, Jonathan, Univ. of Florida, Gainesville, FL; BOYER, Doug, Stony Brook Univ., Stony Brook, NY; SILCOX, Mary, Univ. of Winnipeg, Winnipeg, MB, Canada; HOUDE, Peter, New Mexico State Univ., Las Cruces, NM

Two nearly complete skeletons of *Labidolemur* from upper Paleocene and lower Eocene freshwater limestones from the Clarks Fork Basin, Wyoming, are the oldest apatemyid skeletons known and the first from North America. They allow detailed comparison to the well-preserved middle Eocene skeletons of *Heterohyus nanus* from Messel, Germany. Unlike the Messel apatemyid skeletons, which are flattened and subadult, both specimens described here are adults and almost completely undistorted.

*Heterohyus* has been interpreted as an agile arborealist. *Labidolemur* had deep knees, a grooved astragalus, elongate metatarsals and deep, mediolaterally narrow unguals, supporting a similar reconstruction. Apatemyids are unusual among mammals in having elongate 2nd and 3rd digits of the hand. Compared to *Heterohyus*, *Labidolemur* has a notably longer fourth digit and moderately longer first and fifth digits, reducing deviations in length among fingers I-V. *Labidolemur* further differs in



having an unfused distal tibia-fibula, relatively longer intermediate phalanges, and less elongate incisors. It is likely that the earliest apatemyids, possibly somewhat specialized for exudativory and vertical clinging, had long fingers. A reduction in length of the intermediate phalanges, and overall length of digits 1, 4, and 5, occurred in later forms possibly corresponding to the evolution of specialized percussive foraging behaviors.

Analyses of 2 skulls with well-preserved auditory regions (including in-place ossicles), in part using uhrCT data, indicate that *Labidolemur* lacked an ossified bulla, had a groove on the promontorium marking the course of a functional internal carotid artery, and had a large, free ectotympanic ring. The lateral semi-circular canal is as large as that of modern leaping primates. While the phylogenetic significance of the dental and cranial anatomy of primitive apatemyids is not resolved, especially regarding their relationship to primates, features of the postcranium suggest that apatemyids evolved from an arboreal omnivore similar to that hypothesized for the euarchontan morphotype.

### 3:00 **Ferrusquia, I.:** A NEW EOCENE PALAEANODONT FROM CENTRAL MEXICO

FERRUSQUIA, Ismael, Institute Geology Univ Mexico, Mexico City, DF., Mexico

Recently an andesitic lava flow intercalated in the lower member of the Guanajuato Conglomerate of Central Mexico, a key unit to understand the regional geologic evolution, has been K-Ar dated as 49 Ma old (~ early Bridgerian). Intermittent collecting in this member from sandstone strata placed above the lava flow has yielded in the last fifty years, a unique Eocene mammal fauna composed of endemic taxa; here another unusual taxon is reported.

It is based on three specimens. The first is a rostrum part of a tiny individual; it is funnel-shaped, slightly compressed and bears six small (0.6 to 1.8 mm long), thin enameled, peg-like teeth, rearwardly directed, separated by diastemata; their occlusal surface has no enamel, and is lingually tilted. The associated jaws are shallow, robust, symphysized and bear two procumbent, appressed incisors and four cheek teeth similar to the uppers, but forwardly directed; the jaws do not reach the tip of the (toothless) snout. The second specimen is part of a braincase, its roof is tilted forward, and bears two transversely ovoid, peg-like teeth. The third specimen is a brain case slice, its roof is strongly tilted forward; it includes too the left zygomatic arc, and bears three peg-like teeth. The associated rear part of the jaw bears two peg-like teeth; the ascending ramus is complete, and meets the horizontal one nearly at a right angle.

The Guanajuato taxon superficially resembles Paleogene caenolestoid marsupials, dasypodid xenarthrans, and palaeanodonts. A closer comparison shows that it shares features with the epoicotheriids (numerous teeth that reach the end of the horizontal ramus, no medial buttress, and a short, high brain case) and the metacheiromyids (simple, thin enameled teeth, no enamel in the occlusal surface, and diastemata), but unlike any palaeanodont, the Guanajuato taxon has appressed incisors, no caniniform teeth and the jaw is shorter than the snout; therefore, it is parsimoniously interpreted as a new palaeanodont genus not as yet assigned to a family. The new genus is the southernmost record of Eocene palaeanodonts in North America.

**TECHNICAL SESSION XIV  
GOVERNOR'S SQUARE 14  
MODERATOR: DAN FISHER**

1:30 **Green, J.:** CHRONOLOGIC VARIATION IN BODY SIZE AND TOOTH SIZE BETWEEN IRVINGTONIAN AND RANCHOLABREAN *MAMMUT AMERICANUM* SPECIMENS FROM FLORIDA

GREEN, Jeremy, North Carolina State Univ., Raleigh, NC

The American mastodon (*Mammut americanum*) is generally considered to be more evolutionarily conservative than other proboscideans, such as elephants and gomphotheres. Chronologic variation in mastodon size has never been studied. Irvingtonian and Rancholabrean *M. americanum* third molars, mandibles, and humeri were examined for significant size differences. Upper and lower third molar length, lower third molar width, posterior mandibular height, and humeral length and circumference were found to be significantly smaller in Irvingtonian specimens. Sexual dimorphism was mathematically tested for in each element studied. Only anterior mandibular height was found to be sexually dimorphic in Rancholabrean mastodons, and mandibles associated with gender determined skeletons from Florida (n = 3) support this finding. Irvingtonian mastodons lack mandibular sexual dimorphism. Mandibular tusks were found in all (n = 5) adult Irvingtonian mastodons, while present in only 20% (n = 15) of adult Rancholabrean mastodons. There is no significant change in adult mastodon mandibular tusk size across the Pleistocene.

Florida mastodons significantly increased adult body size (~20%) relatively more in proportion to tooth size (~5%), and developed sexual dimorphism in the anterior portion of the mandible from the early Pleistocene (~1.5 Ma) to their LAD (10,000 years ago). Significant increase in adult body size and tooth size may be an ecophenotypic response to increased food supply and browsing habitat in the Rancholabrean of Florida. Sexual dimorphism in the anterior portion of the mandible may aid in gender determination of mastodon skeletons lacking the pelvis. Mastodon mandibular tusks were selected against from early to late Pleistocene. Some previous authors have thought that mandibular tusks in adult mastodons were sexually dimorphic. No adult mandibles inferred to belong to males (based on anterior mandibular height) have tusks present. This, combined with mandibular tusk presence ratios, suggests mandibular tusks were not sexually dimorphic in adult Florida mastodons.

1:45 **Smith, K.:** METAPODIAL PATHOLOGIES IN *MAMMUT* AND RECENT ELEPHANTS : EVIDENCE OF DISEASE OR PHYSICAL STRESS?

SMITH, Kathlyn, Michigan State Univ., Lansing, MI

A variety of pathologies have been noted on *Mammut americanum* (American mastodon), including undermining of the articular surfaces on metapodials (also seen in extinct bison). Metapodial undermining in fossil proboscideans has been ascribed to tuberculosis (bacterial infection by *Mycobacterium tuberculosis*), but this has not been tested by rigorous comparisons with Recent material. A number of questions relating to whether or not metapodial undermining is pathognomic for tuberculosis in fossil proboscideans remain unanswered, and are here addressed by comparisons with Recent elephants; these include the following: (1) To what degree do Recent elephants show the undermining? (2) Does the undermining vary based on species, age, gender, or whether the animals are wild or captive? (3) Does articular surface undermining preferentially affect a specific metapodial? and (4) Can this undermining be firmly linked to tuberculosis in Recent elephants, and thus be used to infer the presence of the disease in fossil proboscideans, including American mastodon?

To begin answering these questions, 148 metapodials from 14 skeletal specimens of Recent elephants were examined for the presence of two features: (1) articular surface undermining of the subchondral bone, as noted in mastodons and bison, and (2) “lipping” of the articular surface, a character that may indicate the beginning stage of undermining. Of the 148 metapodials studied, 87 (59%) showed lipping and undermining, and 40 (27%) showed lipping only. The third metapodial was most often affected (29 of 33; 88%). Undermining differentially affected wild adult male African elephants and captive adult female elephants. No juvenile elephants in the study showed undermining. Because articular surface undermining in Recent elephants affects only larger adults, and is most strongly developed in the third metapodials, which occupy a central position in the mesaxonic limbs of proboscideans, it is likely the result of pressure on the feet from the weight of the animal, and thus a normal part of Recent proboscidean skeletal anatomy rather than the result of an infection.

2:00 **Fisher, D.:** SEASON OF MUSTH AND MUSTH-RELATED MORTALITY IN PLEISTOCENE MAMMOTHS

FISHER, Daniel, Univ. of Michigan, Ann Arbor, MI

Musth, the male reproductive period observed in extant elephants, is a time of increased mortality due to combat between conspecific adult males. Did Pleistocene mammoths go into musth, and did musth-related combat contribute significantly to mammoth mortality? Recognition of musth is critical for understanding the relative importance of other potential causes of death, one of which, by the latest Pleistocene, was human hunting. A key to resolving these issues is analysis of mammoths that died during musth. Their records of tusk growth and stable isotope composition can be used to characterize the musth interval, as distinct from other portions of the annual cycle and/or life history profile. The best known case of musth mortality in mammoths involves the Crawford (Nebraska) mammoths, two similar-sized adult males that died and were recovered with their tusks interlocked. A second probable case, the Brooks mammoths, was recognized recently in collections of the Nebraska State Museum. Known informally as the “Stacked Tusks Locality,” it preserved two left-right tusk pairs. The longest tusk for each individual measures nearly 4 m on the outside curve. Little remains of the rest of the skeletons, probably due to exposure and weathering of the site prior to burial by Peorian loess. The proximal end of one tusk eroded prior to recovery, but samples of dentin adjacent to the pulp cavities of the other three tusks were sectioned and analyzed to determine season of death. One individual died about ten weeks into its last spring, and the other, about 13 weeks, but since the winter-spring boundary is determined by each individual’s response to growing conditions, simultaneity of death is not ruled out. Both deaths occur after drops in tusk growth rate that resemble similar reductions in prior years and match the signature of fasting associated with musth in extant elephants. This places musth of prime-age adults in the late spring or early summer, compatible with a twenty-two month gestation period like that of extant elephants and calf birth in early spring.

2:15 **Delmer, C., Tabuce, R., Tassy, P. and Mahboubi, M.:** A NEW SPECIES OF *MOERITHERIUM* (PROBOSCIDEA, TETHYTHERIA) FROM THE LOWER UPPER EOCENE OF ALGERIA: IMPACT ON THE DEFINITION OF THE GENUS AND IMPLICATIONS FOR TETHYTHERIAN PHYLOGENY

DELMER, Cyrille, Museum National d’Histoire Naturelle, Paris, France; TABUCE, Rodolphe, Univ. Montpellier-2, Montpellier, France; TASSY, Pascal, Museum National d’Histoire Naturelle, Paris, France; MAHBOUBI, Mohamed, Univ. d’Oran, Oran, Algeria

*Moeritherium* is an early proboscidean known from upper Eocene and lower Oligocene levels of North Africa, mainly from the Fayum region, Egypt. Until the 1980’s, it was widely regarded as the

most primitive proboscidean known, and its bunolophodont dentition was usually retained as the closest to the dental ancestral morphotype of the order. The discovery of three new taxa attributed to the order in lower and middle Eocene localities from Morocco and Algeria, *Numidothorium koholense*, *Phosphatherium escuilliei* and *Daouitherium rebouli*, shed new light on the origin and diversification of the Proboscidea. The lophodont dentition and primitive cranial and post-cranial features of these three taxa, which are much older than *Moeritherium*, led to the idea that a lophodont pattern of the teeth is primitive for Proboscidea.

A new specimen of *Moeritherium* from the lower upper Eocene (early Priabonian age) levels of Bir El Ater, Algeria lends support this theory: although possessing features that justify their attribution to the genus, these teeth show a distinctly lophodont pattern, especially on the molars. This lophodonty is associated with some dental characteristics not yet encountered within the genus but often present in lophodont early proboscideans. This discovery supports the hypothesis that the bunolophodont pattern shown by *Moeritherium* is derived from a lophodont pattern. This result also suggests that cladistic analyses that include *Moeritherium* should code constituent species rather than only the better preserved specimens from the lower Oligocene level, which are strongly bunodont.

2:30 **Gobetz, K. and Green, J.:** OPAL PHYTOLITHS IN DENTAL DEPOSITS AS DIETARY INDICATORS FOR MASTODONS (*MAMMUT AMERICANUM*) FROM KANSAS AND FLORIDA

GOBETZ, Katrina, Univ. of Kansas, Lawrence, KS; GREEN, Jeremy, North Carolina State Univ., Raleigh, NC

Opal phytoliths, or silicified plant cells, isolated previously from calculus of American mastodons (*Mammut americanum*) from Kansas include abundant grass short cells, mostly from pooids, indicating cool, moist conditions, but including smaller amounts from chloridoids and panicoids. Dicot aggregates occurred in much smaller quantities. The frequency of grasses may reflect the habitat of Kansas mastodons, which lived in a mixed forest-grassland ecotome and may have been mixed-feeders. Alternatively, grass phytoliths occur in greater abundance than dicots due to higher silica content in grasses. These results are compared with phytolith isolates from the calculus of 18 mastodon teeth from Aucilla River (late Rancholabrean) of Florida. Previous studies of Florida mastodon diet using isotopes, stereoscopic microwear, and gastrointestinal contents indicate that mastodons were primarily browsers. The relatively well-constrained dietary record for Florida mastodons provides a basis for testing the phytolith isolation method as a dietary indicator, and for comparison of diets between mastodons from Florida and Kansas.

Preliminary analysis of Florida mastodon phytolith isolates contain very few grass phytoliths, which are represented only by pooid short cells. In addition to these are possible platy aggregates from deciduous dicots. These isolates closely resemble phytolith assemblages from modern browsers, such as moose (*Alces alces*) and tapir (*Tapirus bairdii*) in general abundance of phytoliths. The paucity of phytoliths in browser calculus may be due to low production of silica in dicot leaves, browser selection of young, phytolith-poor plants, or insufficient mastication of plant material to accumulate phytoliths in tooth deposits. Aside from these considerations, phytolith assemblages appear to support a browsing diet for Florida mastodons, and may indicate variation in diet among mastodons from Florida and Kansas. Calculus of mastodon teeth from Tri-Britton and La Belle Highway Pit (Irvingtonian) of Florida will be compared with isolates from Aucilla to determine whether phytoliths reflect dietary changes over time.

2:45 **Solounias, N., Muhlbachler, M., Rivals, F., Blondel, C. and Guthrie, D.:** EVALUATION OF DIET IN MAMMOTHS AND OTHER LATE PLEISTOCENE AND EARLY HOLOCENE UNGULATES FROM ALASKA

SOLOUNIAS, Nikos, New York College of Osteopathic Medicine, Old Westbury, NY; MIHLBACHLER, Matthew, American Museum of Natural History, New York, NY; RIVALIS, Florent, New York College of Osteopathic Medicine, Old Westbury, NY; BLONDEL, Cécile, Univ. de Poitiers, Poitiers, France; GUTHRIE, Dale, Univ. of Alaska, Fairbanks, AK

The dietary ecology of species across the Pleistocene-Holocene boundary has the potential to reveal ecological trends associated with the end of the last ice age and/or reveal interspecies niche dynamics that are dissimilar to today due to associations with extinct species or unique paleoenvironments. We examined diet of late Pleistocene and early Holocene ungulates from Alaska with dental wear patterns that relate to diet abrasion. Browsers have low abrasion diets while grazers have high abrasion diets. Characterizing labial molar wear facets as sharp, rounded, or blunt (mesowear) characterizes dietary abrasion over a long period of ecological time (years, months), whereas the relative number of pits and scratches on occlusal surfaces (microwear) characterizes diet over a shorter amount of time (days, weeks). Dental wear patterns of late Pleistocene species, *Mammuthus*, *Equus*, *Bison*, and *Rangifer*, consistently suggest a surprisingly homogenous diet with levels of abrasion reflecting a significant grassy component. Dental wear patterns of early Holocene ungulates, *Bison*, *Rangifer*, and *Cervus*, indicate similar levels of abrasion. However, early Holocene *Alces* diet was significantly less abrasive, suggesting that it was the sole browser. *Bison* and *Equus*, typical grazers, tend to have finer scratches and a higher proportion of rounded cusps than modern reference samples, suggesting a somewhat less abrasive diet for these species than is typical of today. In contrast, the three deer species, *Rangifer*, *Cervus*, and *Alces*, typical mixed feeders and browsers, show dental wear patterns that reflect somewhat more abrasive diets than that found in modern reference samples. However, among the deer, the relative diet pattern was the same as the modern samples, with *Rangifer* having the most abrasive diet, *Alces* having the least abrasive diet, and *Cervus* with an intermediate diet.

3:00 **Chang, C.-H. and Lister, A.: PLEISTOCENE ELEPHANTID REMAINS IN TAIWAN**

CHANG, Chun-Hsiang, National Museum of Natural Science, Taiwan, Taichung, Taiwan R.O.C.; LISTER, Adrian, Univ. College London, London, United Kingdom

There are two main mammalian faunas in Taiwan during the Pleistocene. One is the “Cho-chen” fauna, represented by *Mammuthus paramammonteus*. The other is the “Penghu” fauna, represented by *Palaeoloxodon huaihoensis*. The “Cho-chen” fauna lived between 0.9 and 0.45 Ma based on nannofossil biostratigraphy. The “Penghu” fauna is considered to be of late Pleistocene age. Because the fossils were collected from the sea bottom around Penghu Island in the Taiwan Strait, the horizon and the age of the “Penghu” fauna are not yet known accurately. The remains of *Palaeoloxodon* are dominant in the “Penghu” fauna; however, some elephantid fossils revealing typical characteristics of *Mammuthus* have been found in the assemblages. Morphometric characteristics and comparisons are given for the elephantid remains from Taiwan and those of China and Japan. We suggest that *M. paramammonteus* evolved in the Japanese Islands and Taiwan in the middle Pleistocene, and *P. huaihoensis* migrated to Taiwan from northern China in the late Pleistocene. *Mammuthus* remains in the “Penghu” fauna possess primitive features of thick enamel and low lamellar frequency. This implies that the woolly mammoth, *M. primigenius*, had not migrated into Taiwan and was limited to the northern part of China in the late Pleistocene. The *Mammuthus* remains in the late Pleistocene “Penghu” fauna can be regarded as a chronosubspecies of *Mammuthus paramammonteus* which descended from the middle Pleistocene form with unchanged plate number but decreasing lamellar frequency due to size enlargement.

## POSTER SESSION B

Authors must be present from 3:30-5:45 p.m.

Posters must be removed by 6:00 p.m.

Booth #

1. **Forasiepi, A., Rougier, G. and Martinelli, A.:** A NEW MAMMAL FROM THE JURASSIC CAÑADON ASFALTO FORMATION, CHUBUT PROVINCE (ARGENTINA)

FORASIEPI, Analia, ROUGIER, Guillermo, Univ. of Louisville, Louisville, KY; MARTINELLI, Agustin, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina

A new mammal from the Callovian-Oxfordian (uppermost Middle to lowermost Upper Jurassic) Cañadon Asfalto Formation (Chubut Province, Argentina) is presented. This taxon corresponds to a new species clearly different from *Asfaltomylos patagonicus* from the same locality and stratigraphic level. The new species is based on three lower jaws with relatively well-preserved dentitions. The dentaries show a basal morphology having a meckelian groove, a prominent medial flange, a deep dentary trough, which possibly indicates the presence, though reduced, of postdentary bones still attached. The lower dental formula is  $i4, c1, p5, m3$ . The premolars are simple, bearing a single main cusp, while the molars show a fully tribosphenic pattern, with an obtuse to right-angled trigonid, and a fully basined talonid with three cusps. The association of plesiomorphic (dentary) and derived (molars) features was inferred, or more partially documented, in several taxa of the recently proposed Australosphenida group. Preliminary comparisons underlie the similarities existing among the new taxon, *Asfaltomylos*, *Ambondro*, and more distantly, other australosphenidans. Accepting these tentative phylogenetic affinities, the tribosphenic molar pattern would have evolved twice, and the seemingly homologous middle ear of monotremes and therian would be convergent. Finally, the new specimen emphasizes the differences that exist between the Jurassic mammalian record of South America and the Jurassic faunas of Laurasia on one hand, and the better documented Cretaceous fauna of South America on the other.

2. **Tsubamoto, T. and Rougier, G.:** EARLY CRETACEOUS SPALACOTHERIID “SYMMETRODONT” (MAMMALIA) FROM EAST ASIA

TSUBAMOTO, Takehisa, Kyoto Univ., Inuyama, Aichi, Japan; ROUGIER, Guillermo, Univ. of Louisville, Louisville, KY

We report a spalacotheriid “symmetrodont” mammal discovered from the Lower Cretaceous (upper Hauterivian to upper Aptian) Kitadani Formation of the Tetori Group, central Japan. The fossil specimen consists of a fragmentary right lower jaw with first incisor and five preserved postcanine teeth (interpreted as  $p5-m4$ ). The specimen has acute-angled molariforms with complete shearing surfaces on the para- and protocristids and relatively tall crowns, all of which are referable to the Spalacotheriidae. It is more derived than zhangheotheriids in having complete shearing surfaces, taller crowns, and more complete cingulids. It differs from other spalacotheriids in having fewer molariforms ( $m1-4$ ), higher number of premolariforms ( $p1-5$ ), and gradual transition between premolariforms and molariforms. Our cladistic analysis of 29 (23 dental and six lower jaw) characters shows the present specimen as the sister group of the remaining Spalacotheriidae. This node is supported by only one character (Bremer support: 1) and therefore not particularly stable. The remaining spalacotheriids are arranged in a fully pectinated tree conforming to the topology of the previous researchers, in which the Spalacolestinae occupy an apical position. The combination of the occurrences of the basal spalacotheriid in Japan and of the Zhangheotheriidae, which is the sister taxon of the Spalacotheriidae, in northeastern China suggests a possibility for an East Asian origin of the Spalacotheriidae, although it implies long ghost lineages for the latest Jurassic to Early Cretaceous East Asian “symmetrodonts.”

3. **Hunter, J.:** ALTERNATIVE INTERPRETATION OF MOLAR MORPHOLOGY AND WEAR IN THE EARLY CRETACEOUS MAMMAL *AUSKTRIBOSPHENOS*

HUNTER, John, New York College of Osteopathic Medicine of NYIT, Old Westbury, NY

The Early Cretaceous Australian mammal *Ausktribosphenos*, known from lower jaws and teeth, has been interpreted as placental, peramurid, monotreme, and as part of a Gondwanan radiation including monotremes, the Australosphenida, that evolved tribosphenic molars convergently with northern continent tribosphenidans. Tribosphenic interpretation of monotreme molars remains controversial, while similar interpretation of *Ausktribosphenos* has been taken for granted even though its upper molars, which could demonstrate the presence of a protocone, remain unknown. Alternative interpretations of molar cusp, crest, and wear homologies of *Ausktribosphenos*, assuming a pretribosphenic ancestry, may better account for peculiarities of this mammal (e.g., the presence of “talonid” accessory crests). The cusp previously identified as the hypoconid is interpreted here as an enlarged cingular cusp, and unnamed cristid 3 as the cristid obliqua. By this interpretation, the large region of the “talonid” of *Ausktribosphenos* labial to unnamed cristid 3 is homologous with the hypoflexid, which can be worn by the paracone in pretribosphenic mammals. A similar cingular cusp occurs in the Porto Pinheiro molar, recently referred to *Nanolestes*. This hypothesis obviates objections to unnamed cristid 1 being the distal metacristid of mammals outside crown Theria, thereby reducing the number of unnamed crests from three to one. Certain wear features also become more intelligible in this interpretation. A continuous wear surface on the distal trigonid, identified previously as facets 1 and 5, is interpreted as facet 1 alone (facets 5 and 6 are formed by the protocone). The surface previously identified as facet 6 is interpreted as an enlarged facet 3, assumed to be formed by the distal side of the paracone. Lack of facet 4 may indicate that the valley between the upper molar paracone and metacone was shallow, as in peramurids. This hypothesis predicts that the upper molar of *Ausktribosphenos*, when discovered, will possess a large paracone that formed a new occlusal contact with the cusp identified here as a labial cingular cusp.

4. **Krause, D.:** SYSTEMATIC REVISION OF THE GENUS *PTILODUS* (PTILODONTIDAE, MULTITUBERCULATA) FROM THE PALEOCENE OF WESTERN NORTH AMERICA

KRAUSE, David, Stony Brook University, Stony Brook, NY

*Ptilodus* is indubitably the best-known genus of North American Multituberculata and among the best known of Paleocene mammals. The first species named, *Ptilodus mediaevus* Cope 1881, was described well over a century ago. Persistent collecting in Paleocene deposits of western North America since then has resulted in the collection of thousands of measurable, specifically identifiable cheek-tooth specimens of *Ptilodus*. These specimens, supplemented by cranial and postcranial material, have permitted detailed descriptions and analyses, the results of which have led to the inference that *Ptilodus* was a small-brained, olfactory-dominated, nocturnal, omnivorous, arboreal quadruped. These samples have also demonstrated that *Ptilodus* was among the most abundant of Paleocene mammals, comprising nearly one-fifth of the mammalian fauna at individual localities. *Ptilodus* flourished particularly in the late Torrejonian and throughout the Tiffanian North American Land-Mammal Ages.

Despite the large samples of *Ptilodus*, the wealth of knowledge concerning its anatomy, and the important role that species of this genus played in Paleocene mammalian communities, a thorough systematic revision of the genus has not been published for 75 years. In the most recent compilation (1987) of the temporal distribution of North American multituberculates, seven named species of the genus were recognized: *P. tsosiensis*, *P. ferronensis*, *P. douglassi*, *P. mediaevus*, *P. montanus*, *P. wyomingensis* and *P. kummae*. In the revision presented here, the following actions are taken: 1) *P.*

*tsosiensis*, *P. mediaevus*, *P. montanus*, *P. wyomingensis*, *P. kummae*, and the recently described *P. gnomus* are recognized as valid species; 2) *P. ferronensis* is regarded as a junior synonym of *P. mediaevus*; 3) *P. douglassi* is confirmed as a valid species of *Baiotomeus*; 4) *Neoplagiaulax fractus* is transferred to *Ptilodus*; and 5) three new species of *Ptilodus*, all from the Tiffanian, are recognized.

5. **Carranza-Castañeda, O.:** A NEW PAMPATHERE (MAMMALIA, XENARTHRA), FROM THE LOWER BLANCAN DEPOSITS OF SAN MIGUEL ALLENDE, GUANAJUATO, CENTRAL MEXICO

CARRANZA-CASTAÑEDA, Oscar, Centro de Geociencias, Univ. Nacional Autónoma de México, Mexico

The early history of pampatheres in North America is poorly known. By the time of the Panamanian Land Bridge re-establishment, representatives of this group migrated from South America. Since the first mention of pampatheres in North America, consisting in numerous records of osteoderms, they are chiefly known from the Pleistocene faunas of Florida, Texas and Mexico; the only Pliocene record is *Holmesina floridanus* from the late Blancan of Haile XV A.

The Mexican pampatheres are known by the armor of *Pampatherium mexicanum* from the Pleistocene of San Miguel Tecamachalco in Estado de Mexico and isolated osteoderms from Valsequillo, Puebla and Jalisco states.

New pampathere material was recovered from the Los Corrales fauna, Arroyo Las Aves and Arroyo Belen localities, in the San Miguel Allende graben. It consists of osteoderms of the scapular and pelvic regions and of the imbricated bands. Comparisons with other pampatheres showed that the osteoderms from the imbricated bands have noticeable differences with any species described so far. The external surface is convex, the overlapping area is less than one-third and are thin with several foramina. Posterior to the overlapping area, a slender transverse concave depression region with small fossettes is present. The ornamented area occupies almost all the osteoderm with numerous small follicular pits, the central figure is imperceptible, and no sulcus or submarginal bands are present. The internal surface is concave, smooth and with two or three foramina, the posterior part has sharp pointed protuberances that match with the external overlapping area of the anterior osteoderm. The remaining scutes are similar to those described for *Plaina*. However, the differences of the imbricated osteoderms are so marked that the material from San Miguel Allende represents a new species of this genus.

This record of Pampatheriidae is the oldest in North America, since the radiometric date obtained from an underlying ash is  $3.9 \pm 0.3$  Ma and that of ash above the pampathere bearing layer is  $3.36 \pm 0.04$  Ma.

6. **Naples, V.:** CHARACTER COMPLEX SIGNIFICANCE IN EREMOTHERE MASTICATORY FUNCTION

NAPLES, Virginia, Northern Illinois Univ., DeKalb, IL

Analysis of masticatory structure and function in eremotheres depends upon an understanding of the interrelationships among the cranial skeletal, dental and masticatory muscle characters. Lines of action of the masticatory muscles in *Eremotherium* demonstrate a different synergist-antagonist pattern from those in other sloths, reflecting a greater emphasis on the mediolateral component of mandibular movement at low angles of gape. Eight cranial complexes, determined by the interrelated contributions made by each component to group functions, have been identified. These include: anterior facial, zygomatic arch, superficial masseter, deep masseter-zygomaticomandibularis, pterygoid, temporal, occipital and occlusal character groupings. The necessity of maintaining masticatory efficiency throughout the evolution of this sloth lineage, from bear-sized animals to those of elephantine



proportions, allows prediction of the order in which masticatory character complexes could evolve from the cranial structure inherited from ancestral forms. The anterior face and premental spout in *Eremotherium* are elongate, allowing protrusion of a long, narrow tongue at small degrees of gape, reflecting an early derivation from antecedents with probable myrmecophagous tendencies. The strongly mediolaterally directed masticatory stroke in *Eremotherium* is a unique solution to permit molariform tooth shearing surfaces to remain in or near occlusion for a greater percentage of each chewing cycle. Having a small gape is common among xenarthrans, and could constrain body size increases, unless adaptations, such as these seen in the eremotheres, can increase their capability for continuous food ingestion and processing.

7. **McAfee, R.:** PRELIMINARY RESULTS OF SPECIES DELIMITATION IN SLOTHS (MAMMALIA: XENARTHRA) USING CRANIAL MORPHOMETRICS

McAFEE, Robert, Northern Illinois University, De Kalb, IL

Alpha taxonomy of extinct mylodontid sloths from North America has been poorly understood and in need of revision for nearly a century. Recent systematic studies have increasingly used multivariate and morphometric methods to address groupings of extant taxa. Of the multivariate methods available, those using principal axes have been shown to be quite effective at delimiting taxa, especially those using morphometric data from cranial measures. Prior to attempting to differentiate extinct sloth genera, multivariate analyses (principal components, canonical function and cluster analysis) were performed on cranial data from extant sloths *Bradypus* and *Choloepus* to determine delimitation success. The results obtained corroborate the generic separation of these genera and also demonstrate the ability to separate the recognized species within each genus. These methods are repeated on a small sample of *Glossotherium/Paramylodon* crania and the preliminary results of those analyses are presented.

8. **Madar, S. and Thewissen, J. G. M.:** POSTCRANIAL REMAINS OF ANTHRACOBUNIDAE (MAMMALIA, TETHYHERIA) FROM THE EOCENE KULDANA FORMATION OF PAKISTAN

MADAR, Sandra, Hiram College, Hiram, OH; THEWISSEN, J. G. M., Northeastern Ohio Universities College of Medicine, Rootstown, OH

Anthracobunids are a pivotal group for the determination of relationships among the Sirenia, Proboscidea, Desmostylia and Hyracoidea. Postcranial remains of anthracobunids have been recovered from the Kuldana Formation of the Ganda Kas region of Punjab Province, Pakistan. To date, the only described anthracobunid postcranial specimens are an astragalus and scapula. Fossils described here are derived from the same early Eocene strata that produce the earliest freshwater and marine archaeocetes. Anthracobunid material from freshwater Kuldana localities includes isolated axial and appendicular elements which are morphologically similar, but substantially smaller than anthracobunid fossils derived from marine beds. The most complete material is from an associated skull and fragmentary skeleton (vertebrae, ribs, radius, ulna, carpus and digits) of *Anthracobune pinfoldi*, a large taxon from the marine upper part of the Kuldana Formation. Anthracobunid dental morphology is considered consistent with feeding in the fresh and saltwater habitats in which they are found. Postcrania bear features consistent with substantive use of aquatic substrates. Like early cetaceans, anthracobunid long bones exhibit microstructural changes consistent with the use of skeletal ballast, implying advanced aquatic specialization.

9. **Morgan, G. and Lucas, S.:** GEOCHRONOLOGY OF EARLY PLEISTOCENE (EARLY IRVINGTONIAN) MAMMOTHS (*MAMMUTHUS*) FROM NEW MEXICO

MORGAN, Gary, LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM

*Mammuthus* is one of the most characteristic mammalian genera in North American Pleistocene faunas, but the timing of its first appearance on the continent is not well constrained. According to the most recent compilation, the earliest occurrence of *Mammuthus* in North America is a large sample from the early Pleistocene (early Irvingtonian) Leisey Shell Pit in Florida dated from 1.1 to 1.6 Ma using biochronology, magnetostratigraphy, and strontium isotope chronostratigraphy. Two early Irvingtonian records of *Mammuthus* from New Mexico are associated with radioisotopic dates ranging from 1.3-1.6 Ma. A complete pair of mandibles with m3s of a very primitive mammoth (4 plates/100 mm) occur in the Sierra Ladrones Formation in Tijeras Arroyo, Bernalillo County, north-central New Mexico. The mammoth jaws occur in a unit containing abundant fluviually-reworked pumice from the lower Bandelier eruption in the Jemez Mountains of northern New Mexico radioisotopically dated (Ar/Ar) at 1.61 Ma. The age of this record has been questioned because the associated pumice is reworked and thus provides a maximum age for the mammoth jaws. Further constraining the age of this mammoth record is the presence in an overlying bed of the Tshirege ash from the upper Bandelier eruption Ar/Ar dated at 1.26 Ma. The Tijeras *Mammuthus* jaws are thus bracketed by Ar/Ar dates of 1.61 and 1.26 Ma. Sedimentological data from the pumice deposits in Tijeras Arroyo and other pumice deposits of similar age several hundred kilometers farther south in the Rio Grande Valley indicate that the Tijeras mammoth is essentially contemporaneous with the pumice dated at 1.61 Ma. A partial skull of *Mammuthus* with complete upper tusks and M3s from the Camp Rice Formation in the Mesilla Basin, Doña Ana County, southernmost New Mexico, occurs in strata bracketed by Ar/Ar dates of 1.59 and 1.32 Ma on fluviually-reworked pumices from the Bandelier eruptions.

10. **McDonald, H. G. and Horrocks, R.:** THE RHINOCEROS *SUBHYRACODON*, AND ASSOCIATED FAUNA FROM THE CENTENNIAL SITE, WIND CAVE NATIONAL PARK, BLACK HILLS, SOUTH DAKOTA

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HORROCKS, Rodney, Wind Cave National Park, Hot Springs, SD

During a paleontological survey of the White River Group in Wind Cave National Park, the skull of the Oligocene rhino, *Subhyracodon occidentalis*, was discovered in the Brule Formation. Further investigation revealed at least one-third of a disarticulated skeleton of a juvenile along with a small associated fauna. The fauna includes tortoise, *Mesohippus*, *Leptomeryx*, rabbit (possibly, *Palaeolagus*), and a small indeterminate carnivore, possibly a creodont. This new locality was named the Centennial Site since its discovery coincided with the park's hundredth birthday.

While the White River Group is a major fossiliferous deposit in South Dakota, most sites are found on the Great Plains with only a few higher elevation sites in the Black Hills. While limited in scope, these isolated sites, which are located between 400 and 500 meters higher in elevation than their counterparts on the Great Plains, provide important information on the distribution of early Oligocene fauna and a better understanding of paleoclimatic and ecological differences between lower and higher elevation sites. Studies of sediments and fauna of the area may also provide information on the timing of the uplift of the Black Hills.

The taphonomy of the Centennial Site indicates that it was probably a waterhole as the remains of the rhino and horse appear to have undergone both disarticulation and trampling prior to burial. Many of the ribs were found in a nearly vertical orientation with pre-fossilization breakage, suggesting that they had been pushed into soft sediments, presumably as they were stepped on. None of the bone exhibits weathering indicative of long exposure prior to burial. While much of the skeleton, primarily long bones, is missing, and although only a small portion of the recovered material has been prepared to date, no evidence has yet been found of bone modification by carnivores. With the exception of the partial

skeletons of *Subhyracodon* and *Mesohippus*, and tortoise, all other faunal remains consist of isolated bones.

11. **Coombs, M.: SCHIZOTHERIINE CHALICOTHERES (MAMMALIA, PERISSODACTYLA) FROM THE MIOCENE FOSSIL-LAGERSTÄTTE OF SANDELZHAUSEN (GERMANY)**

COOMBS, Margery, Univ. of Massachusetts Amherst, Amherst, MA

Although European chalicotheres of the subfamily Chalicotheriinae are known from relatively complete remains, the subfamily Schizotheriinae is uncommon and represented in most cases by fragmentary remains. The best known European schizotheriine taxon is *Ancylotherium pentelicum* from the late Miocene (Turolian, MN 12-13) of Greece.

Between 1966 and 1998, specimens of an early middle Miocene (MN 5, 16.5-16 MYA) schizotheriine chalicothere were excavated from the Upper Freshwater Molasse deposits of Sandelzhausen, near the town of Mainburg in Bavaria (southern Germany). This material, housed in the Institute for Paleontology and Historical Geology, Munich, can be referred to the genus *Metaschizotherium* von Koenigswald. As with other fossil vertebrate material from Sandelzhausen, the bones are mostly disarticulated, but there is good representation of much of the dentition and postcranial skeleton, often belonging to multiple individuals. Juveniles and young adults are frequent.

Although *Metaschizotherium* has derived characters that link it with *Ancylotherium*, the Sandelzhausen chalicothere retains many plesiomorphic similarities to early Miocene schizotheriine chalicotheres, such as the well known North American immigrant *Moropus*. The completeness of the Sandelzhausen material is especially valuable for the analysis of very fragmentary schizotheriine specimens from other European early to middle Miocene localities. *Metaschizotherium* is another member of the diverse Sandelzhausen ungulate fauna, which also includes gomphotheriids, rhinocerotids, anchitheriine equids, suids, palaeomerycids, cervids, lagomerycids, and tragulids. Its presence provides additional evidence for a forested ecosystem in proximity to a persistent limnofluviatile water supply, as postulated in long-term studies of the Sandelzhausen locality by Fahlbusch, Heissig, Rössner, and others.

12. **Metais, G., Antoine, P.-O., Crochet, J.-Y., De Franceschi, D., Marivaux, L. and Welcomme, J.-L.: A NEW OLIGOCENE RUMINANT ASSEMBLAGE FROM THE BUGTI HILLS (BALOCHISTAN, PAKISTAN): ITS SIGNIFICANCE FOR THE EARLY EVOLUTION OF TRAGULOIDS IN SOUTH ASIA**

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In the last decade, the Dera Bugti area in Eastern Balochistan (Pakistan) has become the focus of intensive geological and paleontological research. The Bugti territory extends in the southern part of the Sulaiman Range, where the latter seems amortizing in the Sibi Through, and thus forming a clockwise rotation westward. The Paali mammal locality is stratigraphically located at approximately thirty meters above the major erosional unconformity separating the conglomerates and sandstones of the Chitarwata Formation from the underlying Eocene shales and limestones of the Kirthar Group in the Sulaiman Range. This locus consists of about 10 meters thick sandstone-clay interface rich in small mammal remains with at least two thin red-brown siltstone interbeds which produced rich assemblages of terrestrial plants (angiosperm leaves). The new assemblage of fossil ruminants from Paali consists of at least 5 genera and 8 species. These forms belong to at least four distinct families (Tragulidae,

Lophiomerycidae, Gelocidae, Prodremotheriidae), and they potentially include 3 new species and a possible new genus too poorly documented to be formally erected yet. Several taxa previously restricted to the Oligocene of Europe are reported for the first time in the Indian Subcontinent, and thus considerably enhance their geographical distribution. The ruminant fauna from Paali is clearly distinctive from early-middle Miocene assemblages notably known in the overlying Miocene of the Bugti series, and thus indicates that the faunal turnover that occurred at the Oligo-Miocene boundary seems to have been much better marked in South Asia than in Mongolia. The ruminant assemblage described here suggests the existence of forested habitat probably mixed with more open areas during the early Oligocene in Central Pakistan. The complete analysis of the mammalian fauna from Paali should significantly increase our knowledge on the evolution of mammalian communities in the Indo-Pakistani region at a turning point between the early-middle Eocene faunas from Indo-Pakistani region, and the famous Neogene Siwaliks of India and Pakistan.

13. **Thewissen, J. G. M.: EMBRYOLOGICAL DATA AND THE STUDY OF WHALE ORIGINS**

THEWISSEN, J.G.M., Northeast Ohio Univ. College of Medicine Dept of Anatomy, Rootstown, OH

The origin of whales is one of the best examples of macroevolutionary change documented by fossils. In recent years, a number of cetacean fossils have been discovered that include a series of transitional forms in the Eocene. Therefore, whale origins presents a rich source of data for evolutionary studies, ranging from in-depth studies of form-function complexes of individual organ systems to paleoecological studies on broad evolutionary patterns.

Just like paleontology, embryology is an important tool in the study of evolution. Just like archaic whale fossils, modern cetacean embryos are hard to acquire. Published studies on cetacean embryos, with very few exceptions, relied on opportunistic finds of cetacean embryos, with little control on the species studied or the developmental age of the studied embryo.

We acquired a complete ontogenetic series for the Spotted Dolphin, *Stenella attenuata*. The embryos and fetuses document a range of important developmental events in cetaceans. They document such important developmental processes as the outgrowth and subsequent reduction of hind limb buds, the development of the fluke from a conical tail, and the formation of the hyperphalangeous flipper from a primitive handplate.

In order to make this collection available for study, the Digital Library of Dolphin Development (DLDD) was designed. It contains detailed information on the ontogenetic stages of the Spotted Dolphin, photos and drawings of whole embryos, and special pages highlighting some of the most dramatic developmental events. It also contains a number of labeled histological sections that can be used to teach mammalian embryology.

Finally, and most importantly, the DLDD presents unedited, downloadable TIF and JPG images of all histological sections for each embryo; thousands of sections in the case of the larger embryos. Using the DLDD, dolphin development can be studied on the basis of histological sections by anyone with a web connection. Digitization of the entire collection is in progress, and, when completed, the DLDD will contain the complete ontogenetic series for the Spotted Dolphin.

14. **McKay, M., Kohn, M. and Knight, J.: DINING IN THE PLEISTOCENE: WHO'S ON THE MENU?**

McKAY, Moriah, KOHN, Matthew, Univ. of South Carolina, Columbia, SC; KNIGHT, James, South Carolina State Museum, Columbia, SC

A new fossil locality on the coastal plain of South Carolina has yielded a spectacularly abundant and well-preserved assemblage of ~425,000 yrs BP (late Irvingtonian) megafauna, including sabertooth cat

(*Smilodon fatalis*), wolf (*Canis armbrusteri*), cheetah (*Miracinonyx inexpectatus*), camelids (*Hemiauchenia* sp. and *Paleolama* sp.), tapir (*Tapirus* sp.), deer (*Odocoileus virginianus*), and horse (*Equus* sp.). Of particular interest is the ability to decipher paleoecologies and paleodiets, especially for carnivores, by using carbon isotope compositions ( $\delta^{13}\text{C}$ ) of well-preserved fossil teeth. *Paleolama* and *Tapirus* have the lowest  $\delta^{13}\text{C}$  values (-16 to -13‰, V-PDB); *Odocoileus*, *Canis*, *Smilodon*, and *Hemiauchenia* have intermediate values (-13 to -9‰); and *Equus* has the highest values (-6 to -1‰). High (>-5‰) vs. low (<-8‰)  $\delta^{13}\text{C}$  values indicate ecosystems dominated by warm-climate (C4) grasses vs. trees and shrubs (C3). The high  $\delta^{13}\text{C}$  values for *Equus* indicate grassland occupancy, and imply that grasslands had significant C4 grasses. In contrast the low  $\delta^{13}\text{C}$  values for the other herbivores indicate forest occupancy. Because both high and low  $\delta^{13}\text{C}$  values are represented in the herbivores, both grassland and forest ecosystems must have been present, similar to modern South Carolina. The low  $\delta^{13}\text{C}$  values for carnivores indicate that *Canis* and *Smilodon* preferred hunting in forests, e.g. preying upon camelids, *Odocoileus* and *Tapirus*, and not in grasslands. Instead, the top grassland predator was likely *Miracinonyx*.

15. **Winkler, A.:** A NEW SMALL *THRYONOMYS* (RODENTIA: THRYONOMYIDAE) FROM THE LATE MIOCENE (~ 5.23 MA) OF KENYA

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The cane rat, *Thryonomys*, is known from the late Miocene to Recent of sub-Saharan Africa. Two extant species of *Thryonomys* have been described, *T. swinderianus*, and the generally smaller *T. gregorianus*. Reports of fossil *Thryonomys* are common. Most specimens, however, are isolated teeth, and few are identified to species. At least two extinct species have been described from the archaeological record, but their validity has yet to be substantiated. The late Miocene upper member of the Nawata Formation, Lothagam, Kenya, has yielded five dentaries, a P4, and a lower incisor, which are assigned to a new extinct species. The specimens belong to *Thryonomys* based on a p4 with four lophs, lower molars with three lophs, an anterolabial cusp connected to the protoconid with the valley between the anterolabial cusp and the protoconid open lingually, and relatively wide cheekteeth. In contrast to even the smaller of the two Recent species, teeth of the Lothagam taxon are 12-30% (mean 24%) shorter and narrower, although the length of the m1 and m2 overlaps the lower end of the range of *T. gregorianus*. The morphology of the Lothagam P4 is closer to that of the middle-late Miocene cane rat *Paraulacodus* than to other species of *Thryonomys*. The presence of a *Paraulacodus*-like P4 is important in confirming *Paraulacodus* as the closest sister taxon to *Thryonomys*. Existence of a new small *Thryonomys* had been suggested previously based on Pliocene fossils from the Chemeron Formation, Tabarin, Kenya, the Ibole Formation, Manonga Valley, Tanzania, and the Upper Ndolanya Beds, Laetoli, Tanzania.

16. **Dunn, R. and Rasmussen, T.:** LARGE RODENT FROM THE LATE EOCENE OF UTAH

DUNN, Rachel, RASMUSSEN, Tab, Washington Univ., St. Louis, MO

The Eocene was a time of great diversity for the Rodentia, with forms ranging from *Microparamys*, smaller than most insectivorans, to *Ischyrotomus eugenei*, approaching the size of *Castor*. A new complete rodent skeleton including the cranium and jaws, manus, pes and associated limbs, pelvis and vertebral column is now known from the Uinta Basin of Utah. The cranium is approximately the size of *Castor*. The dentition is complete and includes several milk teeth including P3s, upper and lower P4s, and M1s. All adult teeth are present. The new rodent can be assigned to the subfamily Paramyinae. Taxonomic designation beyond this level is yet to be determined. Past interpretations of paramyine morphology suggest adaptations to terrestriality and fossoriality. This is based on large body size,

robustly built bones, and long, deep ungual phalanges. The new rodent is very robust including prominent crests on the proximal limb bones, a large and rugose olecranon process, and long, deep ungual phalanges. The medial epicondyle of the humerus is robust, and the ungual phalanges have large attachment points for the digital flexors, both indicating powerful flexion of the manus. All above characters can and have been interpreted as adaptations for digging. However, digging and climbing behaviors affect skeletal morphology in similar ways. It is possible that the paramyine rodents were not adapted to digging, but to climbing, which is the hypothesized ancestral behavior of rodents. Large body size cannot rule out the possibility of an arboreal lifestyle, as large climbing rodents exist today.

17. **Smith, K., Cifelli, R. and Czaplewski, N.:** A NEW GENUS OF EOMYIDAE (MAMMALIA: RODENTIA) FROM THE MIOCENE (LATE HEMINGFORDIAN AND EARLY BARSTOVIAN) OF NEVEDA

SMITH, Kent, Oklahoma State Univ. Ctr. for Health Sciences, Tulsa, OK; CIFELLI, Richard, CZAPLEWSKI, Nicholas, Sam Noble Oklahoma Museum of Natural History, Norman, OK

During the Neogene, four genera of Eomyinae and a single genus of Yoderimyinae rodents were present in North America. This was a significant reduction of taxa compared to the Paleogene, which had 17 genera of eomyines and four genera of yoderimyines. In Europe, 11 genera of eomyids occurred during the Neogene; one genus (*Pseudotheridomys*) persisted into the Quaternary. At present, there are no known eomyids from the Quaternary record in North America. Typically, the different groups of North American and European eomyids of Neogene age exhibit one or two of the four distinct patterns on the occlusal surface of the cheekteeth. The four distinct patterns include a variation of the number and occurrence of lophs (ids) and transverse valleys, and appearance of primary cusps. Prior to this study, the yoderimyine group was identified as having only one of the four occlusal patterns of the cheekteeth. In contrast to the yoderimyines, the eomyines from North America have two of the four occlusal patterns. A fourth occlusal pattern occurs in the European genus *Apeomys*.

We describe a new genus (genus A) of a ?yoderimyine eomyid from two local faunas in Nevada (Massacre Lake, late Hemingfordian; and Eastgate, early Barstovian). This new taxon has an occlusal pattern that shares characteristics of both *Arikareeomys* (late Arikareean) from North America and *Apeomys* (Oligocene-Miocene) from Europe. The unique occlusal pattern and large size of genus A suggests that not all eomyids from North America were small or that their lineages lacked a trend towards an increase in size. Genus A also provides evidence which challenges the hypothesis that eomyids within a single lineage from the North American Tertiary became more lophodont in geologically younger genera.

18. **Samuels, J.:** SEMIAQUATIC AND FOSSORIAL ADAPTATIONS IN EXTINCT BEAVERS (CASTORIDAE)

SAMUELS, Joshua, Univ. of California, Los Angeles, Los Angeles, CA

The beaver family (Castoridae) includes ca. 20 genera (50 species) in four distinct subfamilies. Members of this family vary in limb morphology, including taxa with specializations for semiaquatic or fossorial habits. Modern taxa are often used to infer adaptations of their extinct counterparts. Here, detailed morphometric comparisons are used to infer locomotor habits of extinct beavers. Extant rodent taxa with diverse locomotor habits (including *Castor canadensis*, *Ondatra*, *Myocastor*, *Hydrochoerus*, *Aplodontia*, *Marmota*, *Neotoma*, *Spermophilus*, *Cynomys*, and *Thomomys*) were compared with several extinct North American beavers (*Castor californicus*, *Dipoides*, *Procastoroides*, *Castoroides*, and *Palaeocastor*). Specimens were measured for 35 functional osteological characteristics (e.g. limb bone length, breadth, anteroposterior diameter). Limb ratios were used to assess semiaquatic and fossorial

adaptations. Correlations between morphology and locomotor habits in extant taxa were analyzed using principal components analysis and discriminant function analysis; results were used to infer habits of extinct beaver taxa. All extant semiaquatic rodent taxa studied show some morphological convergence linked to this locomotor habit. Ratios and multivariate analyses show *Castor* and 3 genera of extinct beavers from the subfamily Castoroidinae display similar specializations in their limbs related to semiaquatic locomotion. Multivariate analyses show *Procastoroides* and *Castoroides* to be less specialized for semiaquatic locomotion than *Castor*, possibly related to their significantly larger size. Data also reveal some convergence among extant fossorial taxa and the extinct *Palaeocastor*. Locomotor specialization of extinct beavers may help explain patterns of diversification and extinction within the group. Future work will include additional fossil taxa, and when combined with cranial and isotopic analyses will help elucidate the origin of semiaquatic and fossorial adaptations in the various castorid subfamilies.

19. **Liu, L.:** THE FIRST RODENT RECORDS FROM THE BAODE *HIPPARION* FAUNA

LIU, Liping, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Science, Beijing, China

Baode is well known in the world by its famous *Hipparion* Fauna, and has been treated as a typical representation for the Chinese late Miocene mammalian assemblage. Although tons of complete skulls and post-cranial specimens of large mammal were collected, the small mammals, were never tried to be searched. Without them, the Baode fauna is difficult to fit into an ongoing Chinese refined calibrated biostratigraphic chart. In the autumn of 2003, we got quite rich small mammals which are dominated by a murid, together with a gerbil and a siphneid. The micromammalian fossils are collected from the earth dug out from the large mammal fossils tunnels.

The murid *Hansdebruijnia* cf. *pusillus*, are similar to the species *H. pusillus* from the Ertemte fauna, but show an overall primitive pattern compared to that of *H. pusillus*, such as very rare appearance of t1bis and t3bis, weaker posterior spurs on t1 and t3, and less developed medial ridge on the lower molars, suggests the Baode fauna is earlier in age. The earliest member of the genus, *H. perpusillus* from Baogedawula, is distinctly more primitive than the Baode murid. The murid suggests the Baode fauna an intermediate position between the Baogedawula and Ertemte Faunas.

The gerbil from the Baode area accords to the species *Pseudoneriones abbreviatus*, but has an obvious protosinusid on m3, which is a primitive character and well present on the oldest species of the genus *P. latidens*. The Baode gerbil maybe represents a primitive form of the species.

The siphneid is assigned to *Prosiphneus licenti*. Based on the successive stratigraphical record from Qin'an, it appears from 7.6-6.5 Ma in the section. By this micromammalian assemblage, the Baode fauna could be correlated with middle Turolian or MN12 in the European scale.

20. **Anderson, D.:** EVIDENCE FOR DIRECTIONAL SELECTION IN *LEPTOTOMUS PARVUS* (RODENTIA: ISCHYROMYIDAE), BRIDGER FORMATION (MIDDLE EOCENE), GREEN RIVER BASIN, WYOMING

ANDERSON, Deborah, St. Norbert College, De Pere, WI

Hundreds of ischyromyid rodent specimens have been recovered from several distinct stratigraphic levels of the Bridger Formation, Green River Basin of southwestern Wyoming including the earliest appearance of *Leptotomus parvus* in the early Bridgerian (Br-1b). The thick sequence of relatively undisturbed fossiliferous sediments provides an ideal database for studies of evolutionary change in ischyromyid rodents. A morphological and metrical study of *L. parvus* revealed evidence of directional selection in this lineage over approximately 600,000 years.

*Leptotomus parvus* increases gradually in size from biostratigraphic level Br-1b (early Bridgerian) to upper Br-2 (middle Bridgerian), while molar crown pattern morphology remains relatively constant. This is the type of change predicted by Sheldon's plus ca change model for a narrowly fluctuating environment, but contrary to more recent studies using quantitative trait locus sign tests which reveal that directional selection leads directly to phenotypic diversification. These results directly impact taxonomic identification of Bridgerian rodent taxa differentiated primarily based on size distinctions. New specimens of "*L. bridgerensis*" recovered from the Green River Basin occur at lower stratigraphic levels of the Bridger Formation than specimens upon which the species name was based. Due to similarities in size and morphology between specimens of each species throughout the early Bridgerian, synonymy of *L. parvus* (Wood 1959) with *L. bridgerensis* is proposed.

21. **Von Koenigswald, W., Rose, K., Grande, L. and Martin, R.:** APATEMYID AND PANTOLESTID SKELETONS FROM THE EOCENE FOSSIL BUTTE MEMBER (WYOMING) COMPARED TO THOSE FROM MESSEL (GERMANY)

VON KOENIGSWALD, Wighart, Institut Für Paläontologie, Bonn, Germany; ROSE, Kenneth, Johns Hopkins Univ. School of Medicine, Baltimore, MD; GRANDE, Lance, MARTIN, Robert, Field Museum of Natural History, Chicago, IL

In the last decade the Fossil Butte Member in Wyoming, well known for its abundant fish fossils, has produced several mammal skeletons including a pantolestid and an apatemyid from locality H on Thompson Ranch. The Fossil Butte Member is correlated to the uppermost lower Eocene, the Lostcabinian subage of the Wasatchian NALMA, about 52 Ma. The skeletons are imbedded in a laminated limestone and are preserved in full articulation due to the mainly anaerobic conditions at the lake bottom. They are very similar to closely related fossils from the famous Messel site in Germany which is dated as lower middle Eocene, about 49 Ma and thus younger than the Fossil Butte Member.

The apatemyids from the two sites are similar in size, smaller than the common tree shrew *Tupaia glis*. They have a highly specialized dentition with an enlarged incisor and a bladelike p2. In the hands the proximal and intermediate phalanges of digits II and III are slender and distinctly elongated, but the claws are small. The specialization closely parallels that in the extant marsupial *Dactylopsila* and the lemur *Daubentonia*, indicating that apatemyids fed on wood-boring insects. *Apatemys* from the Fossil Butte Member and *Heterohyus* from Messel also show the same adaptations for arboreal life in their laterally compressed claws and long tail. *Apatemys* is more primitive than *Heterohyus* in having somewhat shorter digits II and III, while the other digits are less reduced.

The two pantolestid skeletons show very similar body proportions, except that the specimen from Fossil Butte Member has a longer tail. Both skeletons show the same distinct adaptations for a semiaquatic way of life. As in *Lutra* the tail is very strong for propulsion. The nuchal crest at the back of the skull and the large dorsal spine of the axis vertebra indicate strong neck musculature. The otter-like foraging of pantolestids is documented by fish remains in the gut regions of both.

The apatemyid and pantolestid skeletons from the Fossil Butte Member show greater similarity to their European relatives than has been documented so far.

22. **Perry, J. and Wall, C.:** THEORETICAL EXPECTATIONS AND EMPIRICAL FEATURES OF PROSIMIAN CHEWING MUSCLES

PERRY, Jonathan, Duke Univ., Durham, NC; WALL, Christine, Duke Univ., Durham, NC

The muscles of mastication were examined in two species of lemur, four galagos, a loris, and a tarsier. The masseter and temporalis can be considered a continuum of muscle components. Each consists of three anatomically distinct parts. The medial and lateral pterygoids are easily separated in



dissection, as are the anterior and posterior digastrics. Special attention was given to architectural features commonly used to estimate force production: muscle weight, fiber length, angle of pinnation. These variables were used to compute the reduced physiological cross-sectional area (PCSA) for each muscle part, as a proxy for force production.

In all but one case, the deep temporal muscle has the greatest cross-sectional area. With respect to relative PCSA, we initially saw no significant differences between species of different diets. However, when the tarsier is removed from the analysis, frugivores show significantly greater PCSA than insectivores for the deep masseter, superficial temporal, and zygomatic temporal. This may reflect a trade-off between force production and repeated chewing: insectivorous prosimians may employ repeated, low-force chewing cycles to grind insect exoskeletons.

Based on the PCSA equation, we generated a model of the contribution of pinnation to force. For most realistic shapes of chewing muscles, force is maximized at pinnation angles between 35 and 45 degrees. However, all chewing muscles measured in this study have pinnation values that are less than 30 degrees. Lack of pinnation may reflect the adaptive value of a wide gape in some primates. This hypothesis is consistent with the observation that the anterior fibers of the masseter muscles are generally longer than the posterior ones. Consistently low angles of pinnation may provide hope for reconstructing chewing muscles in fossil prosimians.

Scaling of PCSA relative to skull size, mandibular length, and body mass is determined for ten muscle parts. Log PCSA regressed against log body mass yields a slope similar to that suggested for basal metabolic rate. Deviations from predicted values are assessed in the light of the material properties of diet.

23. **Scott, C.:** TAXONOMICALLY DIVERSE LATE PALEOCENE MAMMAL LOCALITIES FROM SOUTH CENTRAL ALBERTA, CANADA

SCOTT, Craig, Edmonton, AB, Canada

Of the more than 50 fossil mammal-bearing localities of Paleocene age known from the Alberta Basin, those in strata of the Paskapoo Formation exposed in the south central part of the province in the vicinity of Red Deer are among the most productive, collectively documenting mammalian evolution during the middle Tiffanian (T13). These localities, exposed along successive cutbanks of the Blindman River north of Red Deer, and at roadcuts near Joffre Bridge east of Red Deer, have long been known for containing specimens with exceptional preservation, with many of the identifiable mammals represented by partial skulls and nearly complete jaws. Recent comprehensive analyses of the Blindman River and Joffre Bridge mammals have documented taxonomically diverse local faunas, with 42 genera in 11 orders so far discovered. Included in these local faunas are new species of the neoplagiaulacid multituberculate *Neoplagiaulax*, the picrodontid *Picrodus*, the cyriacotheriid *Cyriacotherium*, and a new genus and species of eutherian mammal of uncertain ordinal affinity. Of particular importance are partial skulls of an unidentified plesiadapid, an unidentified palaeoryctid, and the pantodont *Titanoides*, as well as nearly complete upper and lower dentitions of numerous lipotyphlans. The Blindman River and Joffre Bridge local faunas are dominated by mammals of small body size, with multituberculates and “insectivorans” constituting over 50 percent of the total number of specimens; large mammals are few, represented only by rare specimens of *Titanoides* and larger-bodied arctocyonids. A preliminary faunal correlation indicates strongest resemblance to the temporally equivalent Birchwood local fauna of central Alberta. In contrast with many similarly aged local faunas from the more southern parts of the Western Interior, the Tiffanian mammalian record in Alberta fails to show a significant decline in species diversity as would be predicted by recent late Paleocene global cooling models. Local ecological

and/or sedimentological events may have contributed more to this apparent decline than was previously appreciated.

24. **Emry, R., Lucas, S., Bayshashov, B. and Tyutkova, L.:** CENOZOIC MAMMALIAN BIOSTRATIGRAPHY IN THE ILY BASIN, EASTERN KAZAKSTAN

EMRY, Robert, Smithsonian Institution National Museum of Natural History, Washington, DC; LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM; BAYSHASHOV, Bolat, TYUTKOVA, Lyubov, Institute of Zoology, Ministry of Science, Almaty, Kazakhstan

The Ily basin of eastern Kazakhstan is a Cenozoic successor basin between the Tien Shan ranges with a basin fill ~2.5 km thick that encompasses strata of lacustrine and fluvial origin assigned to the (in ascending order) Kyzylbulak, Aktau, Chuladyr, Aygyrzhal, Santash, Ily and Khorgos formations. Fossil mammals provide the most precise age control of this section. At Aktau Mountain, the oldest are from the Kyzylbulak Formation of middle Eocene (Irdinmanhan) age, and include *Aktautitan*, *Sharamynodon*, *Rhodopagus* and a new genus of tapiromorph. The lower part of the Aktau Formation yields the giant hyracodontid *Paraceratherium zhajremensis*, indicative of a late Oligocene (Tabenbulukian) age. An unconformity within the Aktau Formation underlies an early Miocene (= MN5, late Shanwangian) mammal assemblage from the upper Aktau Formation that includes *Gomphotherium angustidens*, *Diaceratherium* (= *Brachypotherium*) *aurelianense*, *Lagomeryx triacuminatus*, *Procervulus gracilis*, *Stephanocemas aralensis*, *S. actauensis*, *Prepalaeotragus actauensis* and *Schizotherium* sp. Lacustrine facies of the Chuladyr and Aygyrzhal formations have not yielded mammals. The Santash Formation yields late Miocene mammals at Botamoinak, which are *Plesiogulo crassa*, *Ictitherium wongii*, *Percrocuta* sp., *Pseudaelurus turnauensis*, *Hipparion* sp., *Dicerorhinus kurmetiensis*, *Chilotherium anderssoni*, *Tragoceros frolovi*, *Miotragoceros* sp. and *Lagomeryx setensis*. At the Kopaly (Aktogai) locality, the Ily Formation yields a Pliocene mammal assemblage that includes *Ellobius* sp., Hystricidae, *Villanyia* aff. *V. petenyi*, *Mimomys haplodentatus*, *Ochotona aktogaiensis*, *Pachycrocuta brevirostris*, *Homotherium* sp., *Leptobos* cf. *L. etruscus*, *Canis etruscus*, *Anancus arvernensis*, *Mammuthus gromovi*, *Equus* cf. *E. stenonis*, *Dicerorhinus* sp. and *Gazella* sp. The Khorgos Formation yield Pleistocene mammals that include *Clethrionomys* aff. *C. kretzoi*, *C. mirus*, *Allophajomys pliocenicus*, *Prolagurus pannonicus*, *Microtus* cf. *M. hintoni*, *Lepus* sp., *Ochotona* cf. *O. antiqua* and *Mammuthus* sp.

25. **Becker, D.:** RHINOCEROTOIDEA AND CLAY MINERALS OF THE JURA MOLASSE (OLIGO-MIOCENE, SWITZERLAND): IMPLICATIONS FOR PALEOECOLOGY AND PALEOCLIMATES

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The taxonomy of the Rhinocerozoidea from the Oligo-Miocene of northern Switzerland is partially revised. A biostratigraphical and paleoecological interpretation of this group is proposed. Results show that trends in diversity and anatomy of the taxa were controlled by paleoenvironmental changes. The recorded mineralogical changes and the evolution of Rhinocerozoidea seem to be controlled by regional or global tectonic and/or climatic events.

During the middle Eocene, only small and cursorial primitive forms of Rhinocerozoidea evolve in a partially open forested environment. During the late Eocene, just before the "Grande Coupure," no Rhinocerozoidea have been reported in Switzerland. The forests become more dense and the climatic conditions remain warm and wet.

The beginning of the Oligocene matches with the occurrence of the first true Rhinocerotidae and the reopening of the forested environments. The climate seems to deteriorate and become more arid. The Rupelian/Chattian boundary is marked by a tendency to cooling. Chattian Rhinocerotidae present weak, but perceptible predispositions to brachypody and hypsodonty. The climate continues to deteriorate and

is marked by a crisis at the terminal Chattian as shown by the abrupt disappearance of palm trees and Taxodiaceae.

From the base of the Miocene, a renewal within the Rhinocerotidae is observed. The environmental conditions improve and offer a wide range of biotopes. At the “Proboscidean Datum” (Burdigalian/Langhian boundary), the Rhinocerotidae are strongly perturbed by Asian migrants, while again the climate changes in a more continental and arid way due to closure of the Tethys. During the late Serravalian, a return to humid conditions is observed. The last recorded Miocene stratigraphic interval corresponds to the mammal zone MN9. Its lower limit is characterized by the “*Hippotherium Datum*,” which opens the migratory corridor of the Bering strait. New migrants from Asia and Africa renew the Rhinocerotidae. The environment remains forested and the relatively warm and wet climate of the late Serravalian persists.

26. **Rofes, J. and Cuence-Bescós, G.:** SMALL MAMMALS FROM THE SPANISH PLEISTOCENE SITES OF ATAPUERCA

ROFES, Juan, CUENCA-BESCÓS, Gloria, Universidad de Zaragoza, Zaragoza, Spain

During the last decade, the research conducted at the karstic localities of the Sierra de Atapuerca (Burgos, northern Spain) has contributed significantly to our understanding of human evolution in Europe. There are three main fossil caves dissected by an old railway trench: Trinchera Dolina (TD), Trinchera Galería (TG) and Trinchera del Elefante (TE). Some active caves, such as Sima de los Huesos, are located in the interior of the karst system.

The age of the Atapuerca sites range from the early to the middle Pleistocene; roughly the time span between the 1.500 ky to the 300 ky. The earliest western European, *Homo antecessor*, is from level 6 of TD. The Matuyama/Brunhes boundary at the level TD7 gives an age of 780 ky for this level. Level TD6 underlies TD7, and is consequently older than 780 ky. The biostratigraphy confirms the early Pleistocene age for levels TD3 to TD6. Sima de los Huesos, dated as middle Pleistocene, has *Homo heidelbergensis*. Some hominin remains are also recovered from TG.

The oldest small mammals from Atapuerca are recovered from Trinchera del Elefante. The insectivores *Beremendia minor*, *Assoriculus gibberodon* and the three *Allophaiomys* species assemblage allow us to propose an early Pleistocene age for TE, older than the oldest levels of Trinchera Dolina with *Beremendia fissidens* and one derived *Allophaiomys*. The upper levels of Trinchera Dolina share with Trinchera Galería and Sima de los Huesos a middle Pleistocene small mammal assemblage dominated by *Allocricetus*, *Microtus* and *Arvicola*.

27. **Fastovsky, D., Hsu, J., Huang, Y., Martin-McNaughton, J., Sheehan, P. and Weishampel, D.:** MESOZOIC DINOSAUR DIVERSITY

FASTOVSKY, David, Univ. of Rhode Island, Kingston, RI; HSU, J., Huang, Y., The Ohio State Univ., Columbus, OH; MARTIN-McNAUGHTON, J., Univ. of Rhode Island, Kingston, RI; SHEEHAN, P., Milwaukee Public Museum, Milwaukee, WI; WEISHAMPEL, D., The Johns Hopkins Univ. School of Medicine, Baltimore, MD

The generic diversity of Mesozoic Dinosauria is examined using a new global database compiled for the second edition of *The Dinosauria*. Based upon a sample of 1266 positively identified body fossils, dinosaurs increased the rate of their diversification throughout the Mesozoic, a pattern at least in part attributable to the development of new innovations driving a concomitantly increasing variety of behavioral strategies. The absolute generic richness of Asian dinosaurs now exceeds that of North America, and together the two constitute 44% of Mesozoic dinosaur richness and 80% of Cretaceous dinosaur richness. The data do not suggest that dinosaurs were decreasing in richness over ca.10 million-

year timescales at the end of the Cretaceous. Refinement of the dating of dinosaur fossil-bearing units, rather than the collection of more dinosaurs, is the most effective way to resolve extinction rates at the Cretaceous-Tertiary boundary.

28. **Dodson, P. and Wang, S.:** COUNTING DINOSAURS 2004 — HOW MANY KINDS WERE THERE?

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The publication of *The Dinosauria* in 1990 occasioned a comprehensive critical review of the fossil record of dinosaurs, in which it was determined that 285 genera were probably valid. The publication of the second edition of *The Dinosauria* in 2004 encourages renewed study of current trends in order to make informed predictions about prospects for continuing discoveries. More than 200 new genera of dinosaurs have been described since 1990. Between 1824 and 1969, an average of 11.5 genera per decade were described; between 1970 and 1989, the rate was 60 genera per decade; from 1990 to present the rate is 133 genera per decade. In 2001 and again in 2003, 24 or more new genera were named worldwide. In 1990, six countries accounted for 75% of all dinosaur genera known: in order — United States, Mongolia, China, Canada, England and Argentina. Today the order, and the rate of increase from 1990 are: United States (62%), China (125%), Mongolia (40%), Argentina (104%), Canada (3%) and England (25%). Fitting a logistic curve to the earlier dataset, Dodson in 1990 estimated total Mesozoic non-avian dinosaur diversity at 1200 genera. We now reexamine assumptions about the nature of the fossil record. Employing the new dataset and a Bayesian statistical model using Markov Chain Monte Carlo analysis, we now revise the estimate of actual Mesozoic diversity.

29. **Candeiro, C., Bergqvist, L., Novas, F. and Currie, P.:** THEROPOD TEETH FROM THE MARILIA FORMATION (UPPER MAASTRICHTIAN), MINAS GERAIS STATE, BRAZIL

CANDEIRO, Carlos, Univ. Federal Rio de Janeiro, Uberlandia, MG., Brazil; BERGQVIST, Lilian, Univ. Federal Rio de Janeiro, Rio de Janeiro, Brazil; NOVAS, Fernando, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina; CURRIE, Philip, Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada

Theropod teeth comprise the most numerous remains of the fossil assemblage from the Serra da Galga Member, Marilia Formation (Upper Maastrichtian) of the Bauru Basin. The material consists of fifty-five teeth recovered from Peiropolis (Uberaba Town, Minas Gerais State, Brazil). To elucidate the taxonomic diversity of Theropoda in the Marilia Formation, available teeth were grouped into nine morphological classes on the basis of cross-sectional outlines, the shapes of the teeth, the sizes of carinal denticles, and topography of the enameled surfaces. Some teeth are identified as Carcharodontosauridae due to the presence of wrinkled enamel on labiolingually flattened tooth crowns. If these really are carcharodontosaurid teeth, then they represent the youngest record (Late Maastrichtian) for this family. The present study shows for the first time that Abelisauridae are present in the *Mar'lia* Formation, which is not surprising considering the known distribution of this family in other regions of Gondwana. An abelisaurid tooth has a relatively low crown with smoothly convex lingual and labial surfaces, although in cross-section the anterior edge is more compressed than the posterior one. Some other teeth from the Marilia Formation are thin and bladelike, and have denticles that vary greatly in size along the carina. These specimens could not be identified to any of the known Cretaceous theropod taxa.

30. **Burnham, D., Senter, P., Barsbold, R. and Britt, B.:** PHYLOGENY OF THE DROMAEOSAURIDAE

BURNHAM, David, Univ. of Kansas, Lawrence, KS; SENTER, Phil, Lamar State College - Orange, Orange, TX; BARSBOLD, Rinchen, Mongolian Academy of Sciences, Ulan Bator, Mongolia; BRITT, Brooks, Brigham Young Univ., Provo, UT

To elucidate relationships within Dromaeosauridae, we ran a phylogenetic analysis including dromaeosaurid species and basal members of other coelurosaurian clades. Results indicate that Dromaeosauridae (defined as all taxa phylogenetically bracketed by *Velociraptor* and *Dromaeosaurus*) consists of *Velociraptor mongoliensis* (the only member of Velociraptorinae) and a speciose Dromaeosaurinae. In the latter, *Adasaurus*, *Saurornitholestes*, *Deinonychus*, *Achillobator*, and *Utahraptor* are successively more closely related to *Dromaeosaurus*. In Microraptoria, (the sister clade to Dromaeosauridae), *Bambiraptor*, *Sinornithosaurus*, and unnamed specimen NGMC 91 are successively more closely related to *Microraptor zhaoianus* + “*Microraptor gui*” + “*Cryptovolans pauli*” (an unresolved trichotomy). We believe that the members of that trichotomy are conspecific, as the character states used to diagnose each are present or on unknown elements in each of the others.

We also find that *Sinovenator* is a basal deinonychosaur, Aves is the sister taxon to *Sinovenator*+(Microraptoria+Dromaeosauridae), and troodontids are more closely related to ornithomimids than to deinonychosaurs.

31. **Baziak, B. and Loewen, M.:** INTRASPECIFIC VARIATION AND ONTOGENY IN CRANIAL ELEMENTS OF *ALLOSAURUS FRAGILIS* FROM THE LATE JURASSIC CLEVELAND-LLOYD DINOSAUR QUARRY OF CENTRAL UTAH

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The Cleveland-Lloyd Dinosaur Quarry (CLDQ) contains an extensive sample of *Allosaurus fragilis*, the largest sample known for any species of large theropod. This assemblage, consisting almost entirely of isolated elements, is particularly significant because several size classes are represented, ranging from juvenile to adult. *A. fragilis* cranial elements from the CLDQ were analyzed to determine shape changes through ontogeny. Multiple measurements were taken on elements such as the premaxilla, maxilla, dentary, nasal, lacrymal and jugal. These measurements enabled the reconstruction of overall skull morphology at different sizes. This study addresses the range of variation within *A. fragilis* and tracks ontogenetic changes in cranial proportions.

Dramatic changes in the shape and width of the skull in dorsal view may be indicative of structural changes in response to increased stress and loading associated with feeding. In particular, the rear of the skull showed significantly more width increase than the front of the skull during ontogeny. An increase in the size of interdental plates may also be linked to feeding stresses with an increase in size. The proportions and sizes of the orbit and lateral temporal fenestra also suggest strengthening of the skull throughout ontogeny. Changes in all of the elements suggest the height of the skull increases more dramatically than the width during ontogeny, as evident in other theropods. In addition, pneumatic features on cranial elements such as the maxilla, nasal and lachrymal are quite variable in the pattern and size of pneumaticity. This suggests that changes in these features may be less reliable for taxonomic identification due to the amount of variation observed in the CLDQ sample.

32. **Kobayashi, Y. and Barsbold, R.:** RE-EXAMINATION OF A PRIMITIVE TOOTHLESS ORNITHOMIMOSAUR, *GARUDIMIMUS BREVIPES*, FROM THE LATE CRETACEOUS OF MONGOLIA

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*Garudimimus brevipes* was discovered in the Upper Cretaceous Bayanshiree Formation in the southeastern part of Mongolia during the Joint Soviet-Mongolian Paleontological Expedition. It is a toothless but primitive ornithomimosaurian dinosaur (basal to Ornithomimidae). In 1981, Barsbold briefly described this taxon based on a single skeleton with a well-preserved skull and incomplete postcranial material and coined the family, Garudimimidae. Re-examination of the holotype reveals a great deal of anatomical information, which allows us to revise the original diagnosis of this taxon and to make comparisons with other ornithomimosaur taxa to understand the evolution of the clade.

Characters that were originally used to differentiate this taxon (short ilia, short metatarsals, exposure of the proximal end of metatarsal III, presence of pedal digit I, and absence of pleurocoels) are not apomorphies, but diagnose larger clades. The holotype shows some unique characters that diagnose *Garudimimus brevipes* (posteriorly positioned jaw articulation, fossae at base of dorsal process of supraoccipital, paired depressions on neural spines of proximal caudal vertebra, and deep groove on lateral surface of pedal phalanx III-2). Metatarsals of *Garudimimus brevipes* display a non-arctometatarsalian condition as in the Early Cretaceous form, *Harpymimus okladnikovi*, but the constriction of metatarsal III in *G. brevipes* is intermediate between *H. okladnikovi* and the arctometatarsalian condition in *Gallimimus* sp. (GIN 100/14) as well as other derived ornithomimosaur (ornithomimids). *Garudimimus brevipes* is the only non-ornithomimid ornithomimosaur with edentulous jaws, which were probably covered by a rhamphotheca. The loss of teeth, coverage by a rhamphotheca and development of cutting edge in the dentary of *Garudimimus brevipes* suggest the acquisition of feeding habits similar to ornithomimids.

33. **Heckert, A., Lucas, S., Rinehart, L. and Hunt, A.: BIOSTRATIGRAPHY, BIOCHRONOLOGY, AND EVOLUTIONARY TRENDS OF COELOPHYSOIDS (THEROPODA:CERATOSAURIA)**

HECKERT, Andrew, LUCAS, Spencer, RINEHART, Larry, HUNT, Adrian, New Mexico Museum of Natural History, Albuquerque, NM

Coelophysoid theropods were the first predatory dinosaurs to achieve a Pangean distribution and as well as dominate the terrestrial predator guild. Coelophysoids appear during Adamanian (latest Carnian) time, where they are known from extremely fragmentary material in North America. Revueltian coelophysoids are marginally more common, complete, Laurussian in distribution and include a new taxon from Arizona, *Eucoelophysis*, *Procompsognathus*, *Liliensternus*, *Gojirasaurus* and at least some material referred to *Protoavis*. At least some of these taxa are true coelophysids. *Liliensternus* and *Gojirasaurus* attained large (>4-5 m body length) size by this time, falsifying hypotheses of “ecological release” resulting in the rapid radiation of large theropods following a putative end-Triassic extinction. *Coelophysis bauri* from the Apachean Whitaker (Ghost Ranch) quarry well-represents the coelophysid *Bauplan*, and robust and gracile sexual dimorphs are first apparent in this sample. Based on their abundance in the Upper Triassic Chinle Group, coelophysids did not dominate the terrestrial predator niche before Apachean time. *Megapnosaurus* (= *Syntarsus*) had a widespread distribution during Early Jurassic time and is the first Gondwanan coelophysid. Coelophysid theropods were the dominant 1-3-m-sized terrestrial predators from the latest Triassic through at least the Sinemurian (~30 m.y.). The stratigraphically superposed evolutionary sequence of *Eucoelophysis* (Revueltian), *Coelophysis* (Apachean) and *Megapnosaurus* (Hettangian) demonstrates phyletic gradualism (and near-stasis) in coelophysids over approximately 25 m.y. This near-stasis also argues against a significant Late- or end-Triassic terrestrial extinction event. Large size in coelophysoids may be correlated to heterochrony, specifically the retardation of sexual maturity relative to skeletal growth. Documentation of variation of the Ghost Ranch *Coelophysis* sample remains necessary to test this hypothesis and to stabilize

coelophysid systematics. Indeed, intraspecific variation may perennially stymie phylogenetic hypotheses of the group.

34. **Rinehart, L., Lucas, S., Heckert, A. and Hunt, A.:** VISION CHARACTERISTICS OF *COELOPHYSIS BAURI* BASED ON SCLEROTIC RING, ORBIT, AND SKULL MORPHOLOGY

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New Mexico Museum of Natural History specimen P-42200 is a gracile (probably female) morph of *Coelophysis bauri* from the Whitaker Quarry in the Apachean- age Rock Point Formation of the Chinle Group of north-central New Mexico. This specimen preserves the first documented complete sclerotic ring in *C. bauri*. The skull length is 123 mm, which places it in the large juvenile to small adult range.

We corrected the skull, orbit, and sclerotic ring for slight taphonomic distortion, reconstructed the ring, and allometrically projected the specimen to adult size. The ring and orbit morphology were analyzed and compared to extant lizard and bird outgroups as well as the ornithischian dinosaur, *Hypsilophodon foxii* and the basal bird, *Archaeopteryx*. The bird outgroup comprised 18 species representing 10 orders; the lizards, 9 species from 6 families. Relative importance of vision to all the study animals was estimated by plotting orbit size versus skull size. In this regard, *Coelophysis* ranks with most of the birds and well above most lizards. Eye morphology was assessed in two ways: ring area versus orbit area, and cross sectional shape of the ring (indicative of eye shape) were both compared to the outgroups. In both cases the eyes of *Coelophysis* are most similar to those of the Falconiformes (hawks and eagles), in which eye shape is globose and accommodation power is very high. Night vision capability was assessed by comparing cornea size to orbit size. *Coelophysis* shows poor nocturnal capability, similar to most lizards and nonraptorial birds. Night vision in *Hypsilophodon* and *Archaeopteryx* rated approximately equal to the Falconiformes. We note that in *Coelophysis* poor night vision probably indicates a round, as opposed to slit pupil. Skull and orbit measurements indicated an overlap in the left and right visual fields of 26 (minimum) to 40 (maximum) degrees, depending on the shape of the cornea. We conclude that *Coelophysis* was a diurnal, visually oriented predator and that high power of accommodation and good frontal binocular vision is extremely probable.

35. **Rose, P.:** A TITANOSAURIFORM SAUROPOD (DINOSAURIA, SAURISCHIA) FROM THE EARLY CRETACEOUS OF CENTRAL TEXAS

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A sample of primitive titanosauriform sauropod from the Lower Cretaceous Twin Mountains Formation, central Texas, represents one of the richest accumulations of sauropod bones in North America of its age, and occurs in close proximity to sauropod trackways that date to about 112 Ma. Autapomorphic characters of the taxon include anterior and middle caudal neural arches with prominent spinoprezygapophyseal (sprl) and spinopostzygapophyseal (spol) laminae that are restricted to the anterior and posterior aspects of the neural arch, respectively, and do not extend onto the lateral surface of the neural spine; anterior and middle caudal neural arches with intraprezygapophyseal lamina (tprl) forming, with the sprl and spol, a prespinal fossa above the neural canal; anterior and middle caudal transverse processes relatively long, dorsoventrally compressed and broad anteroposteriorly; accessory neural arch lamination on anterior dorsal vertebrae. Ischial distal shafts meet to form a broad angle in cross-section that is intermediate between the primitive (acute angle) and derived (coplanar) conditions. The lack of prespinal (prsl) and postspinal (posl) laminae on anterior caudal neural spines is an example of retention of a primitive character exhibited by this taxon.

Cladistic analysis places this sauropod firmly within Titanosauriformes and either as a sister taxon to Somphospondyli or *Brachiosaurus*. It does not share derived characters that define Somphospondyli; however, it exhibits characters such as an anteroposteriorly compressed femoral shaft, crescent-shaped sternal plates, and iliac preacetabular process oriented perpendicular to the body axis, which have all been used to define the more derived group Titanosauria. The latter characters shared with titanosaurians are interpreted as independently derived conditions.

36. **Martinez, R., Casal, G., Luna, M., Ibiricu, L., Cardozo, S. and Lamanna, M.:** LAST OF AN ANCIENT LINEAGE: REMAINS OF THE YOUNGEST AND MOST AUSTRAL INDISPUTABLE DIPLODOCOID (DINOSAURIA: SAUROPODA) EVER RECORDED, FROM THE UPPER CRETACEOUS BAJO BARREAL FORMATION OF CENTRAL PATAGONIA

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Associated remains of a sauropod dinosaur have been found in exposures of the Upper Cretaceous Bajo Barreal Formation of northern Santa Cruz Province, Argentina. Material includes an anterior and two posterior dorsal vertebrae, four anterior caudal vertebrae (three of them articulated), a left scapula, ribs, and other elements yet to be recovered. The anterior dorsal vertebra has a forked neural spine, while the posterior dorsals have unforked neural spines. Dorsal centra have pleurocoels. The most anterior caudal have wing-like transverse processes and high neural spine that progressively widen dorsally. The distal end of the scapula is well expanded, but its width is less than twice the minimum width of the blade. Several of these features allow us to include this specimen within Diplodocoidea, the first non-rebbachisaurid diplodocoid from the Upper Cretaceous. Our present knowledge of the Bajo Barreal Formation permits us to recognize two different dinosaur faunas within the unit. The older of the two is middle Cenomanian-Turonian in age, and contains abelisauroid and tetanuran theropods, a basal ornithopod, and at least two sauropod lineages: Titanosauria and Diplodocoidea. The younger fauna is Campanian?-Maastrichtian in age, and consists of Megaraptor-like theropods, an undescribed ornithopod, and the titanosaurian *Aeolosaurus* sp. Stratigraphic data demonstrate that the bed that produced the new diplodocoid overlies the older dinosaur-bearing levels of the Bajo Barreal Formation but is nonetheless older than the Campanian?-Maastrichtian beds. Because of this, the age of the new diplodocoid can be no younger than Turonian. The presence of this ancient sauropod lineage in Upper Cretaceous Patagonian continental assemblages dominated by titanosaurians could shed light on the last surviving diplodocoids, which may have been relicts of a former Pangean distribution that ended their long and successful history in geographically remote central Patagonia.

37. **Mateus, O., Laven, T. and Knotschke, N.:** A DWARF BETWEEN GIANTS? A NEW LATE JURASSIC SAUROPOD FROM GERMANY

MATEUS, Octavio, Universidade Nova de Lisboa & Museu da Lourinha, Lourinha, Portugal; LAVEN, Thomas, KNOTSCHKE, Nils, Dinosaurier-Freilichtmuseum Munchehagen, Rehburg-Loccum, Munchehagen, Germany

Remains of several Late Jurassic sauropod dinosaurs were found in Oker, near Goslar (Lower Saxony, Germany). Only one single layer, datable to Middle Kimmeridgian, provided sauropod bones in Oker quarry, however, more than about 650 remarkably well preserved cranial and postcranial bones were collected. The first sauropod bone from Oker was found by Holger Ludtke in 1998. Most notably these remains include the first sauropod skull known from Europe. It belongs to a new macronarian sauropod close to brachiosaurids. At least, 10 individuals were present, with body-lengths varying



between 1.8 and 6.2 m long, when extrapolated from *Camarasaurus grandis*. One of the smallest specimens has a 119 mm tibia. The body length distribution is symmetrically unimodal with the mean around 3.5-4.5 meters long. Contrary to this, the normal age frequency graphic of wild animal populations is positively asymmetrical (more juveniles and fewer adults). The presence of so many bones from one single species corroborates with the monospecific gregariousness implied for other species. Possibly, such species lived in herds. If we presume that the death and body accumulation resulted from a single event isolated in time, this proposes that sauropods formed multi-aged gregarious groups. The premaxilla has a short muzzle, the nares are large and the jugal has an important role in the lower rim of the skull. Histological studies show adult development of the bones, deduced by the sampling of seven long bones show that we are dealing with dwarf forms.

38. **Konishi, T.:** REDESCRIPTION OF UALVP 40, A SMALL CHASMOSAUR DINOSAUR, WITH ADDITIONAL MATERIAL, AND ITS IMPLICATIONS TO CANADIAN CHASMOSAUR SYSTEMATICS

KONISHI, Takuya, Edmonton, AB, Canada

UALVP 40, one of the few Canadian chasmosaur specimens with long postorbital horncores, was initially collected by G. F. Sternberg in 1920, near Sand Creek, Red Deer River, Alberta, Canada. Previously, however, only the left side of the specimen had been described in literature due to incomplete preparation, and thus the entire skull morphology of the specimen was unknown to us until recently.

In this study, the right half side of the skull and the associated dentary fragment of UALVP 40 are described for the first time after the specimen was completely prepared. The new observations show that there are some substantial differences in the cranial features between the right and left side of the skull, adding new information previously unknown to the specimen. These observations in particular suggest that UALVP 40 very likely pertain to an immature individual of a chasmosaur dinosaur, in contrast to the earlier study. Also, some cranial features on the right side of the skull seriously contradict some of the previous interpretations made on the specimen based only on the data from the left side of the skull.

The current systematics assigns UALVP 40 to *Chasmosaurus* sp.; however, the comparisons of the specimen with other known Canadian chasmosaur specimens with long postorbital horncores seem to suggest a possibility that the specimen could be assigned to *C. canadensis*, the taxon proposed by Lehman in 1989 but currently abandoned, from ontogenetic as well as ecological points of view.

39. **Brill, K. and Carpenter, K.:** ARTICULATED DERMAL ARMOR OF THE ANKYLOSAUR *GASTONIA*

BRILL, Kathleen, CARPENTER, Kenneth, Denver Museum of Nature and Science, Denver, CO

A large slab of articulated dermal armor of *Gastonia*, a polacanthine dinosaur, was found at Lorrie's Site, a monospecific bonebed in the Cedar Mountain Formation (Lower Cretaceous) in east-central Utah. The osteoderms are arranged in distinctive series of interconnected rosettes consisting of large osteoderms surrounded by rings of smaller osteoderms, closely fitted together like tiles. The largest osteoderms (35 to 55 mm diameter) are roughly elliptical with a short peak that are typically placed off-center. The peaks are asymmetrical and pitted. The large osteoderms often have faint grooves, which radiate from the peaks to the margins. The smaller osteoderms (approximately 6 to 25 mm) are irregularly-shaped polygons with straight margins where they interface with a neighboring element. The smaller osteoderms have flat, parallel top and base surfaces with a rough texture. Because armor elements are often scattered or not described, armor pattern is poorly known in ankylosaurs.

The armor sheet was preserved with the external surface up. It was found in mudstone, which directly overlaid a hard concretion layer, approximately 20 to 30 cm thick, which encased the bones of *Gastonia*. The sheet is undulating, conceivably indicating that the skin was flexible when deposited. Cervical ribs, dorsal ribs, vertebra fragments, ossified tendons, and a single ulna were adjacent to the armor. This, and the absence of larger armor elements, could signify that this skin was from the anterior of the animal.

40. **McWhinney, L., Matthias, A. and Carpenter, K.:** CORTICATED PRESSURE EROSIONS, OR “PITTING”, IN OSTEODERMAL ANKYLOSAUR ARMOR

McWHINNEY, Lorrie, MATTHIAS, Angela, CARPENTER, Kenneth, Denver Museum of Nature and Science, Denver, CO

The osteodermal armor of ankylosaurs often exhibits a pattern of depressions that are clearly not associated with taphonomic alteration. An investigation of this pathology was initiated using *Gastonia* osteodermal armor material primarily from the Lorrie’s Bone Bed Site in the Ruby Ranch Member of the Cedar Mountain Formation, eastern Utah. The site is a monospecific bonebed of the polacanthid *Gastonia* with a minimum of a dozen individuals, possibly more. Additional osteodermal armor material from other collections was also used for correlation. The internal wall of each depression is lined with cortical bone indicating an antemortem osteoblastic response to an unknown disease process. This one characteristic is useful in distinguishing this pathology from a non-pathologic, postmortem alteration as seen in exposed, eroded trabecular bone. Based on cortical erosion in modern bone (human and animal), probable differential etiologies include: foreign bony granuloma, intraosseous epidermoid inclusion cyst, fungal and/or bacterial infection, and glomus tumor. Independent of the etiology, the “pits” on the osteodermal material should be referred to as “corticated pressure erosions.”

41. **Ruiz-Omeñaca, J., Canudo, J. and Cuenca-Bescós, G.:** ORNITHOPOD DINOSAURS FROM THE EARLY CRETACEOUS OF THE IBERIAN PENINSULA (SPAIN AND PORTUGAL)

RUIZ-OMEÑACA, José, CANUDO, José, CUENCA-BESCÓS, Gloria, Universidad de Zaragoza, Zaragoza, AL, Spain

Early Cretaceous ornithopods are known from the Iberian Peninsula since the last quarter of the 19th century. Skeletal remains are found in the early Berriasian and early Hauterivian-middle Albian of the provinces of Burgos, Castellón, Cuenca, La Rioja, Soria and Teruel in Spain, and Estremadura in Portugal. They are usually fragmentary and non-diagnostic elements, isolated teeth being the most abundant ones. Ornithopod tracks occur in Burgos, Estremadura, La Rioja, Soria, Teruel, and in Algarve (Portugal).

Currently, hypsilophodontids, dryosaurids, “iguanodontids,” an euornithopod of uncertain affinities (with maxillary teeth resembling those of *Tenontosaurus*), and possible heterodontosaurids and hadrosaurs have been identified. They have been left in open nomenclature in most cases (e.g. cf. *Hypsilophodon* sp., *Valdosaurus* sp., *Iguanodon* cf. *atherfieldensis*). The only proposed species is the possible heterodontosaurid *Trimucrodon* *cuneatus* from the early Berriasian? of Porto Pinheiro (Estremadura). The dryosaurid “*Camptosaurus*” *valdensis* and the iguanodontid *Iguanodon* *bernissartensis* have been identified in the Hauterivian-Barremian of Salas de los Infantes (Burgos, Pinilla de los Moros Fm) and the early Aptian of Morella (Castellón, Morella Fm), respectively.

The presence of *Hypsilophodon* *foxii* in the Iberian Peninsula cannot be confirmed with the available material; the partial skeleton described in Poyales (Galve, Teruel; Camarillas Fm, early Barremian) as *H. foxii* pertains actually to a new, unnamed hypsilophodontid genus. The “iguanodontid” remains from

La Maca (Galve; Camarillas Fm) and Golmayo (Soria; Golmayo Fm, late Hauterivian-earliest Barremian) could be two new unnamed species not assignable to the genus *Iguanodon*.

If it is confirmed by more diagnostic materials than teeth, the presence in the late Hauterivian-earliest Barremian of ?Heterodontosauridae indet. (Colladico Blanco, Galve; El Castellar Fm) and ?Hadrosauridae indet. (La Cantalera, Teruel; Blesa Fm) may represent the youngest heterodontosaurid and the oldest hadrosaur known.

42. **Moreno, K., Carrano, M. and Snyder, R.:** MORPHOLOGICAL CHANGES IN PEDAL PHALANGES AND THE EVOLUTION OF QUADRUPEDALISM IN ORNITHOPODS: A BIOMECHANICAL APPROACH

MORENO, Karen, Univ. of Bristol, Earth Sciences Dept., Bristol, United Kingdom; CARRANO, Matthew, SNYDER, Rebecca, Smithsonian Institution, NMNH, Washington, DC

During ornithopod evolution, a change of posture occurred from bipedalism to facultative quadrupedalism, with a consequent forward shift in the center of mass. Pedal morphology was modified accordingly: the basal digitigrade posture became more unguligrade; unguals evolved from claws to hooves; and phalanges that were longer than wide became more derived and flattened, as seen in hadrosaurids. Similar changes did not occur during the evolution of theropods, which retained a more primitive pedal morphology. Despite these differences, the footprints of theropods and ornithopods are easily confused, primarily because they share the same phalangeal formula.

Many studies have attempted to distinguish between the two types of footprints, but preservational biases can hinder the ability to recognize features such as the presence of sharp claw marks or slight differences in the length-to-width ratio. The only clear indicator of an ornithopod trackmaker is the presence of manus prints. However, postural differences imply that there may have been difference in kinematics between the two orders, and therefore in the distribution of forces along the pes. This may be evident in the external and internal architecture of the pedal bones. Thus an understanding of the biomechanics of dinosaur feet may be useful for footprint identification.

In order to examine these biomechanics we studied the trabecular structure of ornithopod and theropod pedal phalanges, which reflects the principal stresses experienced by the bone. Three-dimensional images of phalanges obtained by CT and laser scanning were used to 1) quantify trabeculae architecture and 2) to create a model to predict the principal stress distribution in a wide variety of phalangeal morphologies. With this method phalangeal morphological changes could be correlated with the forward shift in the center of mass during ornithopod evolution. Comparisons between theropod and ornithopod foot morphologies reveal distinctions that appear to reflect important postural, mechanical, and evolutionary differences.

43. **Aguillon-Martinez, M., Zelenitsky, D., Brinkman, D. and Eberth, D.:** EGG SHELL FRAGMENTS FROM THE UPPERMOST CERRO DEL PUEBLO FORMATION (UPPER CRETACEOUS; MEXICO)

AGUILLON-MARTINEZ, Martha, SEPC-Museo del Desierto, Saltillo, COAH., Mexico; ZELENITSKY, Darla, Univ. of Calgary, Calgary, AB, Canada; BRINKMAN, Donald, EBERTH, David, Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada

A large number of fossil eggshell fragments was collected from a new vertebrate microfossil site in the uppermost Cerro del Pueblo Formation near El Pantano, southern Coahuila, Mexico. Studies of pore morphology, ornamentation, and microstructure using SEM and oriented thin sections show that at least three ootaxa are present: *Porituberoolithus* (non-avian theropod), ?*Prismatoolithus* (possible troodontid

affinities), and *Spheroolithus* or *Paraspheroolithus* (hadrosaurine affinities). This assemblage represents the greatest variety of fossil eggshell yet found in the Upper Cretaceous of Mexico.

The El Pantano microfossil site also yielded the first occurrence of a multituberculate tooth in mainland, northern Mexico. Other associated material includes baby theropod and hadrosaur teeth, trionychid and crocodylian bone fragments, *Lepisosteus* scales and amiid vertebra. This combined microfossil assemblage further underscores the importance of the Cerro del Pueblo Formation and its fossils in studies of North America's southernmost Late Cretaceous paralic ecosystems and vertebrate communities.

44. **Lockley, M., Odier, G. and Mickelson, D.:** ABUNDANT NEW ICHNOFAUNAS OF SMALL THEROPODS FROM THE ENTRADA FORMATION OF EASTERN UTAH

LOCKLEY, Martin, Univ. of Colorado Denver, Denver, CO; ODIER, George, Moab, UT; MICKELSON, Debra, Univ. of Colorado at Boulder, Boulder, CO

The Entrada Formation (traditionally divided into three members in the Moab area: Dewey Bridge, Slick Rock and Moab Tongue in ascending order) was once thought to be almost completely devoid of evidence of vertebrate life. In the 1980s and 1990s, abundant theropod tracks were discovered at the top of the formation in association with the transgressive upper tongue of the Summerville Formation. These tracks fall into two categories: large *Megalosauripus* typically from 40-50 cm in length and larger intermediate-sized *Therangospodus* from 24-33 cm in length. These are associated with a single surface megatracksite that extended for more than 1,000 km<sup>2</sup>.

In contrast new ichnofaunas of small well-preserved theropod tracks, about 5-7 cm in length, are quite common in the main body of the Moab Tongue and are associated with dune foresets that also reveal invertebrate traces. These tracks represent diminutive theropods that lived within the dunes, rather than in coastal regions where the erg was reworked by marginal marine processes. The dominance of diminutive theropod tracks in the dune facies is reminiscent of similar assemblages in other Jurassic eolian facies. When including an isolated site with a well-preserved smaller intermediate-sized theropod tracks (length 15 cm) from within the main body of the dune sequence, we estimate a minimum ichnodiversity of four. Previously the Entrada was considered completely devoid of body fossils except for one crocodylian (*Entradasuchus*) from the Moab Tongue. Thus, the complete dominance of theropod tracks of all sizes has interesting implications for Entrada paleoecology. Stratigraphic nomenclature of the three Entrada members in the Moab area has changed recently. We provisionally retain the term Moab Tongue for the track-bearing member

45. **King, M., Smith, J. and Foster, J.:** FIRST REPORT OF VERTEBRATE TRACKS FROM THE WINGATE SANDSTONE (TRIASSIC-JURASSIC) OF COLORADO NATIONAL MONUMENT, COLORADO

KING, Michael, Ohio Univ., Athens, OH; SMITH, Joshua, Utah Museum of Natural History, Salt Lake City, UT; FOSTER, John, Museum of Western Colorado, Grand Junction, CO

The Upper Triassic-Lower Jurassic Wingate Sandstone is a vast eolian deposit exposed throughout the Four Corners region of the American Southwest. In Colorado National Monument (western Colorado) this unit forms high cliffs and deep canyons between the slopes of the Chinle Formation below and the Kayenta Formation above. As with many eolian deposits, the Wingate Sandstone is largely devoid of body fossils; however, tracks are known from the formation regionally and here we report the first discovery of dinosaur footprints from the Wingate Sandstone of Colorado National Monument.

Five localities containing a total of 79 tracks, representing approximately 18 trackways, have been identified in strata interpreted as interdune deposits. The tracks, preserved as impressions and natural casts, are 6-17 cm long, and all are referable to the ichnogenus *Grallator*. Freshwater limestone interdune deposits similar to those of the Navajo Sandstone apparently are absent from the Wingate. Although the planar surfaces found between the large-scale eolian crossbed sets (sometimes with thin mud drapes or siltstone lenses) of the Wingate Sandstone are interpreted to represent interdune environments. Track sites found here demonstrate the existence of small theropods in Wingate interdune paleoenvironments. Elsewhere, most Wingate track sites occur in the lower part of the formation, but the discovery of a site near the middle of the unit in Colorado National Monument demonstrates the potential for locating tracks stratigraphically throughout the Wingate Sandstone.

46. **Jimenez-Hidalgo, E., Hernandez-Rivera, R. and Ortega-Palacios, L.:** NEW LATE CRETACEOUS VERTEBRATE TRACKS FROM THE SABINAS BASIN, NORTHEASTERN COAHUILA, NORTHEASTERN MEXICO

JIMENEZ-HIDALGO, Eduardo, Universidad del Mar, Puerto Escondido, Oaxaca, Mexico; HERNANDEZ-RIVERA, Rene, Instituto de Geologia, UNAM, Mexico, D. F., Mexico; ORTEGA-PALACIOS, Lissa, Paleontologos Aficionados de Sabinas A. C., Agujita, Coahuila, Mexico

As a result of field prospecting carried out by Amateur Paleontologists of Sabinas (PASAC) a new locality with vertebrate tracks was discovered last year. It is situated about 15 km SW of the city of Sabinas. The bearing bed consists of fine-grained calcareous sandstone of the lower-middle Maastrichtian Escondido Formation. This bed was just partially excavated and large part is still covered.

There are 29 exposed footprints and diverse scratch marks referable to three dinosaur taxa, crocodiles and turtles. Twenty-four tracks, ten of which are arranged in three trackways, are large, tridactyl, mesaxonic, slightly longer than wide and with acute digit tips. These features indicate that they were produced by large theropods. Given their proportions, size and the age of the bearing bed, they probably were made by juvenile or sub adult forms of tyrannosaurids. One print is small (10 cm long), tridactyl, mesaxonic, somewhat wider than long, have a rounded rear margin and short blunted digits. These characteristics suggest that a juvenile hadrosaur left it. Two other tracks have the typical morphology of sauropod manus impressions; they are wider than long, have a horseshoe outline and there are no signs of separate digits. Other prints have four large scratch marks (4-8 cm) with acute tips and rounded or slightly tapered rear margins; some have associated a long concave trail mark. They have been interpreted by several authors as finger tips/claw marks impressions of swimming crocodiles; those with the trail mark seem to correspond to manual prints. The last impressions are sets of three small (1.5-2.5 cm), parallel scratch marks arranged in an almost alternating left-right pairs that form a trackway. Similar prints have been interpreted as produced by swimming turtles.

This locality represents the first report of Cretaceous vertebrate tracks in the Sabinas Basin; it constitutes the youngest record of dinosaur footprints in Mexico and indicates that the coastline of the Sabinas Gulf was more complicated than believed, since in current paleogeographic reconstructions the locality is far away from any coast.

47. **Odiar, G., Lockley, M. and Lucas, S.:** VERTEBRATE ICHNOLOGY AT THE TRIASSIC-JURASSIC BOUNDARY IN EASTERN UTAH: NEW EVIDENCE FROM THE WINGATE FORMATION

ODIER, George, Moab, UT; LOCKLEY, Martin, Univ. of Colorado at Denver, Denver, CO; LUCAS, Spencer, New Mexico Museum of Natural History and Science, Albuquerque, NM

Although previously considered almost completely devoid of useful vertebrate evidence, the Wingate Formation of eastern Utah and nearby western Colorado yields numerous tracksites at multiple stratigraphic levels. Ichnogenera include theropod tracks (*Grallator*), probable prosauropod tracks (*Otozoum* and cf. *Pseudotetrasauropus*), possible sauropod tracks (*Tetrasauropus*), non-dinosaurian archosaur tracks (*Brachychirotherium* and *Batrachopus*) and various synapsid tracks (cf. *Laoporus*). *Eubrontes* and *Anomoepus* also occur in association with the transition zone between the top of the formation and the overlying Kayenta Formation.

However, the distribution of these nine named ichnogenera is evidently strongly controlled by facies and by differences in age between the base and top of the Wingate Formation. Mammaloid tracks similar to Permian *Laoporus* and/or Early Jurassic *Brasilichnium* (from the Navajo Sandstone) are almost exclusively confined to nearly monospecific assemblages associated with dune foresets. They evidently only co-occur with invertebrate traces and a few small *Grallator* tracks. In contrast large *Grallator*, *Brachychirotherium*, *Tetrasauropus* and cf. *Pseudotetrasauropus* tracks occur in association with horizontal partings marked by thin clay drapes, especially in the lower part of the formation, close to the transition with the underlying Chinle Group (Rock Point Formation), and they are typical Late Triassic index ichnotaxa. Current evidence places *Otozoum*, *Batrachopus*, *Eubrontes* and *Anomoepus*, which are typical Lower Jurassic indices, high in the Wingate or in the overlying transition zone. Thus, the ichnological Triassic-Jurassic boundary lies within the Wingate Formation and is readily correlated with standard sections in eastern North America, Europe and Africa with a similar stratigraphic succession of ichnogenera. The mammaloid tracks are evidently strongly linked to eolian facies and are absent or undocumented from areas where such Tr-J facies are lacking.

48. **Maddin, H., Reisz, R. and Evans, D.:** A NEW SPECIMEN OF *ENNATOSAURUS TECTON* FROM THE PERMIAN OF RUSSIA

MADDIN, Hillary, REISZ, Robert, EVANS, David, Univ. of Toronto, Mississauga, ON, Canada

The Caseidae is a monophyletic group of early herbivorous synapsids known from the Permian deposits of North America and Eurasia. The group contains a range of small (*Casea*) to large (*Cotylorhynchus*) forms, which are characterized by the possession of a disproportionately small head and an exceptionally broad rib cage. More specifically, caseids share a broad skull possessing distinctive, strongly developed sculpturing on its dorsal surface, a procumbent rostrum, large external nares, large orbits, and a large pineal opening. The postcranium, though greatly variable in overall size, is conservative among caseids in morphology. Despite their important role as primary consumers in Early Permian ecosystems, their anatomy and ingroup relationships are poorly known due to brief descriptions.

A new specimen of the poorly known Russian caseid *Ennatosaurus tecton* is described in detail. The specimen consists of a nearly complete skull and lower jaw recovered from the Mesen River Basin. Its resemblance to the North American caseid *Cotylorhynchus* is striking and it has been suggested that *Ennatosaurus* is congeneric with *Cotylorhynchus*. The hypothesis that *Ennatosaurus* and *Cotylorhynchus* have a sister group relationship is tested for the first time using phylogenetic analysis.

The Mesen specimen represents the first record of this taxon from outside the type locality of Pinega, with which it only occurs with varanopids. Interestingly, at Mesen, *Ennatosaurus* is found in association with a rich assemblage of amniotes including varanopid and therapsid synapsids, as well as lanternosuchid and nyctiphuretoid parareptiles.

49. **Harris, S., Lucas, S., Berman, D. and Henrici, A.:** BOLOSOURIDAE FROM THE PENNSYLVANIAN-PERMIAN OF NEW MEXICO

HARRIS, Susan, LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM; BERMAN, David, HENRICI, Amy, Carnegie Museum of Natural History, Pittsburgh, PA

Taxonomy of the enigmatic, parareptilian taxon Bolosauridae is largely based on dental characters of its highly distinctive cheek teeth. The supposed oldest known representative of the group, *Bolosaurus striatus*, from the Lower Permian (Wolfcampian) of Texas, has cheek teeth characterized by a tall, bulbous crown that is slightly widened transversely and separation of the occlusal surface into a blunt cusp and a short, uncomplicated heel. An evolutionary trend toward further transverse expansion of the tooth crown and increased complexity of the heel margin apparently culminated in the Middle Permian (Kazanian) genus *Belebey*, in which these dental characters are pronounced. However, bolosaurid cheek teeth from Upper Pennsylvanian and Lower Permian strata of New Mexico are consistent with both extremes of this dental morphological continuum. A single locality (Anderson quarry) in the Lower Permian (Wolfcampian) Cutler Formation of north-central New Mexico has yielded bolosaurid cheek teeth of two distinct morphologies. Five cheek teeth preserved along the margin of an incomplete dentary clearly possess characters diagnostic of *B. striatus*, whereas a partial maxilla bears transversely expanded tooth crowns with low cusps and elongate heels that are readily distinguished from those of *B. striatus*. Isolated bolosaurid cheek teeth, determined to be taxonomically distinct from those of *B. striatus*, were recovered through bulk sampling of sediments from an Upper Pennsylvanian (Virgilian) locality in the Red Tanks Member of the Bursum Formation of central New Mexico. Transverse expansion of the tooth crown has produced an elongate heel along which, in at least one tooth, are distinct ridges comparable to those of *Belebey*. The occurrence of three bolosaurid dental morphotypes near the Upper Pennsylvanian-Lower Permian boundary in New Mexico, as well as the recently described *Eudibamus cursoris* from the Lower Permian (Asselian=early Wolfcampian), complicates the simple linear sequence currently understood to characterize bolosaurid phylogeny, and suggests a more complex, “bushier” pattern of early evolutionary history for the Bolosauridae.

50. **Irmis, R.:** AXIAL SKELETON ONTOGENY OF THE PHYTOSAURIA (ARCHOSAURIA: PSEUDOSUCHIA) AND ITS IMPLICATIONS FOR ASSESSING MATURITY IN ARCHOSAURS  
IRMIS, Randall, Flagstaff, AZ

In extant crocodylians the pattern of neurocentral suture closure of vertebrae provides one way of assessing maturity in individuals. This pattern has been extrapolated to evaluate a wide variety of fossil archosaurs, based on the assumption that crocodylians represent the basal state in Archosauria. Phytosaurs are a Late Triassic basal archosaur clade that can be used to determine whether the crocodylian pattern of suture closure is ancestral for archosaurs. Analysis of a large sample of phytosaur postcrania confirms that the caudo-cranial sequence of suture closure found in extant crocodylians is also found in phytosaurs, and is therefore probably the plesiomorphic condition for Archosauria. An additional ontogenetic trend identified in phytosaurs is the deepening with age of lateral fossae on the centra of anterior cervical vertebrae.

Problems exist, however, with the use of identified ontogenetic trends, such as neurocentral suture closure, for maturity assessment in fossil archosaurs. We have little knowledge of what constitutes maturity in fossil archosaurs. For example, individuals that do not have completely closed vertebral columns may still be adults in the biological sense. Further complications arise with the probability of heterochrony and intraspecific variability. This is an area of research that needs to be explored before we can confidently evaluate maturity in fossil archosaurs using patterns such as neurocentral suture closure.

51. **Sauter, M.:** A POPULATION ANALYSIS OF *BOREALOSUCHUS* (=LEIDYOSUCHUS) *FORMIDIBALIS* (CROCODYLIA) FROM WANNAGAN CREEK QUARRY, NORTH DAKOTA

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Despite the importance of population structure to understanding the biology of extinct species, large samples of single populations are relatively uncommon in the vertebrate fossil record. The Wannagan Creek Quarry, in the Tiffanian Tongue River Formation of North Dakota preserves a diverse fauna from near shore lacustrine deposits. It is dominated by an assemblage of partially articulated and disarticulated skeletons of at least 50 individuals of the crocodylian *Borealosuchus* (= *Leidyosuchus*) *formidibalis*. The assemblage has been hypothesized to represent a single population of crocodiles on the basis of taphonomy. We analyzed size variation and bone histological attributes of the Wannagan Creek crocodiles to address questions of sexual dimorphism, ontogeny, and potential population structure in the assemblage.

We measured maximum length, shaft width, distal end width, and proximal end width in 267 limb bones (femur, tibia, fibula, humerus, radius, and ulna) from individuals of varying ontogenetic development. Sample sizes for individual measurements ranged from ten to 62 due to the poor preservation of some specimens. Individual measurements are strongly correlated for each element, and most of these correlations are statistically significant. Based on Kolmogorov-Smirnov tests, many of the frequency distributions of the linear measurements are statistically distinct from both normal and uniform distributions. Bivariate plots of width measurements versus maximum length indicate that the Wannagan Creek *B. formidibalis* sample includes two distinct size classes, small and large, with no intermediate sized individuals represented. These results suggest either that *B. formidibalis* was dimorphic, which is uncommon among extant crocodylians, or that the *B. formidibalis* sample is biased toward small, young individuals and large, old individuals.

Bone histological analysis of ontogenetic series of four limb elements (tibiae, fibulae, humeri, and radii) provide data for addressing age structure of the Wannagan Creek crocodile sample, shedding new light on both the biology of *B. formidibalis* and the taphonomy and depositional history of the Wannagan Creek Quarry.

52. **Marconato, L., Schultz, C., Oliveira, L. and Rubert, R.: THE FIRST AND THE SECOND 'NOTOSUCHIAN' CROCODILES (CROCODYLIA: MESOEUCROCODYLIA) FROM MATO GROSSO, BRAZIL**

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Remains of two different crocodiles were found in northeastern Mato Grosso, Brazil. Both came from Parecis Group (Middle-Upper Cretaceous), Parecis Basin, from a sedimentary sequence of clastic origin, composed mainly of marls, calcifer mudstones, mudstones, massive to laminated siltstones and sandstones with cross bedded stratification deposited in a continental environment that varied upwards from shallow alkaline lacustrine to fluvio-aeolic.

Both specimens have a high and short cranium, lower jaws with a long symphysis in which the splenial takes part, amphicoelous vertebrae, maxilla with seven or fewer teeth and all preserved teeth are serrated.

The first one comprises a partial snout, palate and basicranium, humerus, six articulated vertebrae and scapula, right and left incomplete mandibular rami and symphysis. Teeth are relatively long and have pronounced differentiation between crown and root. All teeth have labiolingually flattened crowns with finely serrated mesial and distal carinae. In the premaxilla it is possible to distinguish a caniniform and another small tooth having a circular root. Maxillary teeth are more spatulated backward and only



the first presents circular root. Roots are three or four times larger than the crown. The last tooth is reduced. The mandibular fenestra is elongated and ellipsoidal.

The second includes a partial snout without the anterior portion, partial dentary with mandibular symphysis and some vertebrae. There are procumbent teeth in the dentary and probably in the premaxilla. Teeth are ornamented with longitudinal ridges of tuberosities and the labial surfaces are more rounded and convex.

Compared with other Mesoeucrocodylia, these specimens indicate two new taxa from the Brazilian Cretaceous. Mesoeucrocodylia related to them are known in Brazil from Sao Paulo (*Sphagesaurus* and *Mariliasuchus*), Maranh'õ (*Candidodon*), Piau' (*Araripesuchus*) and now at Mato Grosso (two new species). These new finds from Mato Grosso indicate a more widespread geographic distribution for this group than has been supposed and fills a gap that existed in this distribution.

53. **Ikegami, N. and Tomida, Y.:** DISCOVERY OF A EUSUCHIAN CROCODYLIFORM FROM THE CRETACEOUS OF JAPAN

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The fluvial deposits of the "Upper" Formation of the Mifune Group (Cenomanian - Turonian) in Kumamoto Prefecture have yielded a diverse fossil vertebrate assemblage including fish, turtles, a crocodyliform, a pterosaur, dinosaurs, and a mammal. Fossil material of the crocodyliform consists of isolated cranial, mandibular and postcranial elements. Identified elements include a partial maxillae, two parietals, a quadrate, a partial dentary, two angulars, an articular, several vertebrae, several limb bones and a large number of isolated teeth from a variety of individuals. The articular bears retroarticular process, which is curved and elongated posterodorsally. The presacral and the caudal vertebrae are procoelous without dimples on the surface of the posterior condyle. These features support a referral this crocodyliform to Eusuchia.

Fossil non-eusuchian crocodyliforms (e.g., *Gobiosuchus*, *Shamosuchus*, etc.) are common through the Late Cretaceous of Asia. The material from the Mifune Group is the first record of eusuchian crocodyliforms from the Cretaceous of Japan, and may have good potential to provide insight into the evolution and paleobiogeography of early eusuchian crocodyliforms. Furthermore, interpretation of the differences in crocodyliform taxa between inland and the eastern margin of Asia during the Late Cretaceous may be possible by stratigraphical and paleoecological approaches in future works.

54. **Martin, J.:** THE TYPE OF *MOSASAURUS MISSOURIENSIS* COMPARED WITH OTHER MOSASAUR SPECIMENS FROM THE MISSOURI RIVER AREA OF CENTRAL SOUTH DAKOTA

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Since the discovery of the type specimen of *Mosasaurus missouriensis* (= *maximiliani*), relatively few specimens have been ascribed to the species. The type specimen was found along the Big Bend of the Missouri River, probably by Major Benjamin O'Fallon in the early 1830's and taken to St. Louis, Missouri. The snout was evidently sent to the East Coast where it was considered *Ichthyosaurus missouriensis*. The remainder of the skull and partial skeleton were given to Prince Maximilian of Weid, who was in America to study Native Americans with his illustrator Karl Bodmer. Maximilian took the specimen to Germany where it was later described as *Mosasaurus maximiliani*. The similarity of the two specimens was later recognized and recent investigation supports the synonymy. The stratigraphic position of the specimen was unknown, but reinvestigation indicates the source was the upper portion of the DeGrey Member (Campanian), not the Virgin Creek Member as suggested previously. Perhaps

because of taxonomic confusion and the relative unavailability of the skull, many authors have assigned specimens from the Missouri River area to *Mosasaurus conodon*, a taxon originally described from the Maastrichtian of New Jersey. However, recent analyses suggest that medium-sized specimens of *Mosasaurus* from the Big Bend area of the Missouri River are assignable to *M. missouriensis*.

55. **Everhart, M.:** CONCHOIDAL FRACTURES PRESERVED ON ELASMOSAUR GASTROLITHS ARE EVIDENCE OF USE IN PROCESSING FOOD

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The association of large numbers of gastroliths (stomach stones) with the remains of elasmosaurs (Plesiosauria: Elasmosauridae) in the Late Cretaceous marine sediments of North America was first reported in 1877. Their anterior position suggests that they were contained within the elasmosaur digestive tract. The stones are usually well rounded and polished to some degree, and occur in a wide range of sizes within the same specimen. Their presence has been explained by previous authors as accidental ingestion, ballast, and for use in a gastric mill. Gastroliths were examined from seven North American elasmosaur specimens varying in age from Cenomanian to Maastrichtian. In all specimens, at least one stone, usually composed of a microcrystalline quartz such as chert, preserved numerous arc-shaped surface markings. Examination indicates that these markings were the result of small (2-5 mm), conchoidal fractures of the chert. The fractures generally cover the surface of the stone, exhibit varying degrees of wear and often cross other fractures. Similar fractures can occur naturally due to stone on stone impacts in river or beach gravels, but do not occur on non-gastroliths in the numbers observed on the gastroliths which were examined. The more frequent occurrence of conchoidal fractures on the edges of angular shaped stones in a controlled experiment indicates that such damage is an important part of the mechanism for rounding and smoothing gastroliths. Gastroliths with arc-shaped markings were found within a recently described plesiosaur specimen in intimate association with the finely comminuted bones of small fish. These markings suggest that conchoidal fractures occurred as the stones were ground against one another by peristaltic contractions within the plesiosaur's digestive tract. The more frequent occurrence of these markings on chert gastroliths in plesiosaurs compared to similar stones from river and shore deposits provides further evidence as to their use in processing food.

56. **Massare, J.:** ICHTHYOSAUR DIVERSITY IN THE UPPER SUNDANCE FORMATION (JURASSIC: OXFORDIAN), WYOMING

MASSARE, Judy, SUNY Brockport, Brockport, NY

Ichthyosaurs were first collected from the Sundance Formation in the late 1800's and early 1900's, and assigned to a new genus, *Baptanodon*. Five species from Wyoming were described: *B. natans*, *B. discus*, *B. marshi*, *B. reedi*, and *B. robustus*. The genus has been synonymized with *Ophthalmosaurus*, known from the slightly older Oxford Clay of England. Some of the species described from the Sundance Formation were based on very incomplete specimens and unreliable or minor morphological differences. Consequently, three of the species names were not recognized in later literature. Only *O. discus* and *O. natans* are represented in museum collections by more than an incomplete type specimen. Early workers speculated that these two species could represent a single growth series, as what was called *O. discus* is larger than *O. natans*. Recent compilations of ichthyosaurian taxa recognize only one species, and retain the oldest name, *O. natans* for the Wyoming ichthyosaurs.

Over the last decade, ichthyosaurs have been collected from several horizons in the Redwater Shale of the upper Sundance Formation in northwestern Natrona County. This is the same unit from which the older material was excavated, although most of those specimens are from Albany and Carbon counties

to the south. A preliminary assessment of the new specimens suggests that two species are present in the Redwater Shale. Their assignment to the previously described species will be presented and discussed.

57. **Claessens, L.: THE IDENTITY AND FUNCTION OF THE PTEROSAUR PREPUBIS**

CLAESSENS, Leon, Harvard Univ., Cambridge, MA

In many pterosaur taxa the ischium and pubis are fused into a single puboischiadic plate. A suture that demarcates the border between the ischium and pubis cannot always be distinguished. A medioventral symphysis of the ischia is present in pterodactyloids, and may have been present in rhamphorhynchoids. However, generally there is no anteroventral symphysis of the puboischiadic plates, and a pubic symphysis may have been absent in pterosaurs. The pubic portion of the puboischiadic plate extends predominantly ventrally and has an anteroventral joint facet for articulation with a prepubis. The morphology of the prepubis is variable, but generally it is expanded distally and contacts the distal expansion of the contralateral prepubis in the ventral midline. The term prepubis has been applied to a variety of anteroventral ossifications of the tetrapod pelvis that may or may not be homologous. The question of whether the pterosaur prepubis is a neomorphic structure specific to pterosaurs or whether it is part of the pubis is complex, and the elements identified as the prepubes may in fact represent the distal portion of the pubes with their midline symphysis.

There are many structural similarities between the pterosaur (pre-)pubis and the crocodylian pubis. Cineradiographic studies and a survey of fossil crurotarsans indicate that movements of the pubic bones actively assist in lung ventilation in crocodyliforms. The potential existence of a mobile (pre-)pubic system in pterosaurs, analogous to the pubic rotation system of crocodyliforms, may point in turn to the parallel evolution of an equivalent accessory lung ventilation mechanism in the Pterosauria.

58. **Knell, M. and Bishop, G.: AN EXAMINATION OF FOSSIL SEA TURTLE TAPHONOMY IN THE CRETACEOUS PIERRE FORMATION USING THE MODERN ANALOGS *CARETTA CARETTA* AND *DERMOCHELYS CORIACEA***

KNELL, Michael, BISHOP, Gale, South Dakota Sch. of Mines & Technology, Rapid City, SD

Two types of fossil sea turtles are found in the Cretaceous Pierre Formation of South Dakota. These include *Archelon* (Family: Protostegidae) and *Toxochelys* (Family: Toxochelyidae). *Archelon* and *Toxochelys* differ greatly in both size and quality of fossil material. *Archelon*, which reached sizes up to 6 meters in length, is commonly found as scattered fragments of both limb and shell fragments. *Toxochelys* was much smaller, about 1 meter in length, and is commonly found as partial or nearly complete skeletons. Taphonomy of fossil sea turtles is difficult to study, which may explain the lack of published material on the subject. By observing taphonomic processes of living sea turtles it may be possible to better understand the same processes when studying fossil sea turtle specimens.

Two living species of sea turtles are examined as analogs for the two types of fossil sea turtles in South Dakota. The loggerhead sea turtle (*Caretta caretta*) is used as an analog for *Toxochelys* and the leatherback sea turtle (*Dermochelys coriacea*) is used for comparison with *Archelon*. Loggerheads (Family: Cheloniidae) are about 1 to 1.5 meters in length and look very similar to *Toxochelys*. Leatherback sea turtles (Family: Dermochelyidae), the largest living, have a skeletal structure very similar to *Archelon*.

St. Catherine's Island, Georgia is one of several coastal islands where sea turtles nest each summer. Both types of sea turtles are found in this region and occasionally wash ashore as dead animals. These stranded sea turtles have been monitored closely over a period of several weeks to document the decomposition and disarticulation of their carcasses. Data compiled from them has been compiled as series of taphonomic models. Each model describes a mode of sea turtle death with associated

taphonomic results, including: (1) predation at sea, (2) natural death at sea, and (3) death and stranding on beaches. It is possible to use these models based on extant sea turtles to understand how the fossil sea turtles may have died.

59. **Lyson, T., Schachner, E., Tremain, E. and Hanks, H.:** PRELIMINARY REPORT OF A SIGNIFICANT ASSEMBLAGE OF BAENID TURTLES FROM THE UPPER CRETACEOUS (MAESTRICHTIAN) HELL CREEK FORMATION OF SOUTHWESTERN NORTH DAKOTA

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A find in the Hell Creek formation of Southwestern North Dakota has yielded over 30 baenid turtles, 2 trionychid turtles, and teeth and cartilaginous jaw elements from the ray fish *Myledaphus*. The site is located approximately 90 meters below the KT boundary. The specimens are fossilized in a medium grained sandstone fluvial deposit. The fossil bearing strata varies in thickness from 80-120 cm and is lying on top of a tabular mudstone deposit and is overlaid with a laminated clay deposit. Various plant material and logs are found in the channel indicating unidirectional flow.

Over 30 baenid shells have been collected along with 15 skulls and other associated skeletal elements. Based upon the skulls found, the site has yielded 3 different genera and 4 different species of the family Baenidae, including *Plesiobaena antiqua*, *Plesiobaena putorius*, *Eubaena cephalica*, and *Palatobaena bairdi*. The most common turtle found at the site has been that of *P. antiqua*. Both skulls and associated shells have been found for this species at various stages of development. Two skulls from the Trionychidae family have been tentatively described as belonging to *Aspideretes*.

*P. putorius* has previously been restricted to the early Paleocene. This specimen moves *P. putorius* further back in the fossil record into the Late Cretaceous. The number of *P. antiqua* skulls shows some variation within the species including variation in the length of the medial contact of the pterygoids and the height of the crista supraoccipitalis. These variation could be due to sexual dimorphism within *P. antiqua*.

60. **Li, C.:** NEW DISCOVERIES OF THE TRIASSIC MARINE REPTILES FROM CHINA

LI, Chun, The Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Science, Beijing, Clipperton

*Keichousaurus hui* is the first Triassic marine reptile fossil found in China. It was found in Guizhou Province and reported in 1958 by C.C.Young. In the about 20 years after that, some poorly preserved ichthyosaur and sauropterygian fossils from the Lower and Middle Triassic were briefly described and revised at the end of last century.

From the beginning of 1998, a large number of Middle-Late Triassic marine reptiles were collected in southwestern Guizhou Province. This new material comprises important groups that were never before recorded from China, including placodonts, thalattosaurs and aquatic protorosaurs. *Sinocyamodus xinpuensis* is a small cyamodontoid with a wide carapace composed of relatively few pyramidal osteoderms, it has a distinctly elongated orbit and a rounded rostrum. As its name indicates, *Psephochelys polyosteoderma* shows a unique combination of cranial characters observed in *Psephoderma* and *Placochelys*. The ventral dermal armor of *Psephochelys* differs from all other known cyamodontoids in that it comprises irregular marginal osteoderms in loose contact with each other, and gastralia between them. Furthermore, the postfrontal of *Psephochelys* appears to enter the anteromedial margin of the upper temporal fenestra, a character otherwise known from *Placodus*, but not from cyamodontoids. *Anshunsaurus huangguoshuensis*, *Xinpusaurus suni* and *X. kohi* are thalattosaurs that could be related to *Askeptosaurus* and *Nectosaurus* respectively. *Dinocephalosaurus orientalis* is an

aquatic protosaurus with an extremely elongated neck which makes it look like *Tanystropheus*. But the large number of the cervical vertebrae and the sauropterygian-like body make the systematic position of the new taxa uncertain. Besides all these new taxa, many ichthyosaurs, such as *Qianichthysaurus zhoui*, *Cymbospondylus asiaticus*, *Phalarodon* sp. and eusauropterygians such as *Lariosaurus xingyiensis*, and *Nothosaurus youngi* were described recently. The new discovery of Triassic marine reptile from China shows close relationship between Eastern and Western Tethyan faunal province.

61. **Krzyzanowski, S., Heckert, A., Rinehart, L. and Lucas, S.:** AN UPPER TRIASSIC (ADAMANIAN: LATEST CARNIAN) VERTEBRATE FAUNA FROM THE BLUE MESA MEMBER, EASTERN ARIZONA AND ITS IMPLICATIONS FOR MICROVERTEBRATE STUDIES

KRZYZANOWSKI, Stan, HECKERT, Andrew, RINEHART, Larry, LUCAS, Spencer, New Mexico Museum of Natural History & Science, Albuquerque, NM

We report a rich and diverse vertebrate locality (NMMNH L-3764) from the Blue Mesa Member of the Petrified Forest Formation in the Blue Hills northeast of St. Johns, Arizona. The fauna of the Blue Hills includes the aetosaur *Stagonolepis* and the phytosaur *Rutiodon*, both index taxa of the Adamanian land-vertebrate faunachron. The bone-bearing horizon is an intraformational conglomerate that rapidly (<10 cm) fines upward into a bentonitic mudstone. The entire bonebed appears to be pedogenically modified, with color-mottled strata and an iron-rich concretionary coating covering most bones. The fossils consist of disarticulated, but associated (often jumbled) bones of small tetrapods and fish. The macrovertebrate fauna includes extremely fragmentary metoposaurid and isolated phytosaur bones, at least one sphenosuchian, several fish, probable theropods, and a possible ornithischian. Among the most intriguing of these are a fish with an elongate, edentulous rostrum, and a tiny dentary bearing teeth that closely resemble those traditionally assigned to Triassic ornithischians. Microvertebrates include hybodont chondrichthyans, actinopterygian fish, at least two archosauriforms, probable theropods, the ornithischian *Tecovasaurus* or a closely allied form, and a possible prosauropod dinosaur.

There are two particularly important aspects of NMMNH L-3764: (1) the extreme richness of the deposit; and (2) its preservation of relatively complete small vertebrate elements, some of which were previously known only from fragmentary microvertebrate remains. The richness of this deposit can not be overstated: we estimate bone density to range from 100 to 5,000/m<sup>2</sup>. The macrovertebrate fauna includes diverse taxa that possess teeth and other elements previously only known from screenwashing. The bonebed therefore is potentially a "Rosetta Stone" where isolated teeth from microvertebrate faunas can be matched to more readily identifiable skulls and lower jaws. Thus, L-3764 not only provides a glimpse into a Late Triassic ecosystem, but will lend insight into ecosystems represented by more fragmentary assemblages elsewhere.

62. **Jenkins, H. and Heckert, A.:** REVUELTIAN (EARLY-MID NORIAN) MICROVERTEBRATES FROM THE UPPER TRIASSIC SNYDER QUARRY, PAINTED DESERT MEMBER, PETRIFIED FOREST FORMATION, NORTH-CENTRAL NEW MEXICO

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The Snyder quarry is a well-documented assemblage of Late Triassic invertebrates and vertebrates from the Painted Desert Member of the Upper Triassic Petrified Forest Formation in the Chama basin, north-central New Mexico. The presence of Revueltian index taxa, including the aetosaurs *Typothorax coccinarum* and *Desmatosuchus chamaensis* and the phytosaur *Pseudopalatus* demonstrate that the Snyder quarry is of Revueltian (early-mid Norian) age. Screenwashing the matrix of the primary bonebed at the Snyder quarry yields a moderately diverse assemblage of microvertebrates, some of

which were not represented in the macrovertebrate fauna. Microvertebrate fossils from the Snyder quarry are mostly scales and bone fragments, complete teeth are surprisingly rare. New records include a tooth of the hybodontoid shark *Lonchidion* and numerous scales of a palaeoniscid fish tentatively assigned to aff. *Turseodus*. Not surprisingly, the microvertebrate assemblage differs somewhat from the known macrovertebrate assemblage, and includes many more fossils of bony fish. Indeed, osteichthyans dominate the microvertebrate fauna, and include semionotids, redfieldiids, palaeoniscoids, and indeterminate actinopterygians. Osteichthyans are largely represented by scales, with the exception of the indeterminate actinopterygians which are represented by fragments of dentigerous toothplates, fossils previously assigned to colobodontids. The microvertebrate tetrapod fauna represented by teeth includes metoposaurid amphibians, juvenile (?) phytosaurs (?), probable dinosaurs, aetosaurs and other diverse, unidentified archosauromorphs. Many of the vertebrae appear to pertain to small archosauromorphs. The microvertebrate assemblage is unusual in that vertebrae and other non-cranial elements greatly outnumber intact teeth. We interpret this as additional support for the hypothesis of a catastrophic origin for the Snyder quarry vertebrate assemblage, as more typical Chinle Group microvertebrate assemblages are attritional deposits in which teeth greatly outnumber vertebrae.

63. **Marty, D. and Billon-Bruyat, J.-P.:** A NEW REPTILIAN FAUNA FROM THE LATE JURASSIC OF WESTERN EUROPE (KIMMERIDGIAN, SWITZERLAND)

MARTY, Daniel, BILLON-BRUYAT, Jean-Paul, Section de paléontologie, Porrentruy, Switzerland

Since 2000, a Swiss paleontological team (the “Section de paléontologie”) has carried out systematic excavations along the future course of the “Transjurane” highway (Jura, northwestern Switzerland). Numerous fossiliferous beds have been excavated and studied at several localities, all in the vicinity of the town of Porrentruy. These beds are precisely dated by ammonites to the early Late Kimmeridgian. They correspond to coastal deposits of a shallow carbonate platform, at the threshold between the boreal and the tethyan realms. So far, the excavations have yielded a rich and diverse fauna of invertebrates and vertebrates (fish and reptiles), notably lots of dinosaur ichnites.

We report here the first synthetic overview of the “Transjurane” reptilian fauna and a comparison with other Late Jurassic Lagerstätten of Western Europe, which have been deposited in similar paleoenvironments (Canjuers, Cerin, Crayssac, Solnhofen, Solothurn). The reptilian fauna includes skeletal remains of chelonians (Plesiochelyidae, “Talassemysidae”), crocodylians (Teleosauridae, Metriorhynchidae) and of a pterosaur. Moreover, the presence of sauropod and theropod dinosaurs is attested by tracks. The composition of the reptilian fauna is consistent with that of the other sites, but three major groups are still missing (lepidosaurs, ichthyopterygians, sauropterygians). The sauropod ichnites are abundant and occur on several levels, with a large range of footprint size and trackway pattern. This supports the hypothesis that some of these large-bodied terrestrial herbivores could habitually enter coastal marine environments.

64. **Mead, J., Laurito Mora, C., Valerio Zamora, A. L., Swift, S. and Cubero, R.:** THE LATE PLIOCENE-EARLY PLEISTOCENE FAUNA OF EL INDIO, SW COSTA RICA

MEAD, Jim, Northern Arizona Univ., Flagstaff, AZ; LAURITO MORA, Cesar, Instituto Nacional de Aprendizaje, San Jose, Costa Rica; VALERIO ZAMORA, Ana Lucia, Museo Nacional de Costa Rica, San Jose, Costa Rica; SWIFT, Sandra, Northern Arizona Univ., Flagstaff, AZ; CUBERO, Rolando, Heredia, Costa Rica

Mammal and reptile fossils were observed as a lag deposit along a 50 m stretch of a small tributary (1-2 m-wide channel) in the Puntarenas Province of SW Costa Rica. Known as El Indio, the fossil setting is situated near the town of San Gerardo, approximately 16 km west of San Vito. The current

position is at approximately 680 m elevation along an unnamed side-stream of the Rio Limon, today about 74 km from the Pacific Ocean up the Rio Grande de Tirraba. The geological setting is within the Paseo Real Formation. Luis D. Gomez (Organizacion Estudios Tropicales) has organized the project to begin formal excavations in 2005. A reconstruction of the depositional and ecological environments includes a fluvial deltaic setting into a marine estuary habitat; drastically different from what it is today. The river was of a volume/gradient to permit flow with enough competence to deposit coarse sands, small-to-medium-gravel conglomerates, and fairly large fossils into the quiet-water estuary. Preliminary identifications from work in February, 2004, indicate the recovery of *Crocodylus*, turtles, *Eremotherium*, pampatheres, camel, *Equus*, and *Curvieronius*. Future work will include an intense screen washing program. The Paseo Real Fm is known to be of late Pliocene to early Pleistocene in age. Occlusal patterns of *Equus* teeth would corroborate this. Many of the turtle, camel, and Equus elements show puncture marks and breakage consistent with those produced by crocodylians.

65. **Wegweiser, M., Breithaupt, B. and Chapman, R.:** ATTACK BEHAVIOR OF TYRANNOSAURID DINOSAUR(S): CRETACEOUS CRIME SCENES, REALLY OLD EVIDENCE, & “SMOKING GUNS”

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Dinosaur paleopathology provides proxy evidence for various types of behaviors and species interactions in the fossil record. Bite marks suggest activity such as feeding, scavenging and predation. Healed bite marks provide direct evidence of predation and hunting behavior that would otherwise be unknown and in such cases provide evidence of failed predation.

We describe a rib from an adult lambeosaurine hadrosaur from the This Side of Hell Quarry, in northern Wyoming. The rib, from the skeleton of a lambeosaur, nicknamed “Lucky,” shows extensive exostosis around the impression of a large tooth. Lucky’s rib was “shaved” as the tooth slid along it and the rib was permanently twisted from the torque and crushing force that was supplied to the living tissue during the attack bite. The tooth embedded itself in the bone during a clear attempt to rip the rib from the body of the lambeosaur. The attempt failed and the rib was ripped almost subparallel to its long axis. The rib healed around a hole that provides an outline of the tooth, leaving a permanent gape with an arching bridge. The tooth that most closely fits the outline most likely belonged to an adult tyrannosaurid dinosaur. This is being studied further using three-dimensional scanning methods and rapid prototyping. Adjacent ribs show signs of suppuration suggesting Lucky survived a massive infection that occurred after the failed attack. It may have taken up to 1-2 years for the complete healing of such a wound based on studies of modern animals, suggesting that the injury to the ribs happened a number of years before the dinosaur’s final demise.

66. **Ruez, Jr., D.:** ON THE NATURE OF FOSSIL LOCALITIES AT HAGERMAN FOSSIL BEDS NATIONAL MONUMENT, IDAHO

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To better understand the impact of climate change on terrestrial communities, comparisons between faunas at different stratigraphic levels is best done on relatively continuous sections. Exposures of the Glens Ferry Formation in southern Idaho provide an excellent opportunity for such evaluations. The nature of the different types of localities must be understood before comparisons between fossil sites can be made at the Hagerman Fossil Beds National Monument (HAFO). Pliocene vertebrates have been recovered not only from *in situ* deposits, but also from anthills, blowouts, and surface collections.

Fossils from the Hagerman Horse Quarry (HHQ), anthills, and blowout localities are considered to be essentially at the original stratigraphic level of deposition. Fossils from HHQ have a long history of research, including varying hypotheses of the method of deposition, but the *in situ* nature of the sediments derived from the HHQ is not questioned. Species of modern ants belonging to *Pogonomyrmex* do gather fossils from more than the immediate area, but the estimated maximum vertical movement is only 1.1 m, which is within the resolution of elevation possible at most HAFO localities. The microstratigraphy of blowout localities is here described; vertebrate fossils recovered in blowouts at HAFO are derived from single layers of about 12 cm. These layers are easily eroded and only found lateral to the blowout where it is still overlain by other layers. Pelecypods occur throughout these layers but are extremely fragile and very difficult to excavate intact. Sediment samples weighing approximately 1 kg were taken from the top, middle, and bottom third of the fossiliferous unit. The top third yielded 270 vertebrate fossils, the middle third produced 1334 vertebrate fossils, and the bottom third contained only a single specimen. Sands above and below the 12-cm layers were typically unfossiliferous. Fossils recovered as surface float generally should be excluded from stratigraphic comparisons because the only provenance data for them is that their level of recovery represents the lowest possible position.

67. **Schafer, A. R., Goodwin, H. T., Brand, L. and Moon, H.:** TAPHONOMY OF MICROFOSSILS FROM THE BLACK MOUNTAIN TURTLE LAYER, EOCENE BRIDGER FORMATION, SOUTHWESTERN WYOMING

SCHAFFER, A. Rahel, GOODWIN, H. Thomas, Andrews Univ., Berrien Springs, MI; BRAND, Leonard, Loma Linda Univ., Loma Linda, CA; MOON, Holly, Andrews Univ., Berrien Springs, MI

Previous work in a section of the Bridger Formation (near boundary of middle and upper levels of Bridger B) showed that abundant fossil turtles were concentrated in mudstones directly above widespread limestone units. Most work has been done on one fossil-rich unit, the Black Mountain Turtle Layer (BMTL). Taphonomic and sedimentological evidence supported a mass mortality interpretation, with episodic volcanoclastic input into a shallow lacustrine environment associated with death and fairly rapid burial of abundant turtles.

In the present study, we investigate taphonomic condition and distribution of vertebrate and invertebrate microfossils obtained by screen washing standard sediment (~19 L) samples from >15 localities geographically representative of the BMTL, with small-scale stratigraphic samples also taken at some localities. Preliminary results indicate that microfossils are essentially ubiquitous in BMTL sediments (present in all samples studied so far), with densities ranging from <0.5 to >120 fossils/L sediment but without clear geographic trend. Most microfossils are highly fragmentary and difficult to identify, but identifiable elements document numerous small mammals and various fish, gastropods, and small reptiles. The fragmentary, widely dispersed assemblage seems most consistent with attritional fossil accumulation; ongoing work will try to resolve the apparent discrepancy between taphonomic pathways suggested by microvertebrates and turtles.

68. **Suarez, M., Suarez, C., Grandstaff, D., Terry, Jr., D. and Kirkland, J.:** SEDIMENTOLOGIC, TAPHONOMIC, AND RARE EARTH ELEMENT GEOCHEMICAL ANALYSES OF THE EARLY CRETACEOUS (BARREMIAN) CRYSTAL GEYSER DINOSAUR QUARRY, EAST-CENTRAL, UTAH

SUAREZ, Marina, SUAREZ, Celina, GRANDSTAFF, David, TERRY JR., Dennis, Temple Univ., Philadelphia, PA; KIRKLAND, James, Utah Geological Survey, Salt Lake City, UT



The Crystal Geyser Dinosaur Quarry (CGDQ) is located southwest of Green River, Utah in early Cretaceous (Barremian) sediments of the Cedar Mountain Formation. The quarry, which is 2m thick, contains a large, nearly monospecific assemblage of basal therizinosauroids in three major bone accumulations. Our research utilizes a combination of classical facies and taphonomic analyses, and a new taphonomic approach, rare earth element (REE) geochemistry, to determine possible scenarios for accumulation of this unusual site. Bones in the lowest accumulation have low plunge, a north-northeast orientation and occur in a discontinuous carbonate layer with abundant chert pebbles and clay rip-up clasts from the underlying Morrison Formation. Bones in the second accumulation are often contained in carbonate nodules in a mudstone matrix and are separated from the third accumulation by a carbonate layer. The third accumulation is also in mudstone and contained within carbonate nodules. These bones have high plunge angles and seem to be truncated by an erosional surface. Thin-section analysis suggests that genesis of carbonates in the CGDQ is complex. Evidence for pedogenic (microcodium), lacustrine (ostracode and charophyte fossils), and spring (feathery and radial calcite texture) carbonates is present. Relative enrichment in light, middle, or heavy REE and other trace elements in fossil bones may be used as proxies for paleoenvironmental redox and pH. All bones sampled from the basal unit have similar middle REE-enriched signatures with positive Ce-anomalies. Bones sampled from the second and third accumulations have varied signatures, different from the basal unit. This suggests a reworked or time-averaged fossil accumulation for these upper units. Incorporation and formation of stable REE signatures in bones occurs shortly after death (within ca. 10-20 Ka). The differences in REE signatures between the bone-bearing units suggest that accumulation events were separated by at least this amount of time. The sedimentologic and taphonomic data suggest that three distinct events concentrated the nearly monospecific assemblages of therizinosauroids at the site.

69. **Bilbey, S. A., Mickelson, D., Hall, E., Madsen, S., Todd, C. and Kirkland, J.:** VERTEBRATE ICHNOFOSSILS FROM THE UPPER JURASSIC STUMP TO MORRISON FORMATIONAL TRANSITION, FLAMING GORGE RESERVOIR, UTAH

BILBEY, Sue Ann, Uinta Paleontological Associates Inc., Vernal, UT; MICKELSON, Debra, Univ. of Colorado at Boulder, Boulder, CO; HALL, Evan, Uinta Paleontological Associates Inc., Vernal, UT; MADSEN, Scott, Dinosaur National Monument, Jensen, UT; TODD, Chauncie, USDA Forest Service, Vernal, UT; KIRKLAND, James, Utah Geological Survey, Salt Lake City, UT

The United States Bureau of Reclamation commissioned the Utah Geological Survey to organize a preliminary survey for paleontological resources along the shoreline of Flaming Gorge Reservoir in northeastern Utah in the spring of 2002. During that work, the authors discovered sauropod trackways on a vertical sandstone cliff of the uppermost Stump Formation. Closer investigation of the strata revealed not only the undertracks of a small adult sauropod but a trackway representing a juvenile sauropod as well. In addition, there are well-preserved casts of sauropod manus and pes prints weathering from an overlying dinoturbated horizon. Approximately 4 m below the sauropod tracks, there are a series of thin bedded, ripple-marked sandstone units with several pterosaur trackways preserved as well as a small quadrapedal trackway. These tracks are preserved in marginal marine deposits along the retreating shoreline of the Sundance Seaway that interfinger with the fluvial and overbank units of Salt Wash Member of the Morrison Formation in northeastern Utah. The typical fluvial crossbedded sandstone units of the Salt Wash Member are well exposed a couple of meters above the sauropod trackway.

70. **Woody, D. and Parker, W. G.:** EVIDENCE FOR A TRANSITIONAL FAUNA WITHIN THE SONSELA MEMBER OF THE CHINLE FORMATION, PETRIFIED FOREST NATIONAL PARK, ARIZONA

WOODY, Daniel, Univ. of Colorado, Boulder, CO; PARKER, William G., Petrified Forest National Park, AZ

The Chinle Formation of Arizona, New Mexico and Utah has undergone considerable revision in recent decades. Much of this work has concentrated on two specific, but related areas of study: the stratigraphy and the paleontology. The occurrence of a significant faunal turnover event coincident with the boundary between the Adamanian and Revueltian Land Vertebrate Faunachrons (LVFs) has been interpreted from recent work. The Adamanian-Revueltian LVF boundary is believed to be contemporaneous with the Carnian-Norian stage boundary. However, the hiatus denoted by the erosional scour located at the base of the Sonsela Member is interpreted to encompass the time of the actual faunal turnover event.

Detailed stratigraphic work by the author on the Sonsela Member of the Chinle Formation within Petrified Forest National Park (PEFO) has proved insightful into the preservation of the Carnian-Norian boundary and to the nature of the coincident faunal turnover event. Consistent with the most recent work on the stratigraphy of the Sonsela, it is shown to consist of several sandstone bodies within PEFO, similar to the type section, and its elevation to member status is supported. However, mapping and consideration of the associated mudstone packages between the main sandstone bodies suggests a different correlation between subunits than that of previous authors.

The new correlations indicate that the Sonsela Member comprises a much larger proportion of PEFO, and its fossil localities, than previously recognized. Importantly, it is shown that several taxa that are considered to be diagnostic of the Adamanian and Revueltian LVFs are found within the Sonsela Member. Therefore, it is concluded that the Sonsela possesses a nearly continuous record through the Carnian-Norian boundary, at least within PEFO. Preliminary analysis indicates that the Sonsela fauna may be considered to be 'transitional' between the Adamanian and Revueltian, making it a prime area for future study of faunal change across the Carnian-Norian boundary.

71. **Lerner, A., Lucas, S., Hunt, A. and Minter, N.:** LOWER PERMIAN TETRAPOD ICHNOFAUNA FROM THE ABO FORMATION, FRA CRISTOBAL MOUNTAINS, SIERRA COUNTY, NEW MEXICO

LERNER, Allan, LUCAS, Spencer, HUNT, Adrian, New Mexico Museum of Natural History, Albuquerque, NM; MINTER, Nicholas, Univ. of Bristol, Bristol, United Kingdom

New Mexico's Early Permian track record, particularly that of the Robledo Mountains near Las Cruces, is recognized as a global standard for nonmarine redbed ichnofossils in Lower Permian strata. While the presence of tetrapod footprints in the Abo Formation of the Fra Cristobal Mountains has been noted in the geological literature since the 1980's, they have not been adequately documented. Recent collecting has established the vertebrate track record from the Red Gap area of the Fra Cristobal Mountains.

New Mexico Museum of Natural History locality 5383 is in the lower part of the Abo Formation (early Wolfcampian) in Sierra County, NM. An extensive tetrapod footprint assemblage that consists mostly of *Batrachichnus* is present in a 0.7-m thick bed of thin-bedded, ripple-laminated sandstone ~25-m above the base of the Abo Formation. *Dromopus* is only a minor component of the overall ichnofaunal census. Also present are two vertebrate ichnogenera previously unknown in the Fra Cristobal outcrops: *Dimetropus* and *Gilmoreichnus*. These tracks, attributed to large and small pelycosaurs, respectively, are also minor components of the footprint assemblage. An invertebrate

ichnofauna is present consisting of traces referable to *Tonganoxichnus robledoensis*, *Robledoichnus*, *Dendroidichnites*, *Diplopodichnus*, *Taenidium*, and ?*Planolites*. One slab shows clusters of bifid scratch marks that are similar to the anterior of *Tonganoxichnus ottawensis*.

The Red Gap site is similar in ichnofaunal composition to the well-known Robledo Mountains vertebrate track localities but differs in some significant aspects. Red Gap is stratigraphically lower in the Abo Formation and therefore is older. Red Gap was an inland sandflat with no tidal influences, whereas the Robledo sites were on tidal flats. Red Gap is unlike Abo track sites found in the central part of the state, which are characterized by the presence of *Amphisauropus*. Red Gap lacks this ichnogenus, as do all other known Early Permian tracksites in the southern part of the state. We conclude that in Wolfcampian strata of New Mexico, *Amphisauropus* is a facies fossil restricted to inland fluvial environments.

72. **Reece, T., Farlow, J. and Argast, A.:** PRESERVATION OF FOSSIL BONE FROM THE PIPE CREEK SINKHOLE (LATE HEMPHILLIAN, GRANT COUNTY, INDIANA)

REECE, Tamra, FARLOW, James, ARGAST, Anne, Indiana Purdue Univ. Fort Wayne, Fort Wayne, IN

The Pipe Creek Sinkhole (PCS) local fauna provides a rare glimpse of late Tertiary continental vertebrates from the interior of the eastern half of North America. Thousands of individual bones preserved in a sinkhole pond deposit record a diverse assemblage of fishes, amphibians, freshwater turtles, land tortoises, snakes, and small and large mammals. The fossiliferous deposit is largely unconsolidated, apart from numerous nodules (many of which incorporate bone) cemented with calcite and iron/manganese oxides. Few bones show surface weathering, suggesting that they were buried soon after death.

Thin sectioning, scanning electron microscopy, and energy-dispersive x-ray spectroscopy were used to examine the internal preservation of PCS bones. Fossil anuran bones (tibiofibula and/or radio-ulna, urostyle, scapula), tortoise shell fragments, rodent incisors, and a piece of ?large mammal ?rib from PCS were compared with material from Recent painted turtle (*Chrysemys picta*) shell, gray squirrel (*Sciurus carolinensis*) incisor, and white-tailed deer (*Odocoileus virginianus*) rib. There is little mineral infilling of pore spaces within PCS bones. Presently unidentified, vaguely circular or elliptical, cryptic growths (often paired) dot the trabeculae of the ?rib interior. Compared with Recent bone, PCS bone has elevated fluorine (F) levels consistent with the stoichiometries of typical fluorapatites. There is no zoning in F concentrations from the interior to the exterior of PCS bones; rather, they are homogeneous throughout. Initial indications are that, except for some addition of F to the bone apatite, the inorganic composition of PCS bone is similar to its composition in life.

73. **Ludtke, J., Prothero, D. and Lucas, S.:** MAGNETIC STRATIGRAPHY OF THE UPPER MIDDLE EOCENE BACA FORMATION, WEST-CENTRAL NEW MEXICO

LUDTKE, Joshua, Biology, San Diego State Univ., San Diego, CA; PROTHERO, Donald, Occidental College, Los Angeles, CA; LUCAS, Spencer, New Mexico Museum of Natural History, Albuquerque, NM

The Baca Formation in west-central New Mexico (near the towns of Quemado and Pie Town) consists of about 180 m of redbeds, mudstones and volcanic ashes deposited in a braided alluvial-fluvial system. It yields a fragmentary but important Duchesnean (late middle Eocene) mammalian fauna, including the primitive entelodont *Brachyhyops*, the creodont *Hyaenodon* (both of which first occur in the Duchesnean), plus the primitive artiodactyl Protoreodon and the brontothere *Diplacodon* (both Uintan holdovers), and fragmentary agriochoerids, camelids and protoceratids. The most complete

section at Mariano Mesa was sampled and the samples were subjected to both thermal and alternating field demagnetization. The samples yielded a stable single component of remanence which passed a reversal test, and was held largely in magnetite with minor goethite overprints. Nearly the entire section is of reversed polarity. Based on a K-Ar date of 38.0 Ma from the overlying Spears ignimbrite (part of the Dátil volcanic group), we correlate the Baca Formation with Chron C17r (38.2-38.5 Ma), or middle Duchesnean. This coincides with the age of the Duchesnean Galisteo Formation in north-central New Mexico, suggesting that the two basins opened and filled at the same time.

74. **Evanoff, E.:** LITHOSTRATIGRAPHY OF THE SCENIC MEMBER OF THE BRULE FORMATION (LOWER OLIGOCENE) IN THE NORTH UNIT OF BADLANDS NATIONAL PARK

EVANOFF, Emmett, Boulder, CO

The Scenic Member of the Brule Formation in the North Unit of Badlands National Park contains some of the richest mammal-bearing rocks in North America. Known as the "turtle-oreodon beds" by the early workers, the detailed regional stratigraphy has continued to be poorly known. Detailed mapping of 92 square kilometers along the Badlands Wall and the description of 27 stratigraphic sections in the Scenic Member results in a much better understanding of the lithostratigraphy and depositional history of the Scenic. The Scenic Member was deposited on an erosional topography cut into the Chadron Formation that had a maximum relief of 24.5 m. The sediments of the lower Scenic are a series of thick brown to tan clayey mudstone beds that blanketed the older topography. Fossil vertebrates are locally very abundant in these mudstones, which are the Lower Nodules of previous workers. These mudstones are overlain by a series of fine to very fine-grained sandstone sheets occurring in three intervals and separated by widespread mudstone marker beds. The lower marker bed is named the Hay Butte Marker, which is a series of thick brown mudstone beds, the middle of which contains euhedral crystals of biotite and other minerals indicating that it is a tuff. The Hay Butte Marker averages 1.9 m thick and can be traced for 62 km along the outcrops. The upper marker bed is named the Saddle Pass Marker, and is a second sequence of brown to red mudstones, 1.0 to 2.2 m thick. Like the Hay Butte, the Saddle Pass Marker can be traced along the entire length of the Badlands Wall. The uppermost sandstone sheets are capped by buff mudstone beds containing thin limestone stringers or carbonate nodules. These buff mudstones comprise the Upper Scenic Member, and contain vertebrate fossils only in the western part of the study region. The contact with the overlying Poleslide Member is lithologically marked by the change from mudstone beds to thick siltstone beds. Vertebrate fossils are not equally distributed throughout the Scenic, but are concentrated in the lower mudstone beds, under the widespread marker beds, and in the upper mudstone beds in the west.

75. **Benoit, M. and Yarborough Fitzgerald, V.:** DECAY CONDITIONS OF AN UPPER TRIASSIC POPOSAUR: EVIDENCE FROM CALCIUM CARBONATE NODULES

BENOIT, Matthew, YARBOROUGH FITZGERALD, Vicki, Yale Peabody Museum of Natural History, New Haven, CT

The presence of calcium carbonate nodules associated with fossil specimens has been recorded since the 19th century, often coupled with soft-tissue preservation. Recent experiments regarding the formation of these nodules have elucidated their origins in the microbial decay processes of animal soft tissues. The composition and formation of calcium carbonate nodules, therefore, are particularly informative with regard to the decay environment of a fossilized specimen. Environmental conditions affect the precipitation of various minerals during the decay process. In some cases, the degree of fossilization itself is affected, as evidenced by apatite-mineralized soft tissue that is often associated with these calcium carbonate nodules. The production of apatite is dependent on the presence of

phosphorous and a local pH level below the carbonate dissociation point (approximately 6.2). In a closed environment, pH tends to decrease during decay processes (assisting in apatite precipitation).

The recent excavation of an articulated, 75% complete poposaur skeleton from the Chinle Formation (Upper Triassic) in Utah revealed associated calcium carbonate nodules. Samples of nodules were taken from various layers of the thoracic area of the animal during preparation. The nodules were embedded in an epoxy resin and thin sectioned. Microprobe analyses (specifically EDAX spectra and element maps) of these thin sections reveal a primary composition of calcite with sparse concentrations of apatite. The decay environment, as indicated by these and other analyses, was likely open, with little to no bioturbation, but with omnipresent microbial activity.

76. **Savage, R.:** INITIAL FINDINGS FROM AN EOCENE FOSSIL LOCALITY FROM THE WIND RIVER FORMATION, SOUTHWESTERN WIND RIVER BASIN IN CENTRAL WYOMING

SAVAGE, Rachel, Casper College, Casper, WY

The first summer of exploration at Tate Museum Field Local 1 (TMF1) produced a wide variety of early Eocene fossils from the Wind River Formation. TMF1 has two fossil bearing areas, made up of 16 different micro- and macro-fossil sites. Sediments in the area consist of variegated mudstones, conglomerates and sands. Area 1, with seven microfossil sites, shows a wider variety of remains. Area 2, with six micro-sites and three macro-sites, had fewer remains and less variety. Finds were mostly surface collected, with small scale excavations on larger specimens.

Site NR-02-82 in area 1 produced the highest number of microfossil remains, and also the widest variety. A number of different fossil animals were represented, including gar, turtles, crocodiles, *Coryphodon*, and a variety of small mammals. The other sites in this area followed the same trend, with crocodile remains among the more common finds.

Area 2 of TMF1 produced a larger sampling of macrofossils. Site NR-03-117 held a twenty percent complete *Trionyx* specimen. Site NR-03-118 contained the partial remains of a medium sized crocodile, with some skull elements. NR-03-121 was the only site containing plant fossils, including a six foot (two meter) tree. Mammal teeth were not as common in area 2, and gar scales were only found at one site and in smaller numbers than at NR-02-82.

Fossils in both areas appear to be restricted along a specific stratigraphic horizon. Sands and conglomerates are more prevalent in area 1. Combined with large numbers of gar scales, and a lack of macrofossil findings, area 1 appears to be more of a deltaic environment. The mudstones in area 2 are thicker, and more complete fossil remains indicate an area of less water activity, possibly a fluvial or lagoonal type environment. Further identification of mammal and plant fossils are needed to determine exactly which members of the Wind River Formation are present.

77. **Tapanila, L., Roberts, E. and O'Leary, M.:** CRETACEOUS-TERTIARY FAUNAS OF THE TRANS-SAHARAN SEAWAY IN NW AFRICA: TRENDS IN PRESERVATION AND PALEOECOLOGY

TAPANILA, Leif, ROBERTS, Eric, Univ. of Utah, Salt Lake City, UT; O'LEARY, Maureen, Stony Brook Univ., Stony Brook, NY

A southern embayment of the Tethyan Sea inundated parts of NW Africa between the Cretaceous-Eocene, and at times may have connected to the South Atlantic via the Taoudeni and Iullemeden Basins in Mali. The Mali sedimentary basins are composed of four main facies that reflect different depositional environments, including (from near-shore to offshore), terrigenous sandstones, phosphate conglomerates, paper shales, and limestones. Except for deltaic sandstone facies restricted to the Cretaceous, all other facies are recurrent throughout the K-T section. These depositional environments

record different aspects of the fauna, but together demonstrate a diverse shallow marine ecosystem for the Trans-Saharan Seaway.

The phosphate conglomerate facies typically preserves reworked and unassociated vertebrate bones and coprolites, to the exclusion of invertebrate carbonate shells. These conglomerates are primarily rich in chondrichthyan teeth and osteichthyan axial and cranial elements, lesser crocodylian and turtle elements and rare mammal bones. As reworked and concentrated deposits, the phosphate conglomerates are most useful in assessing the long-term diversity of the ecosystem. The paper shale facies is typically poorly fossiliferous, although minor invertebrate shells, chondrichthyan teeth and wood have been recovered. By contrast, the limestone facies is highly fossiliferous, primarily in molluscan shells and echinoids, but it also preserves articulated and associated vertebrate specimens. The best preserved Mali specimens occur in the limestone facies (e.g., crocodylian skull with stapes), suggesting that this facies is the best target for studies on systematic and evolutionary paleontology.

Recognizing the differential taphonomic modes of each facies is important for understanding the biases and limitations of these fossil assemblages. Knowledge of these modes will aid in interpreting the paleoecology and evolutionary aspects of the fauna during globally important times (e.g., the Maastrichtian-Paleocene and Paleocene-Eocene boundaries) and it will serve as a prospecting tool to direct future investigations in NW Africa.

78. **Kukihara, R., Lockley, M. and Matsukawa, M.:** MODELLING AN UPPER CRETACEOUS ECOSYSTEM BASED ON VERTEBRATE TRACKS FROM THE LARAMIE FORMATION, FOSSIL TRACE, COLORADO

KUKIHARA, Reiji, LOCKLEY, Martin, Univ. of Colorado at Denver, Denver, CO;  
MATSUKAWA, Masaki, Tokyo Gakugei Univ., Tokyo, Japan

One can apply energy flow models to abundant track data to attempt a reconstruction of the Upper Cretaceous Laramie Formation paleoecosystem at Fossil Trace, Colorado. The sun's energy is converted to carbohydrates by plants and moved through primary consumers to higher level consumers and finally emitted as heat. Three kinds of transform efficiency values (consumption, assimilation and production) are influenced and controlled by the types of animals involved in moving energy from one trophic level to the next. Energy intake, distribution ratios and transmission (output) can be estimated at each trophic level according to the characteristics of each species. Number of animals can be estimated by dividing distributed energy by corresponding energy intake. Ratios of numbers of dinosaurs are estimated from fossil trackway data. Fossil tracks are superior to body fossils for this model (and site) because they are *in situ*, more abundant and have more uniform preservation. Energy intake can be calculated from weights, metabolic types and activity levels. The model was verified as credible by applying it to Serengeti faunas. The results suggest that the Laramie paleoecosystems indicate a dominance of large herbivorous vertebrates which gives high secondary productivity. It is difficult to use predator/prey biomass ratios to determine dinosaur metabolic types. This work provides a basic way of comparing different paleoecosystems and can be applied to a comparative study of transitions between paleoecosystems and their corresponding paleoenvironments.

79. **Lewis, C., Heckert, A., Lucas, S., Hunt, A. and Hutchison, J.:** THE VERTEBRATE FAUNA AND PALEOECOLOGY OF THE UPPER CRETACEOUS MENEFEE FORMATION (LATE SANTONIAN-EARLY CAMPANIAN), NORTHWESTERN NEW MEXICO

LEWIS, Caleb, HECKERT, Andrew, LUCAS, Spencer, HUNT, Adrian, New Mexico Museum of Natural History and Science, Albuquerque, NM; HUTCHISON, John, Univ. of California Museum of Paleontology, Berkeley, CA

The fossil record of terrestrial tetrapods of late Santonian and early Campanian age in the Western United States has so far been comparatively poor. The Menefee Formation of northwestern New Mexico has thus far yielded only a fragmentary tetrapod fossil assemblage, although we believe this formation's fossil assemblage is an important representative for this time interval in the Western U.S. Unfortunately, this assemblage has as of yet not been well studied, in large part because it is not nearly as rich as the younger faunas of the nearby Fruitland and Kirtland formations. Most of the fauna are based on extremely fragmentary material that is not diagnostic below the family level. The Cleary Coal Member yields a vertebrate fauna of indeterminate amiids, lepisosteids, trionychid and baenid turtles, hadrosaurs, ankylosaurs, and an indeterminate tyrannosaur. New vertebrate records from the Allison Member include a fin spine fragment of a hybodont shark, possibly *Lissodus* or *Lonchidion*, lepisosteid fish, the trionychid turtle *Adocus*, a pelomedusid turtle, the baenid *Baena nodosa*, indeterminate trionychids, the solemydid turtle cf. *Naomichelys*, the alligator *Brachychampsa montana* (= *B. sealeyi*) and other, indeterminate crocodylians, the centrosaurine informally known as the "Menefee ceratopsian," indeterminate hadrosaurids, and the dromaeosaur *Saurornitholestes* sp. A possible lambeosaurine, and an indeterminate ornithopod. We propose that better fossil assemblages may be found in the more southwestern parts of the formation's outcrop belt, in large part because these strata represent depositional environments more favorable for vertebrate fossil preservation. Menefee Formation faunal assemblages are consistent with interpretations of this formation as representing primarily swampy and deltaic facies.

80. **Mickelson, D., Lockley, M., Bishop, J. and Kirkland, J.: A NEW PTEROSAUR TRACKSITE FROM THE JURASSIC SUMMERVILLE FORMATION, NEAR FERRON UTAH**

MICKELSON, Debra, LOCKLEY, Martin, Univ. of Colorado at Denver, Denver, CO; BISHOP, John, Marietta College, Marietta, OH; KIRKLAND, James, Utah Geological Survey, Salt Lake City, UT

Pterosaur tracks (cf. *Pteraichnus*) from the Summerville Formation of the Ferron area of central Utah, add to the growing record of *Pteraichnus* tracksites in the Upper Jurassic Summerville Formation and time-equivalent, or near time-equivalent deposits. The site reveals high pterosaur track densities, but low ichnodiversity, and considerable variations in size frequencies, suggesting congregations or "flocks" of many individuals. Footprint length varies from 2.0 to 7.0 cms. The ratio of well-preserved pes:manus tracks is about 1:3.4. This reflects a bias in favor of preservation of manus tracks due to the greater weight bearing role of the front limbs, as noted in other pterosaur track assemblages. The sample also reveals a number of well-preserved trackways suggesting pronounced lengthening of stride indicating acceleration.

One well-preserved medium sized theropod trackway (*Therangospodus*) and other larger theropod track casts (cf. *Megalosauripus*) are associated with what otherwise appears to be a nearly monospecific pterosaur track assemblage. Importantly, several of the pterosaur tracks bear traces of a fifth pes digit suggest some tracks are of rhamphorynchoid, rather than pterodactyloid origin, as usually inferred for *Pteraichnus*. The tracks occur at several horizons in a thin stratigraphic interval of ripple marked sandstones and siltstones. Overall the assemblage is similar to others found in the sametime interval in the Western Interior from central and eastern Utah through central and southern Wyoming, Colorado, northeastern Arizona and western Oklahoma. This vast "*Pteraichnus ichnofacies*," with associated saurischian tracks remains the only ichnological evidence of pre-Cretaceous pterosaurs in North America, and sheds important light on the vertebrate ecology of the Summerville Formation and contiguous deposits.

81. **Costa Rica, J., Wilkins, A., Hahn, L., Costa Rica, S. and Milovina-Meyer, P.:** A PALEO-ENVIRONMENTAL EXAMINATION OF THE UPPER JUDITH RIVER FORMATION OF NORTH CENTRAL MONTANA

COSTA RICA, Justin, North Dakota State Univ., Fargo, ND; WILKINS, Anne, Univ. of Aberdeen, Aberdeen, United Kingdom; HAHN, Leah, California State Univ., Fullerton, CA; COSTA RICA, Stefanie, North Dakota State Univ., Fargo, ND; MILOVINA-MEYER, Peggy, Cupertino, CA

The paleo-environmental interpretation of the Upper Judith River Formation in North Central Montana is undertaken using a combination of disciplines including vertebrate paleontology, invertebrate paleontology, paleobotany and geology. From sedimentology investigations, the study area is believed to have been a low land coastal plain adjacent to the Intercontinental Cretaceous Seaway during the Campanian. Of particular note is the occurrence of Hadrosaur nest sites within this study area.

Sampling of the numerous micro-sites has provided a diversity of fossils. The vertebrate aquatic fauna include cartilaginous fish, bony fish, amphibians, turtles and crocodiles. The vertebrate terrestrial fauna include Theropods such as *Troodon* and *Albertosaurus*, Ankylosaurs, Ceratopsians, Ornithopods and Pachycephalosaurs. Within the sedimentary strata of the study area the invertebrate fauna generally comprise of mollusks including bivalves and both high and low spiraled gastropods. Fossilized wood and leaf impressions of both coniferous and deciduous plants also contribute to the diversity of fossils within the study area. Further research using both palynology and ichnology will help further define the paleoecology of the area.

82. **Hester, P., Heckert, A., Berkhoudt, R. and Mathias, S.:** 30,000 VERTEBRATE FOSSILS ON LINE: NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE'S DIGITAL DATABASE, A RESEARCH TOOL

HESTER, Patricia, BLM, Albuquerque, NM; HECKERT, Andrew, New Mexico Museum of Natural History & Science, Albuquerque, NM; BERKHOUDT, Rene, BLM, Santa Fe, NM; MATHIAS, Scott, New Mexico Museum of Natural History & Science, Albuquerque, NM

The entire catalogued paleontological collection of the New Mexico Museum of Natural History and Science (NMMNH) is now accessible online at <http://164.64.119.14/nmmnh/web/default.html>. The collection includes 30,000 catalogued vertebrate body and another 3,000 vertebrate trace fossils. Paleozoic collections include fish and tetrapods from the Upper Pennsylvanian Kinney Brick quarry and a world class collection of Lower Permian vertebrate tracks from across New Mexico, especially the Robledo Mountains megatracksite, the largest Permian footprint assemblage in the world. Extensive holdings of Upper Triassic tetrapods from the American Southwest and Upper Cretaceous vertebrates from the San Juan Basin make up a large portion of the Mesozoic collection. Triassic vertebrates include thousands of specimens from the Chinle Group in Texas, New Mexico, and Arizona. Upper Cretaceous vertebrates from the Fruitland and Kirtland formations in the San Juan Basin are also a significant portion of the Mesozoic collections. Cenozoic collections include Paleogene tetrapods from the San Juan Basin, including type Puercan and Torrejonian faunas and a growing collection of Neogene vertebrates, principally mammals. The website does not include sensitive geographic locality data and complex (Boolean) searches are not presently a feature of the online database. However, chronologic, stratigraphic, and geographic searches will yield complete faunal lists by locality. The online database is searchable by taxonomic, stratigraphic, chronologic, and geographic criteria, utilizing a drill-down approach, taking advantage of the hierarchical nature of these data to search for specimens or localities at several discrete levels. Taxonomic categories are principally Linnean ranks (class, order, family, genus). Stratigraphic criteria include group, formation, and member. Chronologic criteria are era, period, epoch, stage, and land vertebrate biochron. Geographic criteria are country, state, county, and 7.5-



minute topographic quadrangle. More than 1,400 of the specimens in the database are illustrated digitally, and an image (.jpg) of the fossil will appear if selected.

83. **Foreman, B., Rogers, R., Wirth, K. and Hanna, R.:** GEOCHEMICAL CORRELATION AND CHARACTERIZATION OF TWO MEDICINE FORMATION BENTONITES, NORTHWESTERN MONTANA

FOREMAN, Brady, Macalester College, St. Paul, MN; ROGERS, Raymond, Macalester College, St. Paul, MN; WIRTH, Karl, Macalester College, St. Paul, MN; HANNA, Rebecca, Museum of the Rockies, Bozeman, MT

Volcaniclastic terrestrial sediments of the Two Medicine Formation of northwestern Montana preserve several discrete bentonite beds. These beds hold significant potential for geochemical fingerprinting and high-resolution correlation. This study focuses on two bentonites within the formation, and employs geochemistry and other techniques to distinguish the “Seven Mile Hill bentonite” near Choteau, Montana from the “Hadro-Hill bentonite” near Cut Bank, Montana. Major and trace element concentrations were determined using X-Ray Fluorescence spectroscopy. Plots of immobile trace elements (Zr, Th, Nb, Y, Pb, Sc, U and others) demonstrate that the two bentonites have distinct geochemical “fingerprints.” The two bentonites were also discriminated by plotting ratios of immobile elements on ternary diagrams. Ratios were chosen based on their ability to characterize and compare different magmatic processes and source compositions of the magma chamber. Th/Zr, V/Ti, U/Nb, and Ga/Sc proved to be particularly useful for discriminating between the two bentonite beds. Analysis of these ratios and others not only provides geochemical signatures, but also suggests different volcanic processes and magmatic source compositions. This study indicates that geochemical fingerprints of Two Medicine bentonites can be used to generate a high-resolution stratigraphic framework, and this in turn can be employed to frame a variety of paleobiological questions.

84. **Brady, M., Rogers, R. and Sheets, B.:** AN EXPERIMENTAL APPROACH TO BONE CONCENTRATION

BRADY, Mara, ROGERS, Raymond, Macalester College, Saint Paul, MN; SHEETS, Benjamin, Univ. of Minnesota, Minneapolis, MN

Several studies have examined fluvial transport of skeletal debris, and while these efforts yield critical information about bone dispersal in water, the factors affecting bone concentration in an active flow remain poorly understood. This study seeks to explore controls on vertebrate skeletal concentration in active flows through field characterization and experimentation. The field component includes detailed sedimentological analysis of vertebrate microsites from the Judith River Formation of Montana. Samples were characterized according to size, shape, density, and settling velocity. Weight percent size and shape data are as follows: 83.1% >4 mm, 11.0% 4 mm, 5.5% 2 mm, and 0.4% 1 mm; 46.4% flat, 36.3% equant, 11.7% roller, and 5.6% blade. The average density of bone debris is 1.62 g/ml. Quartz grain equivalents (estimated from settling velocity) of bone material range from 0.1 mm to 8.3 mm.

A sample of bone material (1-4 mm diameter) was mixed with 0.12 mm sand to produce a bone-sediment mixture (10% bone by volume) for use in a flume experiment. The flume had a width of 15.25 cm, a working length of 150 cm, and was filled with a 4 cm thick bed of bone-sediment mixture. Water and the bone-sediment mixture were fed to the system at 18.9 ml/s and 0.16 ml/s, respectively. After an initial set of runs, water discharge was increased to 30.6 ml/s. Localized bone accumulations developed along the full stretch of the flume, including “channel,” “bar-top,” and “delta/shoreline” deposits. Digital images taken at regular intervals document changes in surface concentration. Representative samples were collected from each type of accumulation for size and shape analysis. Additional experiments are

planned, and these will focus on (1) the effects of lower initial background bone concentration (1% and 5% bone by volume) and (2) the transportability of particles and the potential for spatial mixing in concentrations. Spatial mixing will be tracked by color-coding material in relation to initial position in the flume.

85. **Roberts, E. and Deino, A.:** ABSOLUTE AGE OF THE RICHLY FOSSILIFEROUS KAIPAROWITS FORMATION (UTAH) AND CORRELATION OF COEVAL (JUDITHIAN) VERTEBRATE-BEARING STRATA ACROSS THE WESTERN INTERIOR BASIN

ROBERTS, Eric, Salt Lake City, UT; DEINO, Alan, Berkeley Geochronology Center, Berkeley, CA

Vertebrate-bearing nonmarine strata comprising the Kaiparowits Formation of southern Utah have been variously dated as Campanian or Maastrichtian. The most recent biostratigraphic age assessment places the formation within the Judithian Land Mammal Age, primarily based on a highly endemic mammalian fauna. Laser-fusion  $^{40}\text{Ar}/^{39}\text{Ar}$  analysis of five bentonite horizons intercalated throughout the 860 m thick formation produces the first numerical ages for the formation and permits high-resolution chronostratigraphy. This study corroborates the mammalian biostratigraphy, demonstrating a Late Campanian/Judithian age of ~76.1-73.7 Ma for the Kaiparowits Formation. Rock accumulation was unusually rapid (~36 cm/ka) for the formation, and the vast majority of vertebrate fossil localities are restricted to the top of the lower unit and the middle unit (~75-550 m), dated between ~76.0-74.7 Ma.

These new radiometric dates permit a high-level of resolution in correlating faunas from the Kaiparowits Formation with coeval faunas and strata across the Western Interior Basin. To the north, the Kaiparowits Formation is correlative with the Dinosaur Park Formation in Alberta, the upper lithofacies of the Two Medicine Formation, and the upper Judith River Formation (both in Montana). To the south, the Kaiparowits Formation is correlative with the Fruitland Formation and the basal Kirtland Formation of New Mexico, although the fossiliferous middle portion of the Kaiparowits Formation only correlates with the basal Ne-nah-ne-zad Member of the Fruitland Formation. Further south, the Kaiparowits Formation likely correlates with part of the upper shale member of the Aguja Formation (Texas). This study presents a chronological basis for assessing hypotheses relating to paleobiogeography and paleoecology across the Western Interior Basin, and permits estimations of vertebrate evolutionary rates for the Kaiparowits Formation.

86. **Suarez, C. and Suarez, M.:** USE OF FACIES, TAPHONOMY, AND RARE EARTH ELEMENT GEOCHEMISTRY ANALYSES AT THE CLEVELAND-LLOYD DINOSAUR QUARRY: TOOLS FOR BONE BED INTERPRETATIONS

SUAREZ, Celina, SUAREZ, Marina, Temple Univ., Philadelphia, PA

The taphonomy and paleoenvironment of the Late Jurassic Cleveland Lloyd Dinosaur Quarry (CLDQ) was reexamined using the combination of facies analysis, traditional vertebrate taphonomy, and rare earth element (REE) geochemistry. REE signatures of fossilized bones reflect pH and redox conditions of depositional/early diagenetic environments and allow detection of time/spatial averaging within fossil accumulations. Bone samples were taken from the quarry and from limestone outcrops 500m northeast of the quarry. Bones from the quarry show flat REE signatures (NASC-normalized) indicative of neutral pH water chemistry, suggesting an open fluvial and/or pond system. This is supported by the presence of silty calcareous mudstone and limestone, rip-up clasts, weak bone orientation and abrasion, and shallow water microfossils. Signatures are the same for the entire quarry data set, indicating a homogenous depositional setting for the bones in the quarry, and supporting an autochthonous accumulation. Bones in limestone outcrops NE of the quarry show heavy REE enrichment, indicative of alkaline water chemistry, suggesting a closed evaporitic lake system. This is

supported by micritic limestone with charophytes, ostracodes, and some gastropods. Fossil bones in a limestone NE of the quarry are chemically distinct from those in the quarry mudstone or capping limestone, and cannot be correlated to them. Based on this data, and the regional geology, the limestone NE of the quarry is stratigraphically above the main quarry. These data may be consistent with the recent interpretation of the quarry as an accumulation of dinosaur bones in an ephemeral pond/waterhole supported by monospecific accumulations of sub-adult Allosaurs. The bone accumulation at CLDQ probably records more than one drought season where water completely dried out, followed by an influx of neutral water during a wet season. The transition from neutral pH conditions in the quarry mudstone and limestone to alkaline conditions in the limestone northeast of the quarry is consistent with previous interpretations of long-term wet/dry cycles of the paleoenvironment of the Morrison Formation.

87. **Leggitt, V. L., Biaggi, R. And Buchheim, H. P.:** AVIAN EGG SHELL FRAGMENTS CONFIRM LAKE MARGIN FLUCTUATION: TIPTON SHALE MEMBER, EOCENE LAKE GOSIUTE  
LEGGITT, V. Leroy, Loma Linda, CA; BIAGGI, Roberto, Universidad Adventista del Plata, Entre Rios, Argentina; BUCHHEIM, H. Paul, Loma Linda Univ., Loma Linda, CA

Eggshell fragments are common in a nearshore, oolite facies of the Tipton Shale Member of the Eocene Green River Formation. The eggshell fragments occur in a 9 m thick carbonate sequence exposed on the southwest flank of Essex Mountain, Sweetwater County, Wyoming. The eggshell was determined to be of avian origin by examination of radial eggshell microstructure by SEM and PLM. Common allochems in the limestone include: ooids, pisoids, oncoids, ostracods, gastropods, intraclasts, caddisfly larval cases, fish bones, avian bones and avian eggshell fragments. Carbonate mineralogy varies between 95% calcite and 95% dolomite. Oxygen stable isotopes vary between negative 1.3 and negative 10.1 (PDB). Carbon and oxygen stable isotopes covary and display significant trends.

Covariance of oxygen and carbon stable isotopes indicates that Lake Gosiute was hydrographically closed during the formation of this oolite sequence. Positive excursions of oxygen stable isotope values are correlated with dolomite, caddisfly cases and avian eggshell fragments. These factors are likely associated with lake regression and more saline conditions. Negative excursions of oxygen stable isotope values are correlated with calcite, gastropods and intraclasts. These factors are likely associated with lake transgression and lake freshening. In the 9 m oolite sequence studied there are three inferred transgressions and regressions.

The avian eggshell fragments appear to occur in sediments formed only during low stands of the lake as determined by other lake level proxies (dolomites and more positive oxygen stable isotope values). Since avian eggshell fragments were formed under subaerial conditions, the avian eggshell fragments independently confirm lake regression. In addition, the occurrence of avian eggshell fragments during saline phases of the lake may indicate that the birds that produced the eggshell preferred saline conditions (or that their food preferred saline lake water).

88. **Snyder, D.:** A SAUCERFUL OF SECRETS: NOTES ON BASAL VERTEBRATES FROM THE HIEMSTRA QUARRY, DELTA, IOWA

SNYDER, Daniel, Univ. of Iowa, Iowa City, IA

Basal vertebrate remains from the Jasper Hiemstra Quarry, a Late Mississippian sinkhole site in southeastern Iowa, include two previously unknown taxa (a gyracanthid and an actinopterygian) and a rhizodont of uncertain affinity. Gyracanthid fossils, including elements of the pectoral girdle and body scales, have been found in a near-articulated state. In light of the ambiguities associated with gyracanthid systematics, the Hiemstra Quarry fossils are tentatively assigned to a new taxon. An unusual actinopterygian, presently known from more than a half-dozen disarticulated specimens, shares

characters with the Devonian *Mimia toombsi* and *Moythomasia durgaringa*, and with the Pennsylvanian *Coccocephalus*. Like the tetrapod *Whatcheeria deltae* from the same site, this actinopterygian suggests biogeography in the Mississippian involved closely-related taxa separated over large distances. Fossil remains of a rhizodont are tentatively assigned to *Strepsodus*. The validity of the assignment rests not only on post-cranial material, as in most rhizodonts, but on interpretations of a disarticulated and weathered skull. In light of the ambiguity of the material, it may be wiser to erect a new species than to try to assign it to a previously-erected taxon.

Fragmentary remains of a dipnoan are assigned to *Tranodis castrensis*, which has already been reported from limited material at the Hiemstra Quarry. New fossils suggest that *Tranodis* was more abundant than previously thought, in keeping with observations from elsewhere in the Upper Midwest.

89. **Beeson, E. and Shimada, K.:** VERTEBRATES FROM A UNIQUE BONEBED OF THE UPPER CRETACEOUS NIOBRARA CHALK, WESTERN KANSAS

BEESON, Emily, DePaul Univ., Chicago, IL; SHIMADA, Kenshu, DePaul Univ., Chicago, IL

FHSM VP-644 is a 4 kg rock specimen in the Vertebrate Paleontology collection of the Sternberg Museum of Natural History, Hays, Kansas. The rock is from the Smoky Hill Chalk Member of the Niobrara Chalk (Upper Cretaceous) in Gove County, Kansas. It is unusual for the stratigraphic unit in that it is packed with numerous, small disarticulated bones and teeth of marine vertebrates where the matrix-to-fossil ratio for the specimen is estimated to be 1:8. We treated a portion of the specimen with acetic acid to extract the vertebrate remains to examine the taxonomic composition of the paleofauna. Our study is still in progress, but the paleofauna is found to be taxonomically diverse, consisting of at least 17 vertebrate taxa. They are: *Squalicorax falcatus*, *S. volgensis*, *Cretoxyrhina mantelli*, *Rhinobatos* sp., *Palaeobalistum* sp., *Ichthyodectes ctenodon*, *Plethodidae*, *Albulidae*, *Pachyrhizodus minimus*, *Cimolichthys nepaholica*, *Enchodus gladiolus*, *E. petrosus*, *E. shumardi*, *Stratodus* cf. *S. apicalis*, two unidentified species of *Teleostei*, and *Mosasauroidea*. Teeth of *Enchodus* spp. are the most common vertebrate fossils in the rock, followed probably by teeth of *C. nepaholica*. We have recovered at least 70 teeth of *Rhinobatos*, a taxon not properly documented previously from the Niobrara Chalk. *Squalicorax volgensis* and *Palaeobalistum* sp. represent new records in the Smoky Hill Chalk. The locality data suggest that the remains are Santonian in age, and the overall taxonomic composition does not contradict with this chronological interpretation. This study provides additional information on the paleoecology of the fauna because our material includes smaller fossil remains and taxa that have been inadequately sampled from the Niobrara Chalk.

90. **Shimada, K., Cumbaa, S. and Van Rooyen, D.:** CAUDAL FIN OF THE LATE CRETACEOUS SHARK, *CRETOXYRHINA MANTELLI* (LAMNIFORMES: CRETOXYRHINIDAE)

SHIMADA, Kenshu, DePaul Univ., Chicago, IL; CUMBAA, Stephen, Canadian Museum of Nature, Ottawa, ON, Canada; VAN ROOYEN, Deanne, Carleton Univ., Ottawa, ON, Canada

The morphology of the caudal fin of the Late Cretaceous lamniform shark, *Cretoxyrhina mantelli* (Agassiz), was previously inferred from scale morphology suggesting that the taxon was a fast swimming shark. A previously undescribed specimen (CMN 40906 housed in the Canadian Museum of Nature, Ottawa, Ontario) from the Niobrara Chalk of western Kansas, U.S.A., presumably belonging to *C. mantelli*, offers new insights into the morphology of the caudal fin of the taxon. The specimen preserves the posterior half of the vertebral column and a series of hypochordal rays as well as placoid scales. The preserved skeletal elements exhibit features suggesting that *C. mantelli* had a lunate (symmetrical) tail and a caudal peduncle with the lateral fluke. It also supports the idea that the body form of *C. mantelli* resembled that of extant *Carcharodon carcharias* (Linnaeus). Where the total

vertebral count of *Cretoxyrhina mantelli* is about 230, the specimen suggests that the transition between pre-caudal and caudal vertebrae was somewhere between 140th and 160th vertebrae in this taxon. The estimated total body length of the shark individual ranges from 640 cm to 700 cm, marking the largest *C. mantelli* individual estimated to date. New skeletal data further supports the view that *C. mantelli* was an active shark capable of fast swimming.

91. **Takakuwa, Y. and Ando, H.:** NEW SELACHIAN ASSEMBLAGE INCLUDING DEEP SEA SHARKS FROM THE MIOCENE OF GUNMA, CENTRAL JAPAN

TAKAKUWA, Yuji, Gunma Museum of Natural History, Gunma, Japan; ANDO, Hisao, Ibaraki Univ., Mito, Ibaraki, Japan

A diverse selachian assemblage, represented by mostly disarticulated teeth, occurs from the Tomioka Group (lower to middle Miocene), southwestern Gunma, Central Japan. This assemblage includes twenty-two species, eleven of which are deep-sea sharks: *Chlamydoselachus*, *Hexanchus*, *Dalatias*, *Squaliolus*, *Etmopterus*, *Somniosus*, *Centroscymnus*, *Centrophorus*, *Deania*, *Galeus?* and *Mitsukurina?*. Some of these genera (*Chlamydoselachus*, *Hexanchus*, *Dalatias*, *Somniosus* and *Centroscymnus*) have already been reported from the northwest Pacific realm, but the others are the first fossil record from this realm and are of great significance in some points.

The first significance is about the timing of habitat transition for deep-sea sharks from shallow into deep environments. Depositional facies of the Tomioka Group indicate an outer shelf to upper sublittoral zone in sedimentary environments. It is almost the same as the habitat of living deep-sea sharks. This means that sharks found in the Tomioka Group shifted their habitat into the deep sea until early Miocene.

The second significance is concerned with the formative processes and dispersal routes of living selachian faunas in the northwest Pacific realm. All taxa of deep-sea shark fossils from the Tomioka Group are in common with the living selachian fauna in circum-Japanese Islands on the generic level. The deep-sea shark fauna similar to living ones appeared in the northwest Pacific realm during the early to middle Miocene. *Squaliolus* is now distributed in tropical and warm temperate zones. Thus, this small deep-sea shark group like *Squaliolus* can be regarded as a Tethyan element that spread from the Tethys Sea to the northwest Pacific realm, along continental shelf margins before the Miocene. On the other hand, *Somniosus* prefers cold waters. It is distributed in shallow seas of frigid temperate zone and deep sea of warm temperate zone. Then *Somniosus* can be regarded as a Boreal element. The northwest Pacific realm appears to be a junction between the Tethyan and the Boreal provinces for deep-sea sharks.

92. **Grandstaff, B., Smith, J., Lamanna, M., Tumarkin-Deratzian, A. and Lacovara, K.:** CRANIAL KINESIS AND DIET IN *MAWSONIA* (ACTINISTIA, COELACANTHIFORMES)

GRANDSTAFF, Barbara, Univ. of Pennsylvania, Oreland, PA; SMITH, Joshua, Washington Univ., St. Louis, MO; LAMANNA, Matthew, Univ. of Pennsylvania, Philadelphia, PA; TUMARKIN-DERATZIAN, Allison, Vassar College, Poughkeepsie, NY; LACOVARA, Kenneth, Drexel Univ., Philadelphia, PA

Coelacanths have an intracranial joint in the skull roof caudal to the orbit, between the parietonasal and postparietal shields. This joint is part of a mechanism for rapidly increasing oral volume during suction feeding. In Mawsoniidae the postorbital bridges across the intracranial joint. The *Mawsonia* postorbital has an elongate, rostrally-directed process dorsal to the lacrimojugal. It may have been bound to the lacrimojugal by soft tissues. Skull architecture of mawsoniids, particularly *Mawsonia*, therefore suggests reduction in mobility of the intracranial joint. Reduced intracranial mobility may have

decreased the gape and interfered with suction feeding on pelagic prey. It might particularly have limited ability to capture large fish. Smaller, slower benthonic prey could have been plucked individually from the bottom. The large size of mawsoniids (2-4 m) would have permitted capture of a variety of prey even with a small gape angle.

*Axelrodichthys* and *Mawsonia* dentitions consist of shagreened, closely-spaced, small (1-2mm) dome-shaped teeth on bones lining the mouth. These teeth exhibit heavy *in vivo* wear, suggesting a durophagous diet. Bahariya Dinosaur Project field work in the Bahariya Oasis of Egypt has yielded *Mawsonia* remains from tidal channels in the Cenomanian (Upper Cretaceous) Bahariya Formation, from deposits interpreted as a paralic habitat with tree fern cover analogous to modern mangrove environments. Modern mangroves are home to a variety of small crustaceans. Crabs have recently been described from the Bahariya Formation, and might have been eaten by *Mawsonia*. One new *Mawsonia* specimen is associated with snails, which could also have been eaten.

Mawsoniids are typically found in freshwater to estuarine deposits. *Mawsonia* remains could have been introduced to the Bahariya tidal channels by postmortem fluvial transport, or carried by tidal currents from a more open marine environment. However, availability of potential prey suggests that *Mawsonia* could have lived in the mangrove-fern forest's tidal channels.

93. **Wilson, M., George, L. and Falkenberg, A. B.:** SKELETAL GROWTH IN OSTEOSTRACANS DEMONSTRATED BY JUVENILES FROM THE DEVONIAN OF NORTHERN CANADA

WILSON, Mark, GEORGE, Lesley, FALKENBERG, A. Bruce, Univ. of Alberta, Edmonton, AB, Canada

The Osteostraci are often considered to be the closest relatives of the Gnathostomata, yet some aspects of their biology remain poorly understood. One such aspect is the mode and pattern of growth of their skeleton. Until now, ideas about skeletal growth have relied on inferences based on composition of the adult skeleton and on incomplete formation of the inner layers in some, presumably immature, dermal bones. The absence of clearly juvenile osteostracans from the fossil record suggested that the dermal skeleton could not begin ossification until the animal had nearly reached adult size. Fusion of the dermal skeleton in some species showed that the ossified specimens had reached their maximum size and had stopped growing.

The Early Devonian (Lochkovian) MOTH locality in the Mackenzie Mountains, Northwest Territories, Canada, has produced the first articulated juvenile specimens of osteostracans. At least two juvenile stages are represented, the smallest individual being a tiny fraction of the size of the presumed adult individuals, and the intermediate individuals being about half the length and width of the adults. All of the juveniles belong to *Superciliaspis gabrielsei*), one of three named osteostracan species from the MOTH site. They prove that very young individuals had some of the distinctive features of the adult *Superciliaspis*, including the eyebrow-like prominence, barbed cornual spines, and large postcephalic dorsal spine. The tesserae of which the juvenile head shield is formed are smaller in diameter and fewer in number than the tesserae of the adult shield, showing that in this species growth occurred both by addition of tesserae and by enlargement of existing tesserae.

94. **Tulu, Y. and Rogers, R.:** LATE CRETACEOUS CHONDRICHTHYANS FROM THE WOODHAWK BONEBED, JUDITH RIVER FORMATION (CAMPANIAN), FERGUS COUNTY, MONTANA

TULU, Yasemin, East Lansing, MI; ROGERS, Raymond, Macalester College, Saint Paul, MN

The chondrichthyan fauna of the Late Cretaceous of Montana was last comprehensively reviewed by Case in the late 1970s. Since then, smaller-scale studies have been undertaken, but no recent syntheses

have been produced. A collection of teeth made in 2002 from the Woodhawk bonebed of the Judith River Formation (JRF) adds five additional species to the previous known diversity from the JRF, namely *Cretolamna appendiculata*, *Protolamna sokolovi*, *Squatirhina* sp., *Ptychotrygon hooveri*, and *Ptychotrygon triangularis*. The collection also includes previously known species from the JRF, such as *Hybodus montanensis*, *Cretorectolobus olsoni*, *Squalicorax kaupi*, cf. *S. kaupi*, *Hypotodus grandis*, *Hypotodus* spp., *Archaeolamna kopingensis kopingensis*, *Cretolamna appendiculata*, *Protoplatyrhina renae*, *Ischyrrhiza mira*, *Ischyrrhiza avonicola*, cf. *Myledaphus bipartitus* and a chimaerid, *Ischyodus*.

The fauna from this recent collection is moderately diverse, consisting of 18 different species of mostly lamniforms and rajiforms that inhabited a shallow marine environment of the Western Interior Seaway. Many of these species are typically considered cosmopolitan with a wide geographic spread, while others are restricted to the JRF of Montana, or North America. The Woodhawk fauna represents a rather typical chondrichthyan community and is comparable to contemporary faunas from the Late Cretaceous Western Interior Seaway.

The preservation of material from the site ranges from pristine teeth and dermal denticles, and preserved prismatic cartilage, to fragmentary teeth, centra, and friable chimaerid tooth plates. The mixed quality of preservation suggests influence by a range of different taphonomic processes prior to final burial.

95. **Trapani, J. and Stock, D.:** PATTERN FORMATION AND MULTICUSPID TEETH IN TELEOSTS: ARE THERE GENERAL RULES?

TRAPANI, Josh, STOCK, David, Univ. of Colorado, Boulder, CO

Multicuspid teeth are present in representatives of several clades of teleost fishes. However, the first tooth to appear in a tooth family is normally unicuspid; when multicuspid teeth are present, they appear only after at least one tooth replacement event. A recent model of dental pattern formation suggests that species with multicuspid teeth should have more closely-packed teeth than species with unicuspid teeth. We investigated whether this model was supported by morphological evidence in several teleost clades, as well as over ontogeny within single species with unicuspid and multicuspid adult dentitions. To test the relationship between number of cusps and tooth spacing, we measured these parameters in a sample of taxa from two teleost clades (order Characiformes and family Cichlidae) that have representatives with both unicuspid and multicuspid teeth. We also measured variability in these traits in ontogenetic series of three taxa: the characid *Astyanax mexicanus* (multicuspid) and the cichlids *Ctenochromis horei* (unicuspid) and *Pseudotropheus zebra* (multicuspid). Our results indicate that only cichlids show a significant relationship between number of cusps per tooth and tooth spacing; when size of the fish is accounted for, this relationship remains significant only for African cichlids. In characiforms (as well as cichlids + characiforms pooled), these parameters have no relationship independent of size. Ontogenetically, the results largely match intuition: number of cusps per tooth increases in larger fish (multicuspid species), and number of teeth per unit length decreases (all species). These results suggest that dental pattern formation models may not be generalizable over multiple teleost clades, and that developmental models must account for allometric variation in order to make accurate morphological predictions.

96. **Stringer, G., Anderson, L. and King, L.:** TAXONOMIC, PALEOECOLOGICAL, AND EVOLUTIONARY SIGNIFICANCE OF FISH OTOLITHS FROM THE OLIGOCENE (RUPELIAN) OF LOUISIANA

RINGER, Gary, ANDERSON, Lauri, The Univ. of Louisiana at Monroe, Monroe, LA; KING, Lorin, South Dakota School of Mines and Technology, Rapid City, SD

Although early Oligocene seas transgressed over much of Louisiana, marine vertebrate assemblages of this age are virtually unknown in the state. The discovery of three new Oligocene localities with vertebrate remains in Catahoula Parish, Louisiana, is considered highly significant. Sediments at the sites appear to correlate with the Rosefield Marl Beds of the Rosefield Formation (Vicksburg Group, Oligocene), probably P19 planktonic foraminiferal zonation. Bulk samples were collected from each site to study and describe the composition of the chondrichthian and actinopterygian assemblages. Actinopterygians were analyzed through otoliths (earstones) and skeletal remains, while chondrichthian fishes were based on skeletal remains only. The vertebrate remains consisted primarily of fish otoliths, which served as the primary tool for interpretation of the paleoenvironment and evolutionary changes.

A total of 446 otoliths was obtained and represented at least 27 taxa of actinopterygians. Skeletal remains indicated an additional four cartilaginous fish taxa and one bony fish. At least 16 taxa of actinopterygians based on otoliths are reported from the Oligocene of Louisiana for the first time. The paleoenvironments for the sites were determined to be less than 40 meters in depth with normal to possibly estuarine salinity, energy fluctuations, soft substratum, and a subtropical to tropical climate. The Oligocene (Rupelian) sciaenid assemblage appears to be dramatically different from that of the late Eocene (Priabonian). The late Eocene sciaenid assemblage is dominated by “genus *Sciaenidarum*” *claybornensis*, which is absent in Oligocene and younger sediments. The Oligocene sciaenids are characterized by *Sciaena pseudoradians*, *Aplodinotus distortus*, and *Aplodinotus gemma*. This study, which documents at least 32 species, substantially increases the knowledge of Oligocene marine vertebrates from Louisiana as well as the early Oligocene paleoenvironment. Evolutionary changes in the sciaenid assemblage are believed to be related to climatic changes associated with the Eocene/Oligocene transition in the Gulf Coast.

97. **Warren, D. and Carpenter, K.:** A LARGE NODOSAURID ANKYLOSAUR FROM THE CEDAR MOUNTAIN FORMATION OF UTAH

WARREN, David, Castle Rock, CO; CARPENTER, Kenneth, Dept of Earth Sciences, Denver Museum of Nature and Science, Denver CO

Nodosaurids are well known from the Cretaceous of North America, with *Sauropelta* the best known Early Cretaceous form from the Cloverly Formation in Wyoming and Montana. Fragmentary remains of a huge nodosaurid better matched to *Sauropelta* than any other ankylosaur were found weathered out of the Ruby Ranch Member of the Cedar Mountain Formation in eastern Utah. The most describable elements are a very large right humerus and two very large cervical spikes; other identifiable elements include a fibula, centra of dorsal vertebra, and two small scutes. The ~65 cm long humerus indicates an individual approximately 6.8 m long, making it one of the largest known nodosaurids. The presence of *Sauropelta* supports previous interpretations that the upper portions of the Ruby Ranch Member are equivalent to parts of the Cloverly based on the presence of the iguanodontid *Tenontosaurus*. Such a correlation implies that the Ruby Ranch Member is in part Aptian-Albian in age.

98. **Tanke, D. and Rondeau, R.:** DINOSAURS IN THE DEEP SIX: THE 2005 D/S OLDENBURG EXPEDITION

TANKE, Darren, SS Mount Temple Research Project, Drumheller, AB, Canada; RONDEAU, Robin, Oldenburg Dive Expedition Leader, Hardisty, AB, Canada

On December 6, 1916 the ship SS *Mount Temple*, carrying Late Cretaceous dinosaur remains from Alberta, Canada to London, England was sunk in the North Atlantic. About four of her crew died after she was intercepted and fired upon by the German surface raider SMS *Moewe*. The survivors were made prisoner, and the ship ransacked. She was then sunk by demolition charges, not by a “submarine’s



torpedo” as often reported in popular paleontological literature. Charles H. Sternberg and son Levi collected the fossils under contract to the British Museum (Natural History). Study of field letters penned by Charles suggests major portions of four hadrosaurs (two with skulls), a partial *Champsosaurus* skeleton, three turtle shells (one new = *Judithemys*), and a large number of isolated vertebrate fossils were lost. A *Chasmosaurus* skull and partial hadrosaur with skull may also have been on board. *Moewe* survived WWI and served as a merchant ship in WWII (now renamed D/S *Oldenburg*). She was sunk in an air attack while in port in Vadheim, Norway on April 7, 1945. More information on *Moewe*: [www.smsmoewe.com](http://www.smsmoewe.com)

As part of the ongoing *Mount Temple* research, a team will explore the *Oldenburg* wrecksite in January 2005. Colder water in winter has no suspended algae and silt, improving viewing conditions. As well as utilizing technical divers, a 2-man submarine will be used to explore and photograph the wreck. Witnesses to the attack will be interviewed. A book is being written and a documentary is currently under consideration. A detailed *Mount Temple* website was launched January, 2003: [www.ssmounttemple.com](http://www.ssmounttemple.com).

99. **Southwell, E. and Breithaupt, B.:** WILLIAM HARLOW REED’S QUARRY “R”: LOST LOCALITY, OVERLOOKED SIGNIFICANCE

SOUTHWELL, Elizabeth, Laramie, WY; BREITHAUPT, Brent, Univ. of Wyoming, Laramie, WY

William Harlow Reed is best known as O. C. Marsh’s most loyal and prolific fossil collector. He was responsible for discovering Como Bluff and for finding hundreds of tons of Jurassic dinosaur bones, as well as the first Jurassic mammals and ichthyosaurs from North America in the late 1870s. He left Marsh’s employ in 1883, but his extensive knowledge of the geology of the plains of southeastern Wyoming allowed him to continue work in the “bone business,” finding new localities as a collector for the Univ. of Wyoming, Brown University, and the Carnegie Museum. In 1901, Reed contacted Walter Granger (head of the American Museum of Natural History’s field crew) with the news of his latest dinosaur find. He negotiated with the AMNH to sell the bones already collected, as well as the rights to work this new quarry located approximately 14 miles south of Bone Cabin Quarry on the Prager Anticline.

Like Como Bluff, Reed’s new quarry was located near the Union Pacific Railroad line. Over 200 dinosaur fossils were collected from the Reed Quarry from two distinct layers. The upper layer contained bones attributed to very large *Camarasaurus* and *Allosaurus* individuals. The lower layer also contained *Allosaurus* material, but significantly, it produced a large number of limb and girdle bones from juvenile sauropods. A large number of juvenile vertebrae were noted, but apparently never collected. Reed and AMNH field crews worked Quarry “R” for three years (1901-1903). After the death of W. C. Knight in 1903, Reed was hired by the University of Wyoming as curator of their museum. In 1905, the AMNH abandoned all work in the Jurassic of southeastern Wyoming to pursue other paleontological explorations in the Rocky Mountain West.

100. **McLeod, S. and McNassor, C.:** CONSERVATION OF DETERIORATING NITRATE NEGATIVES FROM THE CALTECH FIELD EXPEDITIONS

McLEOD, Samuel, McNASSOR, Cathy, Los Angeles County Museum of Natural History, Los Angeles, CA

When Chester Stock left the University of California at Berkeley and accepted a position at The California Institute of Technology in 1926, he inaugurated a program of field expeditions to build the collections of vertebrate fossil specimens. For the next twenty-five years the Caltech field expeditions were extensively documented in numerous photographs of the locales, the collecting activities, the

personnel and the collected specimens. The photographic records of the Caltech paleontology program are particularly important because few of the field notes from these expeditions have survived, the descriptions of localities in the catalogues are often vague and the locality plots are, when they exist, large circles on small scale maps.

Unfortunately, most of the negatives of these Caltech field work were photographed on nitrate film, which was the standard medium of the day. While nitrate film often has excellent photographic qualities, it is very prone to deterioration over time and is extremely flammable. Deteriorated nitrate film can spontaneously combust at high temperatures, and even under normal storage conditions it can damage items stored with it because of off-gassing. Thus nitrate negatives are typically stored in protected vaults and are generally unavailable.

With the assistance of the NSF, we have begun the process of conserving the Caltech field photographs by producing new negatives, prints and digital computer images. We have also begun to georeference some of the localities represented in the photos by taking prints into the field and recording GPS readings from the original collecting sites.

101. **Smith, A., Jones, M. and Evans, S.:** A HYPEROSSIFIED MEGAFROG FROM THE UPPER CRETACEOUS OF MADAGASCAR

SMITH, Aubrey, JONES, Marc, EVANS, Susan, Univ. College London, London, United Kingdom

Madagascar today boasts a rich diversity of frogs, but apart from a Triassic stem-frog, the fossil history of the anuran fauna is virtually unknown. This is unfortunate given the pivotal position of Madagascar in relation to current debates on Gondwanan biogeography. New frog material from the Upper Cretaceous (Maastrichtian) deposits of the Maevarano Fm (SUNY Mahajanga Basin Project) is thus potentially important.

Most of the anuran remains from the Maevarano Fm can be attributed to a single species. Cranial fragments are very robust and bear distinctive sculpture. They characterize a hyperossified, broad-headed terrestrial or burrowing frog with an estimated snout-vent length in the range of 150-200mm, although some elements hint at larger size. The squamosals bore posterior horns similar to those of the South American Horned Toad, *Ceratophrys*. No frog of this type survives on Madagascar today and no frog of this size has previously been reported from Mesozoic deposits.

Hyperossification occurs in extinct gobiatids as well as several modern groups including pipids, hylids, ranids, 'leptodactylids', and bufonids. The crania of hyperossified taxa often show greater similarity to one another (in terms of sculpture, fusion, ossification level, bony processes and flanges) than to smaller representatives of the same clade. Comparable features are seen in the Maevarano frog and this convergence makes classification difficult, particularly given the fragmentary nature of the material. Nonetheless, a combination of characters (paired frontoparietals, teeth, vertebral procoely, a bicondylar sacro-urostylar articulation, moderately dilated sacral diapophyses, absence of urostylar transverse processes) constrain the possibilities. On current evidence, the closest resemblance is to South American 'leptodactylid' neobatrachians such as *Caudiverbera* and *Ceratophrys*, but this is tentative pending further material and more extensive comparison.

102. **Holman, J., Stevens, N., O'Connor, P., Gottfried, M. and Roberts, E.:** AN ENIGMATIC NEOBATRACHIAN FROG FROM THE PALEOGENE OF SOUTHWESTERN TANZANIA

HOLMAN, J., Michigan State Univ., East Lansing, MI; STEVENS, Nancy, O'CONNOR, Patrick, Ohio Univ., Athens, OH; GOTTFRIED, Michael, Michigan State Univ., East Lansing, MI; ROBERTS, Eric, Univ. of Utah, Salt Lake City, UT

Four anuran families have previously been reported from the Tertiary of Africa: Discoglossidae, Bufonidae, and Ranidae, all from the Miocene of Morocco, and the more widespread Pipidae. We report here on an enigmatic and possibly new neobatrachian from the East African Paleogene. The specimens are from southwestern Tanzania, and were recovered from Paleogene fluvial deposits of the “Red Sandstone Group” that preserve abundant and diverse vertebrates and invertebrates. The new frog material includes an articulated partial hind limb (distal tibiofibula, tarsal elements, and two digits), and a well-preserved distal humerus. Limb proportions and morphology suggest a moderately stout-bodied and at least partially terrestrial frog, with an approximate snout-vent length of ca. 75 mm. Several characters of the humerus and hind limb preclude assignment of the new material to Pipidae, and it also appears to be different from the other three frog families that occur in the Miocene of Morocco. Additional diagnostic elements are needed for a more definitive taxonomic assignment.

The anuran fossils from the Red Sandstone Group add a potentially intriguing new record to the known diversity of African fossil frogs, particularly given that only pipids have previously been reported in the African Tertiary outside of Morocco, and the new Tanzanian specimens are not assignable to Pipidae. In addition, they demonstrate the potential of the Tanzanian deposits for preserving delicate, articulated vertebrates.

103. **Carvalho, A., Zaher, H. And Nava, W.:** A NEW ANURAN (LISSAMPHIBIA: TETRAPODA) FROM THE CONTINENTAL UPPER CRETACEOUS BAURU BASIN, STATE OF SAO PAULO, BRAZIL

CARVALHO, Alberto, ZAHER, Hussam, Museu de Zoologia – Univ. de Sao Paulo, Sao Paulo, Brazil; NAVA, William, Museu de Paleontologia de Marilia, Marilia, Brazil

We present several fossil remains belonging to a new anuran (gen. and sp. nov.) from the Upper Cretaceous Bauru Basin, Brazil. The specimens were collected in sediments of the Aracatuba Formation, in a quarry near the river Peixe, in the vicinity of Marilia, Sao Paulo. Among the 44 specimens, three constitute articulated parts of the whole skeleton, showing many informative features: the first specimen retains the skull, part of the maxillae and dentaries, squamosal, pterygoids, three anterior presacral vertebrae and partially complete articulated forelimbs; the second specimen provides information about the pectoral girdle, six presacral vertebrae, and left humerus; the third specimen shows features of four articulated presacral vertebrae, pelvic girdle, and hindlimbs. The remaining material is represented by damaged and disarticulated bone elements.

Comparisons between *Baurubatrachus pricei* and the new taxon show differences in the degree of exostosis of the dermal skull bones (more conspicuous in the former species) and the morphology of the sacral diapophysis which is tubular in the new taxon. Features shared between the two taxa are: 1) a well developed ilial dorsal crest, 2) a bicondylar sacrococcygeal articulation, 3) a well developed dorsal crest of the urostyle, 4) procoelous presacral vertebrae, 5) arciferal type of pectoral girdle. The last two features, along with the presence of a neopalatine bone in the new taxon, allow its allocation in the clade Neobatrachia. The new taxon shares similarities with members of the paraphyletic Leptodactylidae. Its affinities with leptodactylid forms are supported by the presence of a Leptodactylid Type of ilium and by the fusion of the frontoparietals with the otoccipital bones. However, the new taxon also shares some features with other families, such as the fusion of the pelvic girdle elements present in the Pipidae and Bufonidae, and the fusion of frontoparietal elements found in the Rhinophrynidae, Pipidae, and Brachycephalidae.

104. **Kihm, A. and Hartman, J.:** LATE PALEOCENE BIRD TRACKS FROM THE TONGUE RIVER FORMATION OF NORTH DAKOTA

KIHM, Allen, Minot State Univ., Minot, ND; HARTMAN, Joseph, Univ. of North Dakota, Grand Forks, ND

Paleocene bird tracks have rarely been reported. The site described here (L6421) is in the upper Tongue River Formation, approximately 35 m below the Tongue River-Sentinel Butte formational contact in Billings County, North Dakota. The tracks are preserved on a very fine-grained, quartzose sandstone approximately 0.3 m thick. Although the sandstone is laterally persistent, no other track sites were found. On the basis of mammalian fossils from other sites in the area, Locality L6421 is late Paleocene (Tiffanian 4). At least five different types of tracks are present. Type 1 (three specimens) is a large, unwebbed form 70 to 77 mm long (axial length measured along digit III), 70 to 72 mm wide (maximum width across digits II and IV) with a divergence angle of 84 to 90 degrees. Type 2 (five specimens) is a partially webbed track, 51 to 56 mm long, 51 to 67 mm wide with a divergence angle of 92 to 111 degrees. Type 3 (six specimens) is an unwebbed form, 32 to 40 mm long, 41 to 55 mm wide with a divergence angle of 89 to 147 degrees. Type 4 (one specimen) is webbed, 38 mm long, 41 mm wide with a divergence angle of 65 degrees. Type 5 (one specimen) is a small, unwebbed type, 29 mm long, 32 mm wide with a divergence angle of 80 degrees. A possible sixth type (three specimens) is unwebbed, 25 to 37 mm long, 32 to 44 mm wide and with a divergence angle of 83 to 96 degrees. It is uncertain if this represents a form distinct from Type 3 or Type 5, or possibly a mixture of both. None of the tracks show any indication of a hallux. Four species of fossil birds have been reported from the late Paleocene of North Dakota; three from the Wannagan Creek Quarry (one anseriform, two charadriiforms) which is stratigraphically above L6421, and one (a charadriiform) from the Judson Locality which is below L6421. This study was conducted under a permit issued by the Custer National Forest of the US Forest Service.

105. **O'Connor, J., Chiappe, L., Ji, Q. and Yu, H.-L.:** NEW ENANTIORNITHINE BIRD FROM THE EARLY CRETACEOUS OF GANSU PROVINCE, NORTHWESTERN CHINA

O'CONNOR, Jingmai, Univ. of Southern California Earth Sciences, Los Angeles, CA; CHIAPPE, Luis, Natural History Museum of Los Angeles County, Los Angeles, CA; JI, Q., YU, Hai-lu, Chinese Academy of Geological Sciences, Beijing, China

Asia has greatly contributed to the recent burst of early Cretaceous birds. These numerous occurrences, however, are concentrated in the northeastern Chinese provinces of Liaoning and Hebei. We report on the discovery of an early Cretaceous bird from northern Gansu Province, in northwestern China, an occurrence that adds to the meager record of early Cretaceous birds from central Asia. Represented by a nearly complete left wing and shoulder girdle the size of a rock dove, the new bird was quarried from laminated green-gray mudstones of the Zhonggou/ Xiagou Formation (Xinmingu Group) near Changma, in the Jiuquan area. These deposits have previously yielded the only known specimen of *Gansus yumenensis*, the distal half of a hindlimb with long and slender digits. Several derived characters of the new occurrence supports its allocation within Enantiornithes: (1) a convex lateral margin of the coracoid, (2) a minor metacarpal that projects distally more than the major metacarpal, and (3) a proximal phalanx of the major digit longer than the intermediate (second) phalanx. The general proportions of the wing suggest it was a flier comparable to most other known enantiornithine birds. Although direct comparisons between the new fossil and *Gansus* are not possible, the presence of a completely fused tarsometatarsus with a hypotarsus supports the placement of *Gansus* within Ornithuromorpha, the clade that includes all living birds and the sister group of Enantiornithes. Thus, phylogenetic inferences based on the morphology of the only two known birds from the Xinmingu Group supports their placement into two different clades. The new occurrence thus adds to the

taxonomic diversity of early Cretaceous birds from Gansu Province in particular and central Asia in general.

106. **Yuan, C.-X. and Ji, Q.:** NEW ANATOMICAL OBSERVATION OF *SHENZHOURAPTOR SINENSIS* (AVIALAE) OF JOHEL BIOTA FROM CHINA AND CURSORIAL ORIGIN OF AVIAN FLIGHT

YUAN, Chong-xi, JI, Qiang, Chinese Academy of Geological Sciences, Beijing, China

*Shenzhouraptor sinensis* was discovered from the Lower Cretaceous Jiufotang Formation in western Liaoning, China. This taxon is characterized by the toothless and horny beak, relatively long forelimbs to the hindlimbs, long flight feathers, and many derived characteristics of the shoulder and pelvic girdles that have placed it in the clade of Avialae. The ratio of its forelimb and the well-developed flight feathers suggest that *S. sinensis* developed the capability of powerful flight. The pedal digit I is not reversed, indicating the lack of perching capability. These characters of *Shenzhouraptor* are consistent with the “cursorial” hypothesis on the origin of the avian power flight. However, the preservation of the pedal digits in the holotype specimen has led to some questions about absence of the reversal of digit I or if *S. sinensis* had perching pes. More recently, a second and better-preserved specimen of *S. sinensis* was unearthed from the same formation in western Liaoning, China. The new specimen corroborates the previous observation that *Shenzhouraptor's* forelimbs are longer than hindlimbs (ratio of humerus and femur is about 1.5 to 1), the flight feathers are much longer than the combined length of the ulna and manus (> 140 mm). The new specimen has preserved a massive U-shaped furcula. The new specimen has an exquisitely preserved hindlimbs, and now proves beyond any doubt that pedal digit I is not reversed in *S. sinensis*, and its pedal structure is similar to terrestrial theropods. Thus, we suggest that *S. sinensis* is not only an important transitional taxon in the descent of birds from non-avian theropod dinosaurs, but also provides significant support for the “cursorial” hypothesis on the origin of the bird’s flight because of the inferred capacity for power flight of its forelimb and the pedal structure adapted to terrestrial locomotion.

107. **Nye, A., Stout, G. and Wallace, S.:** A CUSTOMIZED ATTRIBUTE INFORMATION DATABASE FOR MUSEUM COLLECTION STORAGE AND ANALYSIS: GRAY FOSSIL SITE

NYE, April, STOUT, Gregory, WALLACE, Steven, East Tennessee State Univ., Johnson City, TN

The recent (May 2000) discovery of the Gray Fossil Site in Gray, TN, with support from a Tennessee Department of Transportation grant, has provided an opportunity for intense study of a Miocene aged fossil site. Various issues were recognized with the accumulation of fossil specimen data associated with the site. The solution to these unique problems was to create a uniform database that was capable of being stored on a server allowing equal access to all cataloged fossil data. The program used to create the database needed to be flexible, powerful, cost effective, and user friendly. After reviewing several programs that are commonly used for data management, Microsoft Access was selected because it provides the flexibility necessary to address many of the logistical issues of the database including: data input, storage, accessibility across a network, multiple distinct analyses, and security. An additional issue is the need to merge and export spatial information associated with individual specimens to database attributes derived from surveying and Geographical Information Systems (GIS). To address these issues, Access served as the foundation on which to build a customizable, user-friendly input that regulates entered information so as to minimize user error.

108. **Grocke, D.:** CARBON-ISOTOPE ANALYSIS OF PLANTS: A TOOL FOR HIGH-RESOLUTION DATING AND CORRELATION OF TERRESTRIAL SEQUENCES

GROCKE, Darren, McMaster Univ., Hamilton, ON, Canada

Attempts to understand the geological record of the carbon cycle have primarily focused on the investigation of the oceanic carbon reservoirs whereas the more minor carbon reservoirs, such as the terrestrial biomass, have been largely ignored. Many studies have used the carbon-isotope ratios of both organic and inorganic materials to demonstrate that many rapid perturbations occurred in the oceanic carbon reservoir in the geological past. Our attention to the Earth's response to these rapid, short-lived carbon events on the global environment has been dominantly confined to the oceanic realm with leaps of faith to the effect of these events on the terrestrial environment. Our lack of understanding and ignorance of the geological terrestrial record has, in part, been exacerbated by our inability to directly relate the oceanic carbon reservoir with that of the terrestrial environment. Over the past decade the application of terrestrial carbon-isotope stratigraphy using plant matter and/or bulk terrestrial organic matter [and paleosol carbonate?] has successfully been used to infer changes to the paleo-carbon cycle and to provide a method for correlating non-marine and marine sediments. The first principle of terrestrial carbon-isotope stratigraphy is that the dominant control, on geological timescales, is through changes in the isotopic composition of atmospheric CO<sub>2</sub>. As a result, terrestrial carbon-isotope stratigraphy has been applied to many stratigraphic time periods in the Mesozoic and successfully shown to provide direct comparisons between the terrestrial and marine carbon cycle. High-resolution isotopic analysis of terrestrial plant material through time intervals of known major carbon cycle perturbations can provide a time stratigraphic resolution of better than 250 kyrs. Chronologies such as this are extremely valuable in our understanding of the response of the terrestrial biosphere to short- and long-term climatic and environmental change in the geologic record (e.g., radiation of the angiosperms; dinosaur community shifts).

109. **Paul, G. and Sellers, W.:** SPEED IN GIANT TYRANNOSAURS: ANATOMICAL AND SCALING COMPARISON OF RUNNING POTENTIAL WITH LIVING ANIMALS

PAUL, Gregory, Baltimore, MD; SELLERS, William, Loughborough Univ., Loughborough, United Kingdom

It is widely assumed that top speeds inevitably decrease in gigantic animals because muscle force scales to the 2/3s power. It follows that elephants should have exceptionally large leg muscles generating high levels of power just to move slowly. But available measurements indicate that elephant locomotion requires very low power production, and leg muscles are only 10% or less the total mass of large bulls, a ratio also observed in small slow animals. Mice to elephant data shows that the power leg muscles need to produce to run at a given speed also scales to the 2/3s power, so leg muscle/total mass ratios remain uniform as size increases if top speed remains constant. In most tetrapods doubling locomotory muscle power production doubles speed, so top speed rises as leg muscle/total mass ratios rise, and both fast running quadrupeds and bipeds are up to 20 to 30% locomotory muscles.

All giant tyrannosaurs were speed adapted, small bellied predators with weight reducing pneumatics, shortened distal tails, and hypotrophic arms, propelled by long, bird like legs powered by muscles anchored on expansive pelvic plates, prominent cnemial crests, and stout tail bases. Leg muscles would have been 20-30% of total mass. No comparable giants live today. Multi-tonne, heavy bellied herbivorous rhinos achieve full gallops of up to ~13 m/s with short, moderately muscled legs with minimal running adaptations. Similar sized, longer striding, better muscled albertosaurs and daspletosaurs should have been able to achieve higher speeds of 14-18 m/s. Even massive bellied elephants with weakly muscled legs entirely lacking speed adaptations exceed 6 m/s. Because *Tyrannosaurus* had flexed jointed, running legs operated by muscles two to three times larger and more powerful it must have been much swifter, probably as fast as its smaller relations. This conclusion is supported by new computer simulations.

110. **Ikejiri, T.:** RELATIVE GROWTH AND TIMING OF ONTOGENETIC CHANGES IN *CAMARASAURUS* (DINOSAURIA, SAUROPODA)

IKEJIRI, Takehito, Hays, KS

Growth patterns were compared in juvenile through adult individuals of *Camarasaurus*. Data were collected only from articulated or fairly complete skeletons, including six *C. lentus*, three *C. grandis*, and one *Camarasaurus* sp. All measurements were transformed logarithmically, and bivariate analysis was done on 18 dimensions. The greatest length of the femora was used as a standard unit. Regression lines were calculated using  $\text{Log}(y) = b + k\text{Log}(x)$ . Growth was defined to be isometric when the coefficient of determination ( $R^2$ ) was between 0.95 and 1.00. Allometric growth occurred if  $R^2$  was lower than 0.95. Using 95% confidence limits, I found isometric growth in the overall length of the skulls, humeri, ulnae, tibiae, fibulae, pubes, and the centra of cervical no. 8 and caudal no. 5. Negative allometry ( $k < 1.00$ ) was found in the diameter of the occipital condyles, the centrum length of cervical no. 3, dorsal no. 1 or 2, dorsal no. 5 or 6, and the greatest length of the ischia. In addition, the overall length of the scapulocoracoids ( $R^2 = 0.60$ ) exhibits one of the strongest negative allometries. Positive allometric growth ( $k > 1.00$ ) occurred in the centrum length of the axes ( $R^2 = 0.85$ ). There is no significant difference between the 10 skeletons in the relative growth indicating *C. grandis* and *C. lentus* had similar growth patterns. Proportionally, the overall size of skull is the same from the juvenile to adult stage suggesting cranial development occurs in the embryonic or hatchling stage. Four growth stages of *Camarasaurus* can be established based on (1) patterns of skeletal fusion and degree of (2) entheses (ossified tendon) of vertebrae and (3) rugosity of limb articular surfaces. Up to 72% of body size was reached by the end of the subadult stage. Fusion of scapulocoracoids and vertebrae did not occur during the juvenile stage (about 60% of body size) even in sauropods the juveniles are thought to exhibit a faster growth rate in a life cycle.

**SATURDAY MORNING, NOVEMBER 6, 2004**

**TECHNICAL SESSION XV  
PLAZA BALLROOM A/B**

**MODERATORS: MARK GOODWIN AND STEPHEN GATESY**

**8:00 Brusatte, S. and Sereno, P.: TAXONSEARCH: ONLINE DATABASE FOR TAXA, DEFINITIONS, AND AUTHORSHIP**

BRUSATTE, Stephen, Univ. of Chicago, Chicago, IL; SERENO, Paul, Univ. of Chicago, Chicago, IL

Suprageneric taxa within Archosauria have been named since the mid 1700's. Phylogenetic definitions for several of such taxa were initially proposed in 1986, with the introduction of phylogenetic taxonomy. Here we present an online database, TaxonSearch, available at <http://www.taxonsearch.com> and created for use with any clade. The database permits immediate recall of the following: taxon, definition, and authorship information, the structure and status of taxonomic definitions, and the history of the accumulation of taxa and definitions. Our file on Archosauria includes 481 entries that comprise all known suprageneric archosaur taxa excluding those within Pterosauria and the crown clades (Crocodylia, Neornithes). Of the taxa, 386 belong to Dinosauria, 50% of which have been named since 1984. Phylogenetic definitions exist for 154 of the dinosaur taxa (40%), with 45 taxa described by multiple definitions (29% of those defined). Of the dinosaur taxa named since the widespread introduction of phylogenetic taxonomy in 1986, 26% were defined when named, 25% were subsequently defined, and 49% have yet to be defined. As phylogenetic definitions, their revisions, and associated bibliographic data are increasingly complex and extensive, it is hoped that this database will be employed for other fossil and extant clades.

**8:15 Goodwin, M., Colbert, M. and Rowe, T.: HIGH-RESOLUTION COMPUTED TOMOGRAPHY OF THE TYPE *ORNATOTHOLUS BROWNI* (ORNITHISCHIA: PACHYCEPHALOSAURIA) CONFIRMS ITS EARLY ONTOGENETIC STAGE AND SYNONYMY WITH *STEGOCERAS VALIDUM***

GOODWIN, Mark, Univ. of California, Berkeley, CA; COLBERT, Matthew, ROWE, Timothy, Univ. of Texas, Austin, TX

The pachycephalosaurid taxon, *Ornatolithus browni*, was established from an 87 mm long frontoparietal (AMNH 5450), collected in 1913 from the Dinosaur Park Formation near Steepleville, in Alberta, Canada. This thick but undomed frontoparietal was first identified as *Stegoceras*, but later reinterpreted as a "flat-headed" North American pachycephalosaurid dinosaur. This was notable because it ostensibly supported the coexistence of a flat-headed pachycephalosaurid (*Ornatolithus*) with a domed taxon (*Stegoceras*) in the Upper Cretaceous of North America, comparable to the occurrence of the flat-headed *Homalocephale calathocercos* and domed *Prenocephale prenes* from the Late Cretaceous Nemegt Formation, Omnogov, Mongolian People's Republic.

In this study, we utilize high resolution computed tomography (HRCT) to characterize and compare the micron scale bone structure of AMNH 5450 with a juvenile skull of *Stegoceras* (TMP84.05.01) to determine the relative age of this putative "flat-headed" pachycephalosaurid. We use these data to reevaluate the diagnosis of *Ornatolithus* and test the alternative hypothesis that AMNH 5450 represents an early ontogenetic stage of *Stegoceras*, thus supporting the synonymy of *Ornatolithus browni* with



*Stegoceras validum*. The interpretation of *O. browni* as a juvenile *S. validum* has been suggested previously but not confirmed histologically. HRCT permits the examination of their cranial histology in a non-destructive manner.

HRCT of AMNH 5450 reveals a highly vascular complex of fast-growing primary bone with open frontal-frontal and frontal-parietal sutural contacts, indicating a juvenile stage of ontogeny. Cranial histology determined from HRCT of a juvenile *Stegoceras validum* compares favorably with AMNH 5450. AMNH 5450 is smaller than domed specimens of *Stegoceras* and has frontals and a parietal shelf that are thick but uninflated with large, open supratemporal fenestrae. The dorsal surface is covered by small bony tubercles. Accordingly, these features do not appear to be valid diagnostic characters for *Ornatolithus* but instead reflect an early growth stage.

8:30 **Wagner, J.:** HARD-TISSUE HOMOLOGIES AND THEIR CONSEQUENCES FOR INTERPRETATION OF THE CRANIAL CRESTS OF LAMBEOSAURINE DINOSAURS (DINOSAURIA: HADROSAURIA)

WAGNER, Jonathan, The Univ. of Texas, Austin, TX

The cranial crests of Lambeosaurinae and Hadrosaurinae are parsimoniously considered homologous. Suture-pattern mapping indicates that the phylogenetic transition to lambeosaurine crest morphology involved facial rotation, transposition of the dorsal rostrum to the skull roof accompanied by rotation of the nasal capsule. This transformation is partly recapitulated in lambeosaurine ontogeny. The enrolled premaxillary tubes and lateral diverticulum (LD) of the lambeosaurine crest represent ossification around a circumnarial space (CnS) defined ancestrally by the circumnarial fossa (CnF), as posited by Hopson in 1975. The internal surfaces of the LD and tubes are homologous to the CnF. The passage from the LD to the common median chamber (CMC) of the crest is homologous to the osseous narial foramen; the external naris of lambeosaurines is neomorphic. The CMC is partly homologous to the ancestral space between the narial foramina, and the bulk of the nasal capsule proper lay beneath the crest.

In lambeosaurines, the reported absence of a maxillary rostradorsal process (which probably floored the nasal cavity in dinosaurs ancestrally) and lack of an expanded bill and reflected lip on the premaxilla (indicating invasion by the CnS in hadrosaurines) may be attributable to facial rotation. The s-loops of the crest may echo ancestral soft-tissue structures; they curve around a region homologous to paired premaxillary (vomeronasal?) cavities that open to the palate in other ornithomimids. Lambeosaurines lack palatal foramina due to displacement of these cavities. Large maxillary foramina conducted neurovasculature rostrally deep to the premaxillae in hadrosaurs ancestrally. In lambeosaurines, these foramina are oriented dorsally, and premaxillary foramina dorsal to them probably passed this neurovasculature into the narial region. The CnF is present on the lateral surface of the nasal in all hadrosaurids, but this arrangement is concealed within the crest of lambeosaurines. Crest fontanelles represent failure of the crest walls to completely enclose the CnS; these walls may be homologous to the produced CnF margins of some hadrosaurines.

8:45 **Hieronymus, T. and Witmer, L.:** CRANIAL RUGOSITY AND DINOSAUR “HORNS:” RHINO AND GIRAFFE AS MODEL SYSTEMS FOR SKIN RECONSTRUCTION IN FOSSIL TAXA

HIERONYMUS, Tobin, WITMER, Lawrence, Ohio Univ., Athens, OH

The archetypal conception of “horn” is based on bovids in which a horny sheath (a true keratinous horn) covers a bony core. Bovid horns have been the model for dinosaurs such as Triceratops. However, cranial rugosities that do not form cornual processes are often overlooked. These rugosities have sometimes been interpreted as bony scaffolding for elaborations of the dermis and/or epidermis (e.g. the

nasal boss of the ceratopsid *Pachyrhinosaurus*, the dome of pachycephalosaurid dinosaurs, and the nasal rugosities of tyrannosaurs, titanotheres and mylagaulid rodents). Extant animals with cranial rugosities can provide model systems to characterize associations between skin and rugose bone. The rugosities on the nasal and frontal bosses of white rhinoceros are the model for a massive keratinous horn, whereas those on giraffe skulls are the model for a more simple, skin-covered system. Based upon the comparison between these two species, rugosities associated with the massive horn of rhinos can be distinguished by the following characters: (1) grossly fibrous orthogonal bone surface textures that reflect the histological character of the dermis, and that may be oriented obliquely or tangentially to the bone surface; (2) rugosities that are more pronounced around the periphery than at the center (“bull’s-eye” appearance); and (3) mid-size (~1mm) vascular canals that traverse the underlying bone and emerge perpendicular to the bone surface. In contrast, rugosities associated with the non-cornified skin of giraffe show the following characters: (1) grossly nonfibrous surface textures that extend tangentially to form shelves of bone; (2) rugosities that are more pronounced at their center than at their periphery; and (3) mid-size vascular canals that course within the underlying bone tangentially and emerge at very low angles to the bone surface. These hypotheses have not yet been tested within a phylogenetic framework, but as preliminary results they provide “rules of construction” upon which to base case studies of skin reconstruction in fossil taxa.

9:00 **Wolfe, D., Beekman, S., McGuinness, D., Robira, T. and Denton, R.:** TAPHONOMIC CHARACTERIZATION OF A *ZUNICERATOPS* BONE BED FROM THE MIDDLE CRETACEOUS (TURONIAN) MORENO HILL FORMATION

WOLFE, Douglas, BEEKMAN, Steve, MCGUINNESS, Dan, ROBIRA, Tom, Mesa Southwest Museum, Phoenix, AZ; DENTON, Robert, Specialized Engineering, Ranson, WV

At least 7 partial specimens of *Zuniceratops* and 1 *Nothronychus* are contained in a limited interval of the Moreno Hill Formation (the Haystack Butte “bone-bed”) as several hundred, mostly-disarticulated elements amongst carbonized logs. Some partly articulated and associated skeletal elements preserve teeth and delicate processes indicating carcasses were reduced to skeletons prior to burial but that element transport was local. Fine grain size, coal deposits and freshwater aquatic species within the Moreno Hill strata suggest relatively stagnant floodplain deposition. High-angle cross-bed sets, clay, bone and charcoal clasts, “stacking” of logs and bones, and specimen orientation suggest rapid deposition from higher energy floods or debris flow. Fossil wood, *in-situ* stumps and charcoal suggest seasonally emergent conditions nearby. *Zuniceratops* skeletal elements are not equally represented in the bone bed. *Zuniceratops* skull elements include 7 left dentaries and 4 left brow horns. Distal appendicular elements are rare. *Nothronychus* is represented more evenly by elements from throughout the skeleton. Specimen orientations mapped as computer automated drafting and design (CADD) data were converted to a finite element format (ANSYS) comparing element orientation to element length-to-width (aspect ratio). Sorted according to aspect ratio, and plotted according to the orientation frequencies relative to compass direction, results show that bone and wood specimens exhibiting aspect ratios greater than 2: 1 cluster into bimodal frequency distributions approximately 75 to 90 degrees apart (sub-perpendicular) indicating probable orientation to flow during deposition. Seasonal or extreme drought, followed by flood may explain the bone-bed depositional history. Secondary mobilization and winnowing of several *Zuniceratops* skeletons stranded together, foundered in mud, partly buried by flood, or accumulated due to drought may explain the paucity of distal and right-side skeletal elements. Foundered, partly buried elements may have lagged behind the exposed skull and dorsal elements transported into the bone bed/log jam.

9:15 **Sander, M., Laven, T., Mateus, O. and Knoetschke, N.:** INSULAR DWARFISM IN A BRACHIOSAURID SAUROPOD FROM THE UPPER JURASSIC OF GERMANY

SANDER, Martin, Universitaet Bonn, Bonn, Germany; LAVEN, Thomas, Dinosaurier-Freilichtmuseum Muenchehagen, Rehburg-Loccum, Germany; MATEUS, Octavio, Museu da Lourinha, Lourinha, Portugal; KNOETSCHKE, Niels, Dinosaurier-Freilichtmuseum Muenchehagen, Rehburg-Loccum, Germany

Sauropod dinosaurs were the largest animals to ever inhabit the land, with truly gigantic forms in at least three lineages. However, small species of adult body mass of less than 5 t are very rare, and small sauropod bones generally represent juveniles.

Based on the comparison of bone histology, such small bones may also represent island dwarfs, akin to the Pleistocene pygmy island elephants. This is the case in material that comes from marine beds of Kimmeridgian age from Oker (Harz Mountains, Germany). It records individuals of a new brachiosaurid not exceeding 6 m in total body length and represents the first unequivocal case of dwarfing for any dinosaur. The same ontogenetic stages in histology are present at much smaller body size than in the abundantly sampled large sauropods from the Morrison Formation and the Tendaguru Beds.

Growth cycle counts suggest that the dwarfed brachiosaurids reached maximum size at 8-9 years and may have attained sexual maturity as early as 2-3 years. Dwarfing evolved by reduction of growth rate and shortening of ontogeny.

9:30 **Xu, X., Zhou, Z., Zhang, F., Wang, X. and Kuang, X.:** FUNCTIONAL HIND-WINGS CONFORM TO THE HIP-STRUCTURE IN DROMAEOSAURIDS

XU, Xing, ZHOU, Zhonghe, Institute of Vertebrate Paleontology & Paleonanthr, Beijing, China; ZHANG, Fucheng, Institute of Vertebrate Paleontology & Paleonanthr, Beijing, China; WANG, Xiaolin, Institute of Vertebrate Paleontology & Paleonanthr, Beijing, China; KUANG, Xuewen, Tianjin Museum of Natural History, Tianjin, China

An arboreal-gliding hypothesis of flight origin has been long thought to be implausible with the theropod ancestry of birds supported by all modern cladistic analyses. Recent discoveries of basal dromaeosaurids with pedal features comparable to arboreal birds indicate that some non-avian theropods might have been arboreal. Furthermore, the long and asymmetric metatarsal feathers of these dromaeosaurids are inconsistent with any cursorial habit. The above evidence was presented to support an arboreal-gliding hypothesis, but whether the functional hind-wings are present in basal dromaeosaurids remains as an unresolved issue. Here we propose that while taking off, the hind-limbs of basal dromaeosaurids were capable of stretching posteriorly and also defecting laterally in a position that the long pennaceous feathers of the hind-limbs were placed in a subparallel position with respect to the tail. In this posture, the leg and tail feathers made a lifting-surface altogether. Such a posture is slightly different from the parasagittal posture of dinosaurs and is consistent with the osteological features of the pelvis and hind-limbs of eumaniraptorans. A significant modification seen in eumaniraptorans is the posterolateral divergence of the iliac blades, a design that allows a posterolateral orientation of the hind-wings. This modification, together with the opisthopubic condition, makes a flat caudal portion of the pelvis for eumaniraptorans. Recent reexaminations of *Archaeopteryx* specimens revealed the proportionately long pennaceous feathers along the tibia, which suggests the presence of a diminutive hind-wing. Based on this evidence, we propose that primitive eumaniraptorans developed two lift-generating airfoils: the front-wings (also the thrust-generator) and the hind-wings (formed by both hind-limbs and tail); during early avian evolution, the front-wings became the main airfoil while the hind-wings lost their role in producing lift. *M. gui* represents an early stage in the evolution of flight with two

large lift-generating surfaces; Archaeopteryx reduced its leg feathers but compensated with a large feathered tail.

9:45 **Lamanna, M., Martinez, R., Luna, M., Casal, G., Ibiricu, L. and Ivany, E.:** NEW SPECIMENS OF THE PROBLEMATIC LARGE THEROPOD DINOSAUR *MEGARAPTOR* FROM THE LATE CRETACEOUS OF CENTRAL PATAGONIA

LAMANNA, Matthew, Univ. of Pennsylvania, Philadelphia, PA; MARTINEZ, Ruben, LUNA, Marcelo, CASAL, Gabriel, IBIRICU, Lucio, IVANY, Edmundo, Univ. Nac. Patagonia San Juan Bosco, Comodoro Rivadavia, Argentina

Recent discoveries have revealed a surprising diversity of tetanuran theropod dinosaurs in Upper Cretaceous sediments of Patagonia, Argentina. Among the most enigmatic of these taxa is the large predator *Megaraptor namunhuaiquii* from the early Late Cretaceous (Turonian-Coniacian) Portezuelo Formation of Neuquen Province in northern Patagonia. The holotype of *Megaraptor* consists of an ulna, manual phalanx I-1, an incomplete metatarsal III, and a giant manual ungual I that was originally identified as pertaining to the pes. The only other described specimen pertaining to this genus is a newly discovered partial skeleton that preserves a cervical and two proximal caudal vertebrae, haemal arches, a scapula, coracoid, radius, ulna, a complete manus, pubis, and metatarsal IV. Because its anatomy is inadequately known, the phylogenetic relationships of *Megaraptor* have remained unresolved.

We describe two new partial skeletons of *Megaraptor* from the early Late Cretaceous (middle Cenomanian-Turonian) Lower Bajo Barreal Formation of southern Chubut Province in central Patagonia. The smaller skeleton, possibly pertaining to a subadult, includes a cranial dorsal vertebra, two dorsal ribs, three incomplete proximal-mid caudal vertebrae, manual phalanx ?II-2, incomplete manual unguals I-III, ?femur and ?fibula fragments, the distal end of metatarsal II, and two fragmentary nonungual phalanges. The larger specimen consists of manual unguals I and III, a fragmentary femur and tibia, a nearly complete fibula, the distal end of metatarsal I, metatarsal II, several pedal phalanges, and indeterminate fragments.

The Bajo Barreal skeletons preserve axial and appendicular elements not previously known for *Megaraptor*, thus adding considerably to our understanding of its anatomy. A phylogenetic analysis resolves the position of *Megaraptor* within the carnosaurian clade Allosauroidea, as one of its youngest known representatives. *Megaraptor* is thus a relatively basal tetanuran and not a coelurosaur as originally proposed. The Bajo Barreal specimens represent the first occurrences of this genus outside of northern Patagonia.

10:00 **BREAK**

10:15 **Carney, R. and Gishlick, A.:** UTILIZING DIGITAL TECHNIQUES WITHIN AN EXTANT PHYLOGENETIC BRACKETING PARADIGM TO RECONSTRUCT AND ANALYZE THE ROLE OF ARTICULAR CARTILAGINOUS STRUCTURES IN DROMAEOSAUR FORELIMB FUNCTION

CARNEY, Ryan, Univ. of California, Berkeley, Berkeley, CA; GISHLICK, Alan, National Center for Science Education, Oakland, CA

The importance of soft tissues has been a perpetually neglected subject in the field of paleontological functional morphology. Elements such as articular cartilage play an integral role within the musculoskeletal complex, and therefore must be incorporated into models that serve to test functional hypotheses. Unfortunately, soft tissues are not preserved in the fossil record, which poses a substantial problem for developing such models. However, by combining modern digital scanning and modeling

techniques with extant phylogenetic bracketing, we can reconstruct articular cartilaginous structures for extinct taxa.

Three-dimensional range of motion data was taken from alligator and pigeon specimens in order to examine the maximum excursions about the glenoid and humeral joints. The shoulder, brachial, and antebrachial elements of each taxon were defleshed, disarticulated, and then digitally scanned. The intact glenoid capsules were subsequently rescanned with all cartilage completely removed, in order to topographically and volumetrically analyze the cartilaginous structures. Three-dimensional virtual models of the glenoid capsule and brachial systems were then constructed using empirical constraints, and the relationships between cartilaginous structures and forelimb function were examined.

These results were then used to digitally reconstruct articular cartilage on a virtual forelimb model of the dromaeosaur *Deinonychus antirrhopus* that is used to test hypotheses about the evolution of avian flight. The alligator, avian, and theropod models were then spatially superimposed and quantitatively analyzed. Our results verify that the topology of articular cartilage plays a substantial role in the kinematics of the forelimb musculoskeletal system of this clade. Furthermore, considerations of such soft tissues are imperative when modeling the biomechanics of extinct taxa. By combining the extant phylogenetic bracketing method with modern digital techniques, cartilaginous structures and other soft tissues can be objectively inferred and reconstructed for extinct organisms.

10:30 **Sender, P.:** RANGE OF MOTION IN THE FORELIMBS OF *MONONYKUS*, AND FUNCTIONAL IMPLICATIONS

SENDER, Philip, Lamar State College Orange, Orange, TX

The Cretaceous Mongolian coelurosaur *Mononykus olecranus* exhibits stunted forelimbs with bizarre morphology and a single functional digit. This has incited curiosity as to forelimb function in the animal, but until now no functional study of its forelimbs has been undertaken.

In this study, manual manipulation of casts of forelimb elements of *Mononykus* was used to reveal range of motion, which constrains function. The results are surprising. Most theropods exhibit humeri that hang ventrally from the glenoid, a large range of motion at the shoulder and elbow, palms that face medially, and hands and fingers that move in the transverse plane. In contrast, the humeri of *Mononykus* sprawl laterally from the glenoid, shoulder and elbow movement are restricted, the palms face permanently ventrally, and the hand and finger move in a subparasagittal plane. The metacarpophalangeal and interphalangeal joints of the pollex of *Mononykus* exhibit huge ranges of motion.

*Mononykus* could not grasp prey with its forelimbs, and could not exhibit the shoulder and elbow movements required for digging burrows. However, its forelimbs are superbly exapted for using the motions that extant anteaters and pangolins use to break into tough termite and ant nests. These animals face the palms ventrally and use parasagittal movements of a single, enlarged finger that has an enlarged ungual and a huge range of motion to crack into termite mounds, ant mounds, twigs, and vines.

A diet of insects that make tough nests may explain dental morphology in *Mononykus*, which has lost the serrations, recurvature, and large dental size that are typical of the teeth of its carnivorous relatives.

10:45 **Holtz, T.:** TAXONOMIC DIVERSITY, MORPHOLOGICAL DISPARITY, AND GUILD STRUCTURE IN THEROPOD CARNIVORE COMMUNITIES: IMPLICATIONS FOR PALEOECOLOGY AND LIFE HISTORY STRATEGIES IN TYRANT DINOSAURS

HOLTZ, Thomas, Univ. of Maryland, College Park, MD

Well-sampled dinosaur communities from the Jurassic through Early Cretaceous show greater taxonomic diversity and morphological disparity among larger (>50 kg) taxa when compared to communities of the Late Cretaceous. While this apparent difference might be due to low sample size in Gondwanan and European assemblages, this is not the case for Asian and western North American faunas. Additionally, when patterns of theropod diversity are compared to potential prey diversity, the distinctiveness of tyrannosaurid-dominated faunas remains.

Previous work observing these differences has concentrated on diversity and size distribution; this new study adds data on aspects of cranial, dental, fore-, and hindlimb morphologies. Small taxa show comparable or greater disparity in the Late Cretaceous as in earlier faunas. Some large-bodied diversity in pre-Late Cretaceous faunas might be explicable by specialists in different food sources (i.e., spinosaurids with fish), but the pattern of diverse sympatric large theropods persists. In contrast, the large carnivore guild in Campano-Maastrichtian assemblages is monopolized by tyrannosaurids, with medium-sized (50-500 kg) rare or absent. A possible transition from diverse to monopolized predator guilds is represented in the Bayan Shire Formation (Santonian?) of central Asia, in which the large-bodied deinonychosaur *Achillobator* and the small primitive tyrannosaur *Alectrosaurus* exist in sympatry.

The apparent “missing middle” of the Late Cretaceous theropod guilds (i.e., absence or rarity of 50-500 kg carnivores), particularly in North America, would be alleviated by subadults of tyrannosaurid species (and/or taxonomically problematic small-bodied tyrant species) serving as the mid-sized predators. Additionally, life history patterns of non-avian dinosaurs in general suggest higher populations of juveniles and subadults than adults. However, even these factors would not explain the reduction in morphological disparity of theropods (and thus inferred prey acquisition strategies) in the Campano-Maastrichtian, particularly with the taxonomically diverse and numerically abundant available prey.

11:00 **Baier, D.:** *ALLIGATOR FORELIMB KINEMATICS AND THE EVOLUTION OF ARCHOSAUR SHOULDER MECHANICS*

BAIER, David, Brown Univ., Providence, RI

A force balance model of the pigeon shoulder joint predicts that the substantial acrocoracohumeral ligament (AHL) acts as a tensile brace to prevent the massive pectoralis from dislocating the humerus during flight. Mechanical tests, computer simulations, and manipulations of dissected specimens all support this conclusion. Crocodylians possess a homologous coracohumeral ligament (CHL), but a force balance model suggests that the CHL is unnecessary during walking because the joint surface is capable of resisting ventral dislocation. To test this hypothesis, I collected simultaneous X-ray and light video of alligators walking on a treadmill. 3-D polygonal models of the forelimb bones of an alligator were aligned to the 2-D videos using Maya 5.0 to acquire 3-D motion data. During normal striding, the CHL is always slack. Hence, the role of this ligament has evolved significantly. I hypothesize that the changing orientation of the glenoid on the line to birds and the resulting loss of ventral support in the joint necessitate a novel functional role for the AHL. This functional perspective underscores the need for data on the relative position of the ‘biceps tubercle’ and the orientation of the glenoid in fossil birds and non-avian theropods.

11:15 **Chatterjee, S., Templin, R. and Campbell, K.:** *THE FLIGHT PERFORMANCE OF THE GIANT MIOCENE BIRD ARGENTAVIS (CICONIIFORMES: TERATORNITHIDAE)*

CHATTERJEE, Sankar, Texas Tech Univ., Lubbock, TX; TEMPLIN, R., Ottawa, ON, Canada; CAMPBELL, Kenneth, Natural History Museum of Los Angeles County, Los Angeles, CA

*Argentavis magnificens* from the Miocene of Argentina, the world's largest known flying bird, was about seven times heavier than the California condor. We have calculated the flight performance of *Argentavis* (using mass = 70 kg; wing span = 7 m; aspect ratio = 6; wing area = 8 m<sup>2</sup>; wing loading = 85 N/m<sup>2</sup>, cruising speed 65 kph) to study its flight capability through a computer simulation model. For *Argentavis*, takeoff from the ground was possible by combining short bursts of maximum continuous power from gentle downhill slopes of about 10° or more, and having wings extended into at least a 5 m/s headwind. Stronger winds, which were undoubtedly present in the region in the Miocene, would have reduced muscle power required to a minimum. Once airborne, *Argentavis*, which was close to the theoretical upper size limit for safe gliding, was probably soaring long distances for foraging by exploiting wind energy, much as condors do today. The sustained power output of *Argentavis* likely was insufficient to enable takeoff without wind assistance or to sustain continuous level flight. It most likely seldom flapped its huge wings, except during takeoff and landing. Gliding performance deduced from polar curves indicates that *Argentavis* was an excellent soarer, with a gliding angle close to 3°. It could have exploited uplifts along topographic features, or it traveled by gliding from thermal to thermal by alternately circling upward to gain height, subsequently losing altitudes as it glided to enter an adjacent thermal for cross-country journeys. *Argentavis* would have little difficulty in staying within typical thermals of 1 km diameter by holding turns of 30 m radius, as long as its vertical component of velocity was 1m/s or more. *Argentavis* had relatively low wing loading compared to that of condors (117 N/m<sup>2</sup>); hence it could glide at lower speeds.

11:30 **Dial, K.:** WHAT USE IS HALF A WING AND WAIR?

DIAL, Kenneth, Univ. of Montana, Missoula, MT

Wing-assisted incline running (WAIR) represents a locomotor strategy commonly employed among juvenile and adult ground birds and is argued to represent the most parsimonious and robust origin-of-avian-flight hypothesis. WAIR offers the only observable example of a transitional morphological pathway leading to avian aerial flight and appears congruent with the broad array of available data (e.g., paleontology, behavior, life history, ecology, aerodynamics, phylogenetics, physiology, and development). New ontogenetic and locomotor-performance data are presented from extant basal clades (ratites [ostrich, rhea, emus], Tinamiformes [Crested and Chilean tinamous], Galliformes [Chukar partridge, Japanese and Bobwhite quail, Ring-necked pheasant], and Megapodes [Australian brush turkeys]) in an effort to illustrate how forelimbs and hindlimbs interact to accomplish movement upon 3-dimensional terrestrial environments.

Both historic and recently proposed origin-of-avian-flight hypotheses represent *ad hoc* explanations for specific extinct taxa and fail to integrate the plethora of complementary data on the subject. Numerous theropod fossils (*Caudipteryx*, *Velociraptor*, *Microraptor*, *Unenlagia*, *Protarchaeopteryx*, *Nomingia*, *Rahonavis*, *Sinornithosaurus*, *Sinosauropteryx*, *Mononychus*, *Archaeopteryx*, and others) appear congruent with various ontogenetic locomotor stages. It is suggested that all these be re-evaluated as to whether the: (1) proposed morphological and behavioral transitional locomotor stages are identifiable in extant forms, (2) hypothesis integrates relevant sub-disciplines, and (3) vast array of available data from the fossil record are considered. WAIR is the only origin-of-avian-flight thesis that has been investigated experimentally and elucidates a mechanical explanation for half a wing.

11:45 **Gatesy, S., Dial, K. and Jenkins, Jr., F.:** AN INSIDE LOOK AT SKELETAL MOTION IN FLYING BIRDS

GATESY, Stephen, Brown Univ., Providence, RI; DIAL, Kenneth, Univ. of Montana, Missoula, MT; JENKINS, JR., Farish, Harvard Univ., Cambridge, MA

Movement of the forelimb skeleton is a crucial link between the neuromuscular and aerodynamic mechanisms of avian flight. However, due to the 3-D complexity of the wingbeat cycle and the inaccessibility of bony landmarks, accurate measurement has remained elusive. Without a more complete understanding of joint coordination in extant birds, our ability to interpret the functional significance of osteological features in fossils and the evolution of powered flight is severely restricted.

We have embarked on a comparative study that integrates fluoroscopy, computed tomography (CT), and 3-D animation to reconstruct skeletal motion with unprecedented precision. Birds were recorded with three synchronized, high-speed, digital video cameras (one X-ray, two light) while flying over a broad range of speeds in a wind tunnel. Subsequently, the flight chamber, cameras, and a precise morphological reconstruction of the skeleton (made from CT scans of the actual specimen) were modeled to scale in the animation program, Maya. The articulated skeletal model is aligned with sequential video frames (a process known as rotoscoping) to simultaneously animate and quantify joint motion. Using examples from ongoing analysis of pigeons, we will demonstrate how this methodology can measure even minute movements of the body, head, pectoral girdle, and forelimb on a wingbeat by wingbeat basis. Correlation of variation in wing kinematics with a bird's instantaneous lift and thrust will reveal mechanisms of speed control and maneuvering for the first time.

12:00 **Kappelman, J., Maga, A. and Ryan, T.:** BIPEDALISM AND THE STRUCTURE OF THE HINDLIMB IN BIRDS

KAPPELMAN, John, MAGA, A. Murat, The Univ. of Texas at Austin, Austin, TX; RYAN, Timothy, Pennsylvania State Univ., Univ. Park, PA

Although habitual bipedalism is a rather unusual mode of locomotion in most animal groups, its unique interplay between the stance and swing phases of stride as they alternate between the two legs exerts influences upon the overall skeletal morphology of the hindlimb. Nowhere are these effects seen more dramatically than in birds. Although flight is often the signature locomotor mode within this group, the bird hindlimb demonstrates a wide range of adaptations to activities that include perching, takeoff and landing, hopping, and cursorial striding locomotion. These activities involve a wide range of movements but share the central fact that leg is a weight-bearing column under axial compression. Here we present a detailed study of the bird tibiotarsus using High Resolution X-ray Computed Tomography (HRXCT) that examines several mechanical properties including cross-sectional area, shape, and moments of inertia. Unlike most studies that sample these properties at the midshaft only, this study includes cross-sectional data sampled throughout the entire length of the shaft. Our results suggest that differences between hoppers (crows and grackles) and cursorial striders (roadrunners) can be identified from the mechanical properties of the tibiotarsus as they relate to these modes of locomotion. These observations offer the potential for interpreting the locomotor modes of extinct taxa.

12:15 **Balanoff, A. and Rowe, T.:** THE CRANIAL MORPHOLOGY OF *AEPYORNIS* (RATITAE: AEPYORNITHIDAE) OVER ONTOGENY

BALANOFF, Amy, ROWE, Timothy, Univ. of Texas at Austin, Austin, TX

The most drastic change in size from embryo to adult within the avian clade is found among the ratites. Ratites encompass the largest known extant and extinct birds including the largest bird ever discovered, the extinct elephant bird, *Aepyornis*, from the island of Madagascar. This study expands on my previous work on the embryo of *Aepyornis* by incorporating data from the skull of an adult, thus allowing a more complete understanding of the evolutionary development of this unusual taxon. The considerable size increase of *Aepyornis* over its ontogeny correlates with numerous transformations in its cranial osteology. These transformations include the relative degree of pneumatization of the skull,



the morphology of the pituitary fossa, the size and shape of the endocranial cavity, as well as allometric differences in proportions of the skull as a whole. Although these changes take place over the ontogeny of *Aepyornis* they are not necessarily due solely to its increase in size; but rather, many changes may represent plesiomorphic transformations or may be examples of individual variation. An extant phylogenetic bracket was set up using the living ratites and the domestic chicken in order to identify which of these transformations likely represent derived conditions caused by the increase in size within *Aepyornis*. The inclusion of these additional taxa allows the exploration of the implications concerning the developmental and evolutionary history of cranial morphology throughout the ratite clade.

**TECHNICAL SESSION XVI**  
**PLAZA BALLROOM F**  
**MODERATORS: EWAN FORDYCE AND JAEALYN EBERLE**

**8:00 Nummela, S. and Thewissen, J. G. M.: THE CETACEAN EAR: EVOLUTION AND DEVELOPMENT**

NUMMELA, Sirpa, THEWISSEN, J. G. M., Northeastern Ohio Univ. College of Medicine, Rootstown, OH

Fossil whale material shows that radical morphological changes to the generalized mammalian ear took place during the first ten million years of cetacean evolution. Unique specializations enabling cetaceans to hear underwater include: thick medial side of the tympanic bone (involucrum, present even in the earliest cetaceans), enlarged mandibular foramen, elongated tympanic membrane, rotated ossicular chain, enlarged malleus with a loss of manubrium, synostosis of malleus to the tympanic bone through the processus gracilis, relatively diminished incus with changed crural length proportions, elastic contacts between the tympanic and periotic, and disconnection of the tympano-periotic complex from the skull.

During early ontogeny the mammalian ear develops from three distinctly different anatomical regions, which finally form one functional unit. The inner ear develops from the otic vesicle, and becomes embedded in the petrous bone. The middle ear develops from the pharyngeal region. The external auditory meatus is derived from the first pharyngeal cleft, and the tympanic cavity and the Eustachian tube from the first pharyngeal pouch. The intimate connection between the middle ear and lower jaw suggests an important role of Meckel's cartilage in ear morphogenesis. The malleus and incus are derivatives of the articular and quadrate, respectively, originally from the first (mandibular) arch; the stapes is a derivative of the columella, originally from the second (hyoid) arch. The tympanic ring derives from the angular, the processus gracilis from the gonial.

The ontogenetic development of the whale ear was studied in embryos and fetuses of the Spotted dolphin, *Stenella attenuata*, with histological sections and clear and stain-method. This allows us to trace the origin of the cetacean ear specializations in embryology and determine the ontogenetic timing of these events. The inner ear begins to develop first, at the time the ossicles are still mesenchymal. The elongation of the tympanic membrane takes place relatively late, and the rotation of the ossicular chain follows first after ossification.

**8:15 Fordyce, R. E.: THE TRANSITION FROM ARCHAEOCETI TO NEOCETI: OLIGOCENE ARCHAEOCETES IN THE SOUTHWEST PACIFIC**

FORDYCE, R. Ewan, Univ. of Otago, Dunedin, New Zealand

Recent finds from New Zealand indicate that archaeocete-grade Cetacea did not go extinct about the end of the Eocene, with the rise of the modern groups Mysticeti and Odontoceti. Rather, archaeocetes persisted into the Oligocene to remain significant in cetacean ecosystems. Evidence comes from new fossils from the Kokoamu Greensand-basal Otekaike Limestone of the Waitaki Valley region, 26-28+ Ma (New Zealand Duntroonian Stage; upper Oligocene). The key specimen is a skull (OU 22294) with associated teeth and periotics. The species lacks diagnostic maxillary characters of either Mysticeti or Odontoceti, and is similar in grade to Late Eocene Dorudon-like archaeocetes. The rostrum is narrow with smooth-crowned heterodont teeth, there is no evidence of polydonta, and the last upper tooth is M2. Differences with named dorudontines include a narrower rostrum, M2 apparently anterior to the orbit, more-attenuated postorbital process, flatter broader intertemporal region, and low supraoccipital. Of note, as in crown-group Cetacea (Neoceti), the periotic is amastoid, with the posterior process not

exposed laterally on the skull wall. Cladistically, this species is a plesiomorphic sister-species to the Neoceti.

A comparable specimen (OU 22394) is a juvenile, possibly from a second species. Its associated teeth are delicate and perhaps deciduous; the fragmentary skull is also amastoid. Postcranial elements include parts of the forelimb, ribs and vertebrae. These two specimens allow earlier finds, both named and undescribed, to be reidentified as late-surviving archaeocetes. The latter include the large toothed cetacean *Kekenodon onamata* (late Oligocene, New Zealand) and enigmatic *Squalodon [sic] gambierensis* (late early/early late Oligocene, Australia). The New Zealand fossils occur in strata that have also produced a stem-balaenid, putative stem-balaenopterids, stem-delphinoids, and squalodontids and other stem-platanistoid dolphins. Late Oligocene filter-feeding and echolocating cetaceans (Mysticeti and Odontoceti respectively) coexisted with late-surviving archaeocetes that employed neither feeding mode.

8:30 **Pyenson, N.: PHYLOGENETICS, BIOGEOGRAPHY, AND BODY SIZE EVOLUTION IN NEOCETI**

PYENSON, Nicholas, University of California Museum of Paleontology, Berkeley, CA

The magnitude of body size range in extant cetaceans broadly reflects taxonomic divisions between Mysticeti (baleen whales) and Odontoceti (toothed whales). Molecular and morphological phylogenetic analyses indicate that Neoceti (Mysticeti + Odontoceti) evolved during the Eocene-Oligocene transition. Thus, large-scale paleoenvironmental changes in the oceans have been implicated in Neoceti evolution. The emergence of filter-feeding, for example, has been linked to concomitant increases in high-latitude primary productivity in oceans of the Southern hemisphere during the early Oligocene. The implied bottom-up trophic processes driving such ecological change also are hypothesized to account for large body size in cetaceans. This study integrates changes in estimated Neoceti body size with broad biogeographic patterns in a phylogenetic framework to test such hypotheses.

To estimate body size in extinct Neoceti, osteological correlates that closely predict body size in extant odontocetes were tested for phylogenetic effects using independent contrasts. Regression equations predicting body size values in extinct Neoceti were mapped on to molecular, morphological, and fossil cladograms as continuous quantitative characters. These three phylogenetic hypotheses provide a testable context for evaluating evolutionary scenarios in cetacean biogeography by identifying clades where body size changes correlate with specific biogeographic distributions. If primary productivity affects body size, large body sizes in Neoceti are expected to occur in higher-latitude lineages. This signal, however, may become obscured by taxonomic or historiographic biases implicit in the composition of the morphological and fossil-based phylogenies. Incorporating broader geographic sampling of cetacean taxa from both Northern and Southern hemispheres and including molecular data with morphological characters in partitioned or total evidence analyses may aid this study. Moreover, the fusion of biogeography with macroecology and phylogenetics provides one avenue for testing and falsifying hypotheses that explain complex interactions between abiotic and biotic realms in the Cenozoic oceans.

8:45 **Barnes, L., Dooley, Jr., A. and Fraser, N.: A NEW MIOCENE SPERM WHALE (CETACEA; PHYSETERIDAE) FROM VIRGINIA**

BARNES, Lawrence, Natural History Museum of LA County, Los Angeles, CA; DOOLEY, JR., Alton, FRASER, Nicholas, Virginia Museum of Natural History, Martinsville, VA

A new taxon of fossil physeterid, based on a skull (including the petrosal and tympanic bulla), mandible, and numerous teeth, was collected in 1995 from the Carmel Church Quarry, Caroline County,

Virginia. The specimen was collected in place, approximately 3 meters above a marine bonebed in the Calvert Formation, and is either from the upper Miocene St. Marys Formation or possibly the middle Miocene Choptank Formation. However, the correlation of the beds at Carmel Church between the Calvert and Eastover formations is uncertain at present. The skull size indicates a relatively small sperm whale, perhaps approximately 5 or 6 meters in total body length when alive. This new physeterid is remarkable in its unusual mix of characters. Like primitive late Oligocene sperm whales, it has relatively large teeth with complexly ornamented enamel and fully erupted and functional upper teeth. It has a large, triangular, wide-based rostrum that resembles that of the modern genus *Physeter*. It has a large supracranial basin that resembles the middle Miocene sperm whales *Orycterocetus* and *Aulophyseter*, (both of which differ by having greatly reduced upper dentitions), but the nuchal crest bordering its posterior side is not as high as in many other fossil sperm whales. This new sperm whale does not fit cladistically with any previously described sperm whales, and it is not clear to what subfamily it belongs. The recently-described Aulophyseterinae is valid, but not for the reasons listed in the description because the holotype skull of *Aulophyseter morricei* is incompletely preserved.

9:00 **Dooley, Jr., A., Barnes, L. and Kearin, M.:** A NEW TAXON OF SQUALODONTID (MAMMALIA, CETACEA) FROM THE LOWER MIOCENE VAQUEROS FORMATION IN SOUTHERN CALIFORNIA

DOOLEY, JR., Alton, Virginia Museum of Natural History, Martinsville, VA; BARNES, Lawrence, Natural History Museum of Los Angeles County, Los Angeles, CA; KEARIN, Marian, The Keith Companies, Inc., Irvine, CA

The nearly complete cranium, mandible, and associated postcranial skeleton of a squalodontid whale has been discovered in the lower Miocene Vaqueros Formation in the San Joaquin Hills, near Irvine, Orange County, coastal southern California, as part of a paleontological resource management program for the Irvine Community Development Company. The specimen, now in the Natural History Museum of Los Angeles County, is part of a diverse marine vertebrate and invertebrate assemblage that includes platanistid and eurhinodelphinid dolphins, a tooth-bearing mysticete, and several species of baleen-bearing mysticetes. It shares in common with all known members of the family Squalodontidae a fully telescoped cranium, well-developed heterodonty, large procumbent incisors, thick, crenulate enamel on all tooth crowns, and a ventrally deep and narrow rostrum. It differs from all previously known Squalodontidae, however, by having a very short, narrow rostrum combined with a very long and wide cranium, and by having only nine post-canine teeth in each side of the upper jaw. The form of the posterior teeth is comparable to middle Miocene squalodontids such as *Squalodon*. Therefore the low tooth count in the Irvine specimen is a reversal commensurate with the shortness of the rostrum. The family Squalodontidae is rare in the Pacific realm, and this specimen is the first unquestionable record of this group in California.

9:15 **Jett, K., Olson, J. and Adam, P.:** THE TWISTED HISTORY OF THE ODONTOCETE HEAD: PROCRUSTES ANALYSIS AND EVOLUTION OF DIRECTIONAL SKULL ASYMMETRY IN ODONTOCETE WHALES (MAMMALIA: CETACEA)

JETT, Kristin, OLSON, Joshua, ADAM, Peter, UCLA, Los Angeles, CA

Skull asymmetry is a defining feature of the Odontoceti, and is associated with highly modified nasal passages that produce echolocation clicks in life. The degree of skull asymmetry shows considerable interspecies variability, but only a single comparative study has attempted to quantify and document variation among living taxa. This may be due to logistical problems inherent in traditional methods used to study asymmetry that require establishment of a definitive midline axis from which to measure

relative positions of skull features. We adapted axis-free Procrustes methods commonly used to examine fluctuating asymmetry in insect wings to explore directional asymmetry in skulls of 45 extant odontocete species (representing all families) and well-represented fossil species. Our analysis utilized 15 bilaterally distributed landmarks to characterize magnitudes and positions of asymmetry. Taxa were compared using ANOVA and multivariate statistics. Data were further analyzed with respect to various life history and morphological characteristics and phylogeny.

Earlier studies suggesting a correlation between either body size or skull vertex height and degree of asymmetry appear to be incorrect. When interpreted within a phylogenetic framework, we demonstrate that basal odontocete lineages (Ziphiidae, Physteridae, Monodontidae) have the highest degree of asymmetry. Later diverging taxa (Delphinidae, Phocoenidae) appear to have secondarily reduced skull asymmetry. A preliminary analysis of well-preserved Oligocene and Miocene taxa suggests that, with few exceptions, the extent of asymmetry within each major lineage is relatively conserved through time. Our findings indicate that, when appropriately quantified, skull asymmetry has potential taxonomic information at less inclusive levels within the Odontoceti. Our data further imply that putative differences in echolocation ability and characteristics are conserved within distinct odontocete lineages. When coupled with data on functional morphology, characterization of skull asymmetry may allow for finer resolution of feeding strategies in Cenozoic odontocetes.

9:30 **Zalmout, I., Ul-Haq, M. and Gingerich, P.:** MARINE MAMMALS FROM THE MIDDLE EOCENE (LUTETIAN) HABIB RAHI AND DOMANDA FORMATIONS OF EASTERN BALOCHISTAN

ZALMOUT, Iyad, Univ. Michigan, Ann Arbor, MI; UL-HAQ, Munir, Geological Survey of Pakistan, Quetta, Pakistan; GINGERICH, Philip, Univ. Michigan, Ann Arbor, MI

The marine-mammal-bearing Habib Rahi and Domanda formations of middle Eocene (Lutetian) age are exposed continuously from the northern to the southern end of the Sulaiman Range orocline, spanning some three degrees of latitude and more than 300 km of outcrop. On the continental side of this outcrop belt, toward the Indo-Pakistan subcontinent, both formations are exposed in the Zinda Pir anticlinorium. On the opposite offshore side both are exposed in shallow synclines in eastern Balochistan. One of these, the Lakha syncline, has been a focus of our field research in 2000 and 2004. The mammalian fauna is more diverse than that found elsewhere, preserving sirenians (*Protosiren eoethene*) as well as archaeocete cetaceans (e.g., *Artiocetus clavis* and *Rodhocetus balochistanensis*).

Lutetian archaeocetes found here are more complete than those found elsewhere, preserving articulated skeletons with forelimbs, hind limbs, and tails. Most archaeocetes from the Habib Rahi and Domanda formations are primitive protocetids, but the middle part of the Habib Rahi Formation has yielded small skeletons and an astragalus comparable to those of pakicetids, and the upper part of the Domanda Formation has yielded large archaeocetes suggestive of more advanced protocetids or basilosaurids (tentative interpretations that remain to be confirmed by study of newly collected specimens).

The Habib Rahi and Domanda formations of eastern Balochistan are intriguing not only because of their greater diversity of marine mammals and more complete skeletal preservation, but also because they are thinner here and contain more-marginal marine facies than those in the Sulaiman Range and Zinda Pir anticlinorium. Thus there was possibly a persistent offshore 'hinterland' in Lutetian time like that known earlier in Ypresian time.

9:45 **Geisler, J. and Uhen, M.:** PHYLOGENY OF CETARTIODACTYLA AS INDICATED BY SIMULTANEOUS ANALYSES OF MOLECULAR, MORPHOLOGICAL, AND STRATIGRAPHIC DATA

GEISLER, Jonathan, Georgia Southern Museum, Statesboro, GA; UHEN, Mark, Cranbrook Institute of Science, Bloomfield Hills, MI

Although some recent morphological and molecular studies agree that Cetacea is closely related to Hippopotamidae, there is little consensus on other aspects of cetartiodactyl phylogeny. We addressed this problem by conducting two analyses: 1) a simultaneous cladistic analysis of intrinsic data (morphology and molecules) that incorporates observations on recently described hindlimbs of protocetid and pakicetid cetaceans and 2) a stratocladistic analysis, which includes morphological, molecular, and stratigraphic data. Our intrinsic dataset includes 73 taxa scored for 8,229 informative characters, of which 208 are morphological and 8,021 molecular. Both analyses supported the exclusion of Mesonychia from Cetartiodactyla and a close phylogenetic relationship between Hippopotamidae and Cetacea. An agreement subtree for the intrinsic dataset indicates that the Old World taxa *Cebochoerus* and *Mixtotherium* are successive stem taxa to Whippomorpha (i.e. Cetacea + Hippopotamidae), a clade including Ruminantia and Oreodontoidea is the sister-group to Whippomorpha, and Perissodactyla is the sister-group to Cetartiodactyla. In the stratocladistic analysis, we found fewer most parsimonious trees, which in most respects were congruent with a subset of the shortest trees for the intrinsic dataset. Our stratocladistic analysis supports species of *Diacodexis* as the most basal cetartiodactyls; a monophyletic Tylopoda that includes Protoceratidae; and Suina, Entelodontidae, *Amphirhagatherium*, and Anthracotheriidae in a clade of suiform cetartiodactyls. Anthracotheres do not appear to be closely related to hippopotamids, and either Cetacea or Raoellidae + Cetacea is the sister-group to Hippopotamidae. Thus the ghost lineage for Hippopotamidae is still 39 million years long.

10:00 **BREAK**

10:15 **Lihoreau, F. and Boissarie, J.-R.: WHERE DO HIPPOS COME FROM: ANTHRACOTHERES OR PECCARIES?**

LIHOREAU, Fabrice, BOISSERIE, Jean-Renaud, Laboratoire de Geobiologie, UMR CNRS 6046, Poitiers, France

Since the 18th century, the phylogenetic affinities of hippos have been widely disputed but never firmly identified, due to their unique and homogeneous morphology within the order Artiodactyla. The “classic” hypotheses include an origin among suids, cebochoerids, and anthracotheriids. In the 1980’s, several authors advocated for the latter. At the same time, a “tayassuid hypothesis” was founded on the basis of the discovery of the oldest known hippopotamid, *Kenyapotamus* (middle Miocene, Africa), and of anatomical resemblances between modern peccaries and hippos. This hypothesis proposed that hippos derived from a fossil lineage including *Kenyapotamus* and two presumed Old World tayassuids, *Xenohyus* and *Doliochoerus*, from the early Miocene and the middle Oligocene respectively.

We reviewed the characters used to support each of the two hypotheses and performed a more detailed anatomical study. Unlike many of previous studies, primitive Mio-Pliocene hippos were included in the comparative sample. We found that the “tayassuid hypothesis” is based mostly on convergences between modern forms, erroneous observations, and lack of consideration for the derived characters shared by tayassuids and suids. The relationships proposed between *Doliochoerus*, *Xenohyus* and *Kenyapotamus* are based on particularly weak evidence. Many primitive and, especially, convergent characters were also used to support the “anthracotheriid hypothesis”. However, it is not possible to recognize synapomorphies of anthracotheriids that would exclude them from hippo ancestry. Moreover, some features indicate that hippos could have derived from some Bothriodontinae.

In the context of molecular phylogenies consistently supporting a clade regrouping cetaceans and hippos, and of archaeocetes showing unequivocal artiodactyl traits, the results of this study should encourage further exploration of the relationships between early cetaceans and basal anthracotheres.

10:30 **Boisserie, J.-R.:** MIO-PLIOCENE AFRICAN HIPPOPOTAMIDAE (MAMMALIA, CETARTIODACTYLA): A RE-EVALUATION OF THEIR PALEODIVERSITY, AND ITS IMPLICATIONS FOR THE PHYLOGENY OF THE FAMILY

BOISSERIE, Jean-Renaud, Laboratory for Human Evolutionary Studies, Berkeley, CA

In relation with their semi-aquatic way of life, hippopotamids are abundant and often well preserved in the Mio-Pliocene sites of Africa. However, because of their large size and a high morphological variability, the taxonomy and phylogeny of hippos received less consideration than other abundant and ecologically significant African mammals. During the last ten years, the Mission Paleoanthropologique Franco-Tchadienne and the middle Awash research project conducted - in the Djurab desert, Chad, and in the Afar region, Ethiopia respectively - field research that considerably increased the fossil record of African hippos: nine different Mio-Pliocene hippopotamids were found, including four new species (two in Chad, two in Ethiopia).

On the basis of this re-evaluated paleodiversity, the phylogeny of the family was reviewed. A cladistic analysis was performed on 37 cranial and dental characters for 15 fossil and extant taxa. It was completed by a biometric analysis of mandibular symphysis shape and proportions, as well as by a landmark-based geometric morphometric study of the basicranium. This work led to the identification and description of several clades of African Neogene hippos that originated during the late Miocene. They include endemic lineages that evolved in central Africa, Arabia and eastern Africa, Turkana basin and Afar basin respectively. The hippos from southern Asia constitute also an independent lineage with two probable Mio-Pliocene representatives in Africa (Chad and Ethiopia). The unique morphology of the extant Liberian hippo indicates that it belongs to a particularly ancient clade, but with no fossil record. The basal relationships between these lineages are still imperfectly understood. As a consequence, major taxonomic changes are proposed, including at least two new genera, the recognition of the genus name *Choeropsis* for the extant Liberian hippo, and the restriction of the nomen *Hexaprotodon* to the Asian clade and its African representatives. These changes create a favourable context to conduct accurate studies of the paleoecology and paleobiography of the Hippopotamidae.

10:45 **Prothero, D.:** HEADLESS GIANTS, DWARFS, AND SHORT-FACED RHINOS FROM THE ARIKAREEAN OF NORTH AMERICA

PROTHERO, Donald, Occidental College, Los Angeles, CA

Until recently, more than a dozen invalid species for Arikareean rhinos were still in the literature, but most of these have now been synonymized with the common Arikareean species, *Diceratherium armatum*, *D. niobrarense* and *D. annectens*. However, the riches of the Frick Collection yield rare specimens of additional undescribed taxa which increases Arikareean rhino diversity. These include: 1) postcrania (but no skull or jaws) of a huge rhinoceros (probably an undescribed diceratherine) known from Horse Creek and 77 Hill Quarry in eastern Wyoming; 2) a dwarfed new genus and species with peculiar parasagittal crests from the base of Roundhouse Rock, Nebraska; 3) another new genus and species with unusually short face, known only from a mandible from Harris Ranch, Fall River County, South Dakota; 4) the dwarfed but isolated teeth of *Gulfoceras westfalli* from the Toledo Bend l.f. on the Gulf Coast of Texas. These rare specimens more than double the diversity of Arikareean rhinoceroses, so their diversity is changed from only one genus (*Diceratherium*, with *Menoceras* arriving at the end of the Arikareean) to levels comparable to that of the Hemingfordian (as many as 7 genera and 9 species)

and the Chadronian (at least 5 genera and 6 species). These discoveries show that even with a group as well sampled as rhinoceroses, there are new surprises when large sample like that of the Frick Collection are studied in detail.

11:00 **Biasatti, D., Wang, Y. and Deng, T.:** PALEOECOLOGY OF THE CENOZOIC RHINO FAUNA OF LINXIA BASIN, GANSU, NW CHINA, FROM CARBON AND OXYGEN ISOTOPES IN TOOTH ENAMEL

BIASATTI, Dana, WANG, Yang, Florida State Univ., Tallahassee, FL; DENG, Tao, Chinese Academy of Sciences, Beijing, China

Cenozoic localities in the Linxia Basin have yielded an abundance of well-preserved rhino fossils, ranging in age from 30 to 2.5 Ma and include individuals from 12 genera within the families Hyracodontidae and Rhinocerotidae. Stable carbon and oxygen isotopic compositions were determined for 49 individuals of these genera in order to examine paleodiet and ecology. First, three general conclusions were made regarding paleodiet and environmental change: 1) The  $\delta^{13}\text{C}$  values of tooth enamel from all individuals indicate a primary diet of  $\text{C}_3$  browse and/or  $\text{C}_3$  grasses; 2) The carbon isotope compositions of all rhinos suggests that the Linxia Basin was a savannah or a mixed woodland/ $\text{C}_3$  grassland biome from the early Oligocene to the late Pliocene; and 3) The  $\delta^{18}\text{O}$  values of the rhino tooth enamel for all individuals suggest that the climate in the area had not been stable from 30 to 2.5 Ma. Secondly, three more specific conclusions were drawn from this study: 1)  $\delta^{13}\text{C}$  values suggest a generalized feeding habit for *Alicornops*, whereas *Parelasmotherium* was found to have a more specialized diet. This was expected, given that *Parelasmotherium* had the most specialized dentition of all perissodactyls. *Chilotherium* was found to be a specialist at two time intervals, and a mixed feeder at three time intervals; 2) *Allacerops* and *Indricotherium* coexisted at 30 Ma and their average tooth enamel  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  values suggest that *Indricotherium* was more restricted to a closed habitat. Because *Indricotherium* was very large, it probably required a shaded or wet habitat to keep its body cooled; and 3) *Chilotherium* and *Dicerorhinus* coexisted at 6 Ma and isotopic analyses suggest that *Chilotherium* and *Dicerorhinus* shared similar feeding habits. *Dicerorhinus* dentition suggests it was a browser, and although *Chilotherium* had adaptations for grazing, it has been suggested that *Chilotherium* was not a true grazer. Isotopic results suggest that *Chilotherium* was a browser.

11:15 **Bartley, K.:** A TAPHONOMIC STUDY OF CLARENDONIAN (MIOCENE) *TELEOCERAS* (PERISSODACTYLA, RHINOCEROTOIDEA) FROM THE OGALLALA FORMATION NORTHWESTERN KANSAS

BARTLEY, Katherine, Univ. at Buffalo, The State Univ. of New York, Niagara Falls, ON, Canada

Several quarries from the Ogallala Formation in northwestern Kansas have yielded numerous Miocene fossil assemblages. The major constituent of these quarries is *Teleoceras*, a short-legged, barrel-bodied rhinocerotid. A particular site near Oberlin, Kansas has merited scientific interest due to its composition of juvenile *Teleoceras* bones and the unusual nature of their orientation. Sediment analysis and osteological examination were conducted as two phases of a taphonomic investigation of this fossil assemblage.

Over 100 identifiable and mappable specimens have been recovered from the quarry, with a minimum number of two individuals. The two *Teleoceras* individuals recovered from this site include a 5 month old calf and a 1.5 year old infant. Canine impressions, gnawing and crushing visible on several bones suggests the occurrence of predation and scavenging. The bones are not clearly current oriented but the degree of inclination shows great variability with many bones plunging more than 60 degrees. Sieve analysis of the sediment indicates that the majority of the sediment is granule-sized (0 Phi and



larger) and consists almost entirely of clay-sand aggregates (clay balls). This suggests a strong debris flow event responsible for fossil distribution.

Possible explanations for bone accumulation at this quarry include: 1, disease affecting young *Teleoceras*, or 2, predation and scavenging of young *Teleoceras*. Deposition at this quarry was likely due to accumulation of sediment during a debris flow, integrating neighbouring individuals, each consisting of a separate taphonomic history.

11:30 **Colbert, M.:** SPECIES DETERMINATION IN THE FOSSIL RECORD: INTERPRETING PATTERNS OF VARIATION IN EOCENE TAPIROIDS FROM SOUTHERN CALIFORNIA

COLBERT, Matthew, Univ. of Texas Austin, Austin, TX

The referral of specimens to, and establishment of, particular fossil species is often operationally and theoretically problematic. Operationally, fossil species are typically based on small samples comprising fragmentary skeletal remains. These data must account for both geographic and temporal patterns of variation. Theoretical difficulties arise from the numerous and varied definitions applied to the species category. Many of these definitions use criteria that cannot be observed in fossil samples (e.g., interbreeding), and that conflate operational and theoretical concepts. Here, the merits of referring dental, cranial and postcranial remains of Uintan (middle Eocene) tapiroids from southern California to particular species are evaluated using criteria consistent with the general lineage species concept, which considers species to be segments of population lineages. These criteria include identified apomorphies, and statistical estimation of similarity and variability between, and within samples.

The samples document a tapir that, although much smaller in size, shares many derived similarities with the early Oligocene *Protapirus*. Among these is a retracted nasoincisive incisure, which is considered an indicator of prehensile proboscis development. The quantity and quality of these discoveries permits statistical comparison using both student's t-tests and an analysis of the coefficient of variability (CV) to assess the taxonomic and evolutionary import of different samples and combinations of pooled samples. These statistical analyses lead to confident referral of late Uintan material to a single species but indicate that early Uintan samples cannot confidently be referred to a single species. Accordingly, most of the early Uintan samples are referred to a second species, with the exception of one sample of uncertain taxonomic status. Although several evolutionary scenarios are consistent with these patterns of variability, they are most parsimoniously explained as having resulted from a cladogenetic speciation event.

11:45 **Eberle, J.:** AN ARCTIC 'TAPIR' AND IMPLICATIONS FOR NORTHERN HIGH-LATITUDE PALEOBIOGEOGRAPHY

EBERLE, Jaelyn, Univ of Colorado Boulder, Boulder, CO

A new 'tapir' from early Eocene-aged (i.e., Wasatchian) strata of the Margaret Formation, Eureka Sound Group, Ellesmere Island represents the northernmost known occurrence of tapiroids and provides insight into northern paleobiogeography. The Arctic tapiroid bore a relatively enlarged nasal incision, as in *Helalestes* and *Colodon*. Furthermore, phylogenetic analyses of dental and some cranial characters group the Arctic tapiroid with North American middle Eocene-Oligocene-aged *Colodon* and middle Eocene-aged, Asian taxon *Irdinolophus*, all three of which are more derived than the early middle Eocene-aged (i.e., Bridgerian) *Helalestes nanus*. In addition to the paleobiological implications, the Ellesmere 'tapir' infers that relatively advanced tapiroids appeared earlier at northern high latitudes than at mid-latitudes, and supports existence of a high-latitude land bridge and dispersal route between North America and Asia during early Eocene time.

12:00 **Mihlbachler, M.:** TAXONOMIC DIVERSITY OR SEXUAL DIMORPHISM? TOWARDS A RATIONAL TAXONOMY OF NORTH AMERICAN LATE EOCENE BRONTOTHERIIDAE  
MIHLBACHLER, Matthew, American Museum of Natural History, New York, NY

Although brontotheres are taxonomically diverse and range through the Eocene, the bulk of their record, in terms of fossil abundance, is concentrated in late Eocene (Chadronian) deposits that contain classic taxa such as *Menodus*, *Megacerops*, and *Brontops*. Due to the poor field methods and dubious taxonomic practices of early paleontologists, an unrealistic number of 47 Chadronian brontothere species had been named by 1929, most of them based on differences in the size and shape of the frontonasal horns. In other respects, Chadronian brontotheres are less variable. Since 1929, attempts have been made to explain higher-level Chadronian brontothere diversity (genera) but without reevaluating species-level taxonomy or phylogeny. To gain an understanding of the morphologic diversity of this group, hundreds of adult skulls and mandibles from numerous museum collections were examined. Most metric variables, such as tooth row length, yield coefficients of variation (CVs) between 10-14, indicating a degree of size variation only moderately greater than that typical of extant mammalian species. However, metric variables relating to the size of the horn and the thickness of the zygomatic arch yield extremely high CVs, ranging between 32-63. Structures such as horns are typically sexually dimorphic in ungulates. For comparison, size variation was quantified in adult crania of two sexually dimorphic horned ungulates, the giraffe and an extinct rhino, *Menoceras arikarensense*. The magnitude of size variation in the sexually dimorphic structures is extreme, with CVs ranging up to 51. However, non-dimorphic variables such as tooth row length consistently yield CVs less than 10. The disparity in the magnitude of size variation between dimorphic and non-dimorphic structures among sexually dimorphic species, a pattern similar to that of Chadronian brontotheres, strongly suggests that the most of the cranial variation in Chadronian brontotheres is related to sexual dimorphism rather than taxonomic diversity. Based on these results, the vast majority of Chadronian brontothere specimens probably belong to one or a few sexually dimorphic species.

12:15 **Janis, C., Errico, P. and Mendoza, M.:** MORPHOLOGICAL INDICATORS OF CURSORIALITY IN EQUIDS: LEGS FAIL TO SUPPORT THE “ARMS RACE”

JANIS, Christine, Brown Univ., Providence, RI; ERRICO, Paul, Univ. of Rhode Island, North Kingston, RI; MENDOZA, Manuel, Brown Univ., Providence, RI

Previous work by the senior author examined the coevolution of the relative limb length (metatarsal/femur ratio) in carnivores and ungulates. The conclusion was that cursoriality in ungulates could not have been primarily evolved for speed for predator escape (the classic “Arms Race” hypothesis), as the evolution of long-legged ungulates predated that of longer-legged carnivores by some 20 million years. The alternative suggestion was made that longer limbs were initially evolved for efficiency at slow gaits, perhaps for foraging demands with changing climatic conditions. If longer legs were primarily for more efficient walking (i.e., longer strides), the evolution of long distal limb segments should be decoupled from, and should predate, other morphological indices of cursoriality. Such other features are those that involve lightening of the distal limb, or more restricted articulation of the limb joint surfaces; both types of features are associated with the cost and speed of recycling the limbs at higher speeds rather than simply increasing the stride length.

To test this hypothesis we measured features of limb morphology from associated hindlimbs of equid species housed in the AMNH. Discriminant analysis showed that derived equids (Equinae) could be distinguished from more primitive ones (Anchitheriinae and Hyracotheriinae) by the size of the distal femoral condyles in relation to the width of the patellar groove, and by the relative width of the distal tibia. Both features indicate a relatively lightened lower limb, more restricted to parasagittal motion.

Anchitheriines and hyracotheriines could not be distinguished from each other. Equines are also more derived in the loss of the distal ulna and fibula, and the acquisition of distal metapodial keels. However, longer metatarsals were acquired within the Anchitheriinae, rather than at the junction between Anchitheriinae and Equinae. These results show that, at least in the case of equids, limb lengthening occurred before other cursorial adaptations of the limbs, supporting the hypothesis that cursorial adaptations are initially related to increasing locomotor efficiency at slow gaits.

**FROM CUSPS TO QUARRIES TO CONTINENTAL CATASTROPHES:  
VISUALIZING SPATIAL AND TEMPORAL PALEONTOLOGICAL  
ELEMENTS IN A DIGITAL ENVIRONMENT  
GOVERNOR'S SQUARE 14  
CONVENOR: PENNILYN HIGGINS**

8:00 **Welcome and Introduction**

8:15 **Turner, L., Chadwick, A. and Spencer, L.: USING ROCKET SCIENCE TO STUDY ROCK SCIENCE**

TURNER, Lawrence, CHADWICK, Arthur, Southwestern Adventist Univ., Keene, TX; SPENCER, Lee, EHRC, Running Springs, CA

The Global Positioning System (GPS) has become a standard method of locating one's position on the earth. The modern paleontologist who hopes not to become extinct must be familiar with this technology. While it is not necessary to be a GPS expert, it is useful to understand how GPS works and how current paleontological research can be enhanced by utilizing this increasing indispensable tool.

The handheld GPS units are quite inexpensive and serve to determine locations to within 5 m. While this is satisfactory for recording a general location, it cannot be used for the precise determinations needed in a fossil quarry. Fortunately, standard high-precision surveying GPS equipment is available that has a precision of less than 1 cm. To achieve the spectacular results that GPS is capable requires the application of modern technology and physics. The simple handheld units use Einstein's General Theory of Relativity!

The GPS utilizes a constellation of satellites in half-sidereal day orbits transmitting information on two frequencies. The data is encoded in such a way that the distance to each satellite can be computed using a simple passive receiver with an inexpensive clock. The detection and capture of four satellites permits the computation of the clock error and the location of the unit in three-dimensions.

The use of two frequencies permits correcting for the major effects of the variable propagation delay of the signals as they pass through the ionosphere. Utilizing a base station with a known location that receives the satellite information and transmits corrections to a rover unit that is simultaneously receiving data from the same set of satellites provides a more precise location of the rover. Applying phase information of the carrier frequencies finally permits the desired sub-centimeter precision.

While this equipment was designed for high-precision surveying problems and is typically used for obtaining surface topology, the precision achieved allows the measurement of individual fossils. The location data is recorded and saved in a digital format that permits direct input into GIS software for analysis and display.

8:30 **Chadwick, A., Turner, L. and Spencer, L.: FIVE YEARS EXPERIENCE USING GIS FOR DATA COLLECTION AND ANALYSIS IN AN UPPER CRETACEOUS DINOSAUR QUARRY IN THE LANCE FORMATION**

CHADWICK, Arthur, TURNER, Lawrence, Southwestern Adventist Univ., Keene, TX; SPENCER, Lee, EHRC, Running Springs, CA

We have pioneered techniques for data analysis using GPS-based GIS analysis in an active dinosaur quarry site in the Upper Cretaceous Lance Formation in eastern Wyoming. After five years, massive amounts of spatial data have been accumulated, necessitating the development of methods of analysis

for handling these data. We are currently able to display the data for successive years as composite georeferenced images, without losing the ability to display bones individually by type or by vertical distribution within the quarry. We will describe and illustrate these techniques.

Field and post-field analysis using the GPS/GIS tools have enabled us to determine that the bone bed is contained in a single mudstone unit dominated by the disarticulated bones of Edmontosaurus, with smaller contributions from Triceratops and other ornithischian dinosaurs, and Nanotyrannus, Tyrannosaurus, and other smaller theropods. The bed exhibits a three degree regional dip to the west. The deposit accumulated as a massive graded bed over an area of at least a square kilometer. Densities of 20 to 30 bones per square meter are common. Several estimates based on the distribution of individual skeletal elements in the areas quarried suggest as many as several thousand individual dinosaurs may have been represented in the deposit.

Aerial distribution of bones by type or by species can be generated in the computer, permitting a variety of taphonomic analyses to be carried out. The distribution of individual skeletal elements appears to be random across the four quarry sites for which we have extensive data. Analysis of the vertical distribution reveals the bones are normally graded, and shows a pervasive and curious sorting by bone type that may be explainable in terms of different bone densities. Many other kinds of analyses critical to taphonomic studies are now possible from the computer console.

8:45 **Wright, J., Thomas, D. and Hansen, R.: USING HIGH RESOLUTION GPS TO MAP DINOSAUR TRACKSITES**

WRIGHT, Joanna, THOMAS, Deborah, HANSEN, Richard, Univ. of Colorado - Denver, Denver, CO

Geo-technologies (geographic information systems (GIS), global positioning systems (GPS) and remote sensing) have a variety of applications in earth science, geology, and paleontology. Recent projects in paleontology have implemented these technologies in resource management, to create inventories of sites, as well as to support museum education and research.

Small hand held GPS units are now used extensively for recording the location of paleontological sites; these have an accuracy of a few meters horizontally. Survey-grade GPS units, however, are accurate to within a few centimeters horizontally and vertically. These high resolution GPS units were used to map two dinosaur tracksites in the western US. One site was mapped conventionally several years ago and so the GPS generated map forms a comparison with the previously published map. This site had the added complication of being preserved on a steep slope so that the recorded GPS data had to be rotated to a horizontal plane to produce a map of the surface. The second site was mapped for the first time with GPS.

At each site, GPS data were recorded for two purposes. The first outlined the footprints and the second recorded specific points on the footprint which could be used to measure trackway parameters such as lengths of footprint, pace and stride. Recording the footprint outline provides a separate accuracy check because significant aberrations would be obvious in the outline. The points along the outline can also be used to quantitatively compare the shapes of footprints within a trackway. In addition, digital photographs were taken of every footprint. These can then be added as a third layer in the GIS and georeferenced to other existing data such as aerial photographs. Using this method to map tracksites takes less time than conventional methods, is considerably more accurate and generates data which can be used in more widespread comparisons.

9:00 **Matthews, N., Noble, T. and Breithaupt, B.: A QUEST FOR CONTROL; INVESTIGATING TECHNIQUES FOR COLLECTING 3-D DATA ON DINOSAUR TRACKS AND BONES**

MATTHEWS, Neffra, NOBLE, Tommy, USDOJ Bureau of Land Management, Denver, CO; BREITHAUPT, Brent, Univ. of Wyoming, Laramie, WY

Geographic Information Systems allow for the integration, visualization, management, analysis, interpretation, and presentation of a variety of paleontological data. All types of observations collected about a specimen, a locality, a rock unit, a state, or any other type of geographic container can be integrated using GIS. Complex relationships such as the concentration, orientation, and location of bones in a quarry or the tracks of dinosaurs can be documented and evaluated as never before. The use of GIS is strengthened as the tools used to locate ourselves on the earth's surface evolve, making our maps easier to produce and update.

Yet a GIS is only as accurate as the x, y, z coordinate points (which represent each piece of data) it is built upon. There are a variety of excellent techniques for establishing coordinate data for a project. These techniques range from the use of high-tech equipment such as Global Positioning Systems, and Light Detection and Ranging (LIDAR) to more traditional methods, such as compass and string-line grid, total station, and traditional aerial photogrammetry. Each of these methods presents the user with a variety of challenges and benefits based on site location, extent, accessibility, expense, and operation time. Research conducted over the past six years at Late Jurassic bonebeds in Wyoming and Utah, as well as Middle Jurassic and Late Cretaceous dinosaur tracksites in Wyoming, Colorado, and Utah have utilized a variety of these techniques. However, the challenge remained to establish a control network (accurate to the millimeter level) over small areas quickly, easily, and affordably. Fortunately, with the recent development of relatively inexpensive, high quality digital cameras and a suite of software that calculates measurements and constructs 3-D models from photographs, this challenge has been met. Highly accurate 3-D coordinates can be extracted from photographs when a few basic guidelines are observed. These photographs not only support precise measurements in a digital setting, but also preserve a visual record of the in-situ relationships for future study and analysis.

9:15 **Jones, R. and Ambrose, P.:** RADIOLOGICAL SURVEY OF DRY MESA QUARRY OF COLORADO, TO EVALUATE THE AMOUNT AND LOCATION OF SUBSURFACE FOSSIL BONE REMAINING IN THE QUARRY

Jones, Ramal, Castle Dale, UT; Ambrose, Peter, USDA Forest Service, Delta, CO

The Dry Mesa Quarry has been excavated almost continuously since it was discovered in 1971. At the request of US Forest Service personal operating the quarry, a radiological survey was conducted in July of 2002. The survey was conducted to determine the amount of bone remaining in the quarry and map the bone's locations. The radiological survey instrument used, was the same instrument that was developed and patented by the author.

Preliminary readings taken on previously excavated vertebrae, determine that the fossil bone had concentrated enough uranium for the survey instrument to distinguish them from uranium in the surrounding soil. The radiological survey provided a radiological map of the quarry showing the amount of bone remaining in the quarry and its locations. The author has surveyed other quarries that were essentially abandoned and found that there was still buried bone remaining in the quarries.

9:30 **Smith, Jennifer., Smith, Joshua, Lacovara, K. and Lamanna, M.:** THE USE OF DGPS AND GIS IN COLLECTING, MANAGING AND ANALYZING EXCAVATION AND TAPHONOMIC DATA: EXAMPLES FROM EGYPT, WYOMING, AND THE CANADIAN ARCTIC

SMITH, Jennifer, SMITH, Joshua, Washington Univ., St. Louis, MO; LACOVARA, Kenneth, Drexel Univ., Philadelphia, PA; LAMANNA, Matthew, Univ. of Pennsylvania, Philadelphia, PA

The coupling of differential GPS and GIS into an integrated system for acquisition, analysis, and visualization of spatial data has generated a powerful and efficient tool applicable to numerous facets of paleontological research. Use of this technology at localities in vastly different modern environments (the Cenomanian Bahariya Fm, Egypt, the Eocene Buchanan Lake Fm, Axel Heiberg Island, Canada, and the Lance Fm, Wyoming) has illuminated several of its broadly useful aspects. The submeter precision of DGPS is critically important in regions where topographic base data is either absent or of a resolution too low to resolve the necessary detail. The DGPS can also be used to rapidly generate accurate stratigraphic columns, making possible high-resolution stratigraphic correlation of thin strata. While DGPS precision may not be great enough to map small, closely spaced elements, it can be used to identify control points which tie quarry maps into a larger spatial context. Mapping of quarry limits from year to year can identify changes in fossil yield (specimens per unit volume sediment); this data can guide future excavation in the most productive direction. Once spatial data has been collected, GIS permits automated or semi-automated collection of standard taphonomic data such as 2-dimensional orientations of elements, bone density distribution, and degree of articulation. In addition, landscape-scale distributions of fossil localities identified through pedestrian prospecting can be partially corrected for observer bias using digital elevation model based estimates of terrain ruggedness. The efficiency of any given prospector can be determined for terrains of varying ruggedness by evaluating his/her performance on a landscape segment with a known fossil distribution. Finally, slope stability analyses of the terrain in which fossils are found can be used to identify localities most in danger of imminent erosion, and thereby set priorities for excavation.

9:45 **Murphey, P. and Matthews, N.:** GEOLOGIC MAPPING AND FOSSIL DISTRIBUTION STUDIES IN THE BRIDGER FORMATION (MIDDLE EOCENE), SOUTHWESTERN WYOMING: A PROGRESS REPORT

MURPHEY, Paul, SWCA Environmental Consultants, Mission Viejo, CA; MATTHEWS, Neffra, Bureau of Land Management, Denver, CO

Detailed stratigraphic work and geologic mapping in the fluvial and lacustrine Bridger Formation has resulted in a high resolution stratigraphic and temporal framework for the positioning of fossil sites, as well as the production of 1:24,000 scale bedrock geologic maps for an approximately 1,000 square km area of the southern Green River Basin in Wyoming. Thousands of fossils from hundreds of sites have been georeferenced. We present our methodology for developing the stratigraphic framework and producing the geologic maps within a GIS, as well as our ongoing efforts to document the distribution of fossils in the upper part of the formation (Twin Buttes Member). In combination with  $^{40}\text{Ar}/^{39}\text{Ar}$  dates obtained from ash fall tuffs, and sedimentologic and taphonomic data, one of the purposes of our growing geospatial fossil distribution database is to test hypotheses regarding rates of sedimentation and the characteristics of Eocene depositional environments of the Green River Basin. Preliminary results are presented.

10:00 **BREAK**

10:15 **Corsini, J., Smith, T. and Leite, M.:** FOSSIL DENSITY IN THE WHITE RIVER GROUP, WESTERN NEBRASKA: CLUES TO TAPHONOMY AND PALEOECOLOGY

CORSINI, Joseph, SMITH, Toni, LEITE, Michael, Chadron State College, Chadron, NE  
Systematic collecting of fossil turtles and associated taphonomic data from the White River Group (Chadronian through Whitneyan) was undertaken as part of a long-term paleoecological and evolutionary study in the Nebraska badlands. The study encompasses the Peanut Peak and Big

Cottonwood Creek members of the Chadron formation and the Orella and Whitney members of the Brule Formation. Geographic information systems (GIS) aided by Global Positioning System (GPS) data collection were employed to derive estimates of fossil density. Maps generated from GPS track data provided useful documentation of prospected area, and were used to quantify the prospected surface area (and the related rock volume) on steep Whitney and Orella slopes. This surface area information was used to analyze stratigraphic variation in fossil density in 10 meter stratigraphic intervals as a function of the total outcrop area sampled. Analysis of variance results from 3 systematic transects through the Lower Whitney ash indicate that the 10 meter intervals exhibit significant differences in turtle density at a confidence level of 0.15 (85%). These estimates of stratigraphic fossil density change will eventually be incorporated into models of evolutionary and ecological change through time.

10:30 **Sagebiel, J., Springer, K., Austin, C. and Scott, E.:** THE USE OF GIS TECHNOLOGY TO CHARACTERIZE FAUNAL CHANGES THROUGH TIME AND SPACE ACROSS A DEPOSITIONAL BASIN

SAGEBIEL, James, SPRINGER, Kathleen, AUSTIN, Chris, SCOTT, Eric, San Bernadino County Museum, Redlands, CA

Seven years of uninterrupted field investigations in the Diamond and Domenigoni Valleys of Riverside County, California yielded the discovery and collection of more than 2700 discrete fossil localities. This dataset covers more than ten square miles with the majority of sites sampling a temporal range of 50000 to 10000 ybp. Geographic locality data were recovered via several methods, including direct on-site GPS survey, and field map plots. All data were compiled into a single computerized database that is accessible to an array of GIS software including ARCGIS, ARCVIEW Spatial Analyst and 3-D Visualization software. These tools enable the researcher to spatially enable the data, allowing one to visualize the dataset in a way that is simply not available through traditional methods. The integration of existing specimen and locality database information with GIS software allows complex queries in a geographic framework. Geological data is readily integrated with species distribution data to create taphonomic information that would be otherwise impracticable to obtain.

Faunal analyses typically include interpretations of the paleoenvironment based upon taxonomic composition and depositional setting. The accuracy and precision of this data is generally extrapolated from the fidelity of modern species distributions to habitat characteristics. This broad dataset presents a rare opportunity to assess the power of faunal data from open sites to resolve questions relating to the paleoenvironment. Using standard GIS tools with the existing database of sites and specimens, we can construct queries that begin to address this issue. By comparing taxonomic distributions from widely separated, but stratigraphically equivalent localities, one can begin to place some confidence limits on taxa as environmental proxy data.

10:45 **Higgins, P.:** MODELING CLIMATE AND VEGETATIONAL CHANGE SINCE THE LAST GLACIAL MAXIMUM USING STABLE ISOTOPES AND DIGITAL ANALYSIS

HIGGINS, Pennilyn, Univ. of Florida, Gainesville, FL

We are interested in understanding patterns of climate and vegetation change throughout North America since the Last Glacial Maximum (LGM) using stable isotopes from the tooth enamel of fossil grazers. Data collection involves selecting appropriate specimens (for which latitude, longitude, and age in years before present are known) from museum collections, analyzing them, and cataloging the results into a large database. Simple graphs, such as plotting  $\delta^{13}\text{C}$  values by latitude for a given range of dates, can be plotted easily from the database with spreadsheet software. For a project involving such a broad geographical area, it is informative to plot data according to latitude and longitude over a base map of



North America, and, through the use of Geographical Information Systems (GIS), apply color-coded contours to illustrate geographical changes in isotopic values.

Examples will be presented for localities in western North America ranging in age from 26ka to modern. Values of  $\delta^{18}\text{O}$  are contoured to show overall patterns of temperature, whereas patterns of  $\delta^{13}\text{C}$  are contoured to show overall patterns of abundance of C3 vs. C4 vegetation. The mathematical algorithms within the GIS used to create the contours are limited by the density and accuracy of data points available, making it clear where additional data points are needed. The effects of combining data from various taxa or considering each taxon by itself are also obvious when examining contoured maps. However, the overall patterns agree with previously published research based upon different datasets. Visualization of isotopic data in the GIS environment clarifies geographical patterns of isotopic change and helps direct further research toward filling gaps that appear during study.

11:00 **Deblieux, D., Kirkland, J., Butler, M., Hayden, M. and Titus, A.:** DEVELOPING RESEARCH AND MANAGEMENT TOOLS FOR PALEONTOLOGY AT GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT (GSENM) AND OTHER PUBLIC LANDS IN UTAH: USING COMPUTERS TO MANAGE DATA AND EXPLORE PATTERNS IN THE DISTRIBUTION OF FOSSILS AND PALEOENVIRONMENTS

DEBLIEUX, Donald, KIRKLAND, James, BUTLER, Matt, HAYDEN, Martha, Utah Geological Survey, Salt Lake City, UT; TITUS, Alan, Grand Staircase-Escalante National Monument, Kanab, UT

The Utah Geological Survey (UGS) has been using Geographic Information Systems (GIS) analysis to investigate paleontological resources on public lands throughout Utah. Our investigations include ground surveys conducted using standard paleontological prospecting techniques and hand-held GPS units to record localities. Locality data are entered into the digital State Paleontological Database that is being created at the UGS in cooperation with the Bureau of Land Management (BLM). The information in the database can be easily accessed, the data can be queried and sorted in a multitude of ways to address specific research and management questions, and maps can be created using GIS software. We have also been integrating existing digital geologic maps produced by the UGS to generate paleontological sensitivity maps using GIS. We have developed this type of map for public lands in Utah, for which we assign sensitivity levels to the different geologic units based on the type and distribution of fossils. These maps can serve as models for paleontological resource management by aiding land managers in making decisions regarding the protection of fossil resources.

As an example, we present the results of a multiyear project, conducted in cooperation with the BLM, in the Wahweap Formation (lower Campanian) of GSENM. We have used GIS to investigate large-scale trends in the distribution of fossils and paleoenvironments throughout this formation. Our work has resulted in the discovery of hundreds of new localities. Noteworthy among these are cranial and skeletal remains of several Ceratopsian and Hadrosaur dinosaurs. During 2003, multiple dinosaur tracksites were recognized in the middle mudstone member of the Wahweap Formation. These discoveries have greatly supplemented our knowledge of the dinosaurian fauna during this poorly known time interval. In addition to the GSENM project, inventories of other public lands in Utah have resulted in the discovery of dozens of scientifically important vertebrate body fossils and tracksites. The results of these studies are summarized in digital maps created using GIS.

11:15 **Greenhalgh, B., Nolte, M., Lyman, J. and Britt, B.:** INTEGRATION OF DIGITAL MAPS AND DATA TABLES TO FACILITATE TAPHONOMIC EVALUATION OF THE DALTON WELLS DINOSAUR QUARRY (LOWER CRETACEOUS, CEDAR MOUNTAIN FM), UTAH

GREENHALGH, Brent, NOLTE, Mark, Brigham Young Univ., Provo, UT; LYMAN, Jeanette, Univ. of Oxford, Oxford, United Kingdom; BRITT, Brooks, Brigham Young Univ., Provo, UT

New techniques have streamlined the process of creating interactive digital quarry maps and performing taphonomic analysis on large datasets. We applied these techniques in a study of a dinosaurian fauna comprised of 8 dinosaurian genera represented by ~4500 specimens from the Lower Cretaceous Cedar Mountain Fm near Moab, Utah. Manually drawn quarry maps were digitized and augmented with maps of a 40-m-long vertical section of the bone-bearing lithosomes, plus maps of small bone fragments as well as larger bones in test squares (horizontal and vertical) to provide details on bone distribution.

Bones were taphonomically evaluated in the field and data recorded on paper records identical to the database structure for data uniformity and effective recovery/entry. A field record contains 37 fields pertaining to collecting, taphonomy, and significance. Following preparation, field data is tied to specimen catalog, taxonomic, and taphonomic data tables. This database is in turn linked to the digital maps. Results of database queries are depicted visually on the map, making spatial distribution of bones from a specific taxon, shape class (Voorhies Group), taphonomic signature, or any data in the database readily accessible. For example, bone distribution is used to recognize fluvial channels and bone orientation within the channel is used to determine paleo flow direction. Because most specimens recovered from the quarry consist of incomplete and disarticulated bones with a density of 10's of bones/m<sup>2</sup> the digital information is particularly useful in determining bone associations, i.e. individuals.

The vertical map reveals the quarry consists of four stacked fluvial depositional events, the lowest sitting on an unconformable contact between the Cedar Mountain and Morrison Formations. Neither the individual lithosomes nor the formation contact can be discerned without the detailed vertical maps of individual bone fragments.

In addition to using the integrated database/digital map for taphonomic purposes they are especially helpful in the prep lab to determine priorities and decipher field relationships.

## POSTERS ASSOCIATED WITH GIS SYMPOSIUM

Posters must be set up by 8:00 a.m.

Authors will be present from 11:30 a.m. - 12:30 p.m.

Booth #

1. **Beasley, B., Schumacher, B., Peter, A. and Dersch, J.:** USE OF GIS IN MANAGING FOSSILS ON FEDERAL LANDS, THE USDA FOREST SERVICE FOSSIL YIELD POTENTIAL CLASSIFICATION (FYPC) SYSTEM

BEASLEY, Barbara, USDA Forest Service, Chadron, NE; SCHUMACHER, Bruce, USDA Forest Service, LaJunta, CO; PETER, Ambrose, USDA Forest Service, Delta, CO; DERSCH, John, USDA Forest Service, Denver, CO

The Rocky Mountain Region of the USDA Forest Service has actively developed a paleontological program since 1992. In that time, the program has refined a number of management tools used by agency paleontologists for planning purposes. Although the primary functionality of these tools is land management, they also serve a useful role in education and research.

The primary tool employed by the USFS Paleontological Program is the Fossil Yield Potential Classification (FYPC). The FYPC assigns a numerical value to all lands of the National Forest System, including the National Grasslands. The FYPC values indicate the probability of fossil resources occurring, on the surface and in the shallow subsurface. FYPC values are determined primarily by base geologic maps, but other factors are surficial deposits, vegetative cover, topography, and accessibility.

GIS is used to combine all of this information and produce FYPC maps. Maps are produced at the finest resolution possible, usually limited to the degree of geologic resolution available. Map scale is variable and is determined by the overall size of a particular Forest or Grassland. These predictive potential maps allow non-specialists to quickly get an overall sense of the paleontological scenario in any particular part of the Forest System. By consulting such maps, planners can qualitatively assess the likelihood that significant paleontological resources will be impacted by land management activities. Likewise, agency paleontologists use the maps to determine prolific fossil areas to target for survey and salvage efforts.

The Forest is in the process of formalizing FYPC efforts across the Rocky Mountain Region. The intent is to produce a widely utilized national model. As we continue to accumulate baseline data about paleontological resources on National Forests, the FYPC system will continue to be refined and updated. Ultimately, the goal of the FYPC system is to establish a permanent cyclical program of survey, salvage, conservation, and law enforcement efforts that provide the maximum preservation and protection to fossil resources on public lands.

2. **Jennings, D.:** PALEOENVIRONMENTAL AND TAPHONOMIC APPLICATIONS OF GEOSPATIAL TECHNOLOGY AT A NEW DINOSAUR QUARRY ON THE WARM SPRING RANCH, THERMOPOLIS, WYOMING

JENNINGS, Debra, Univ. of Kansas Dept of Geology, Lawrence, KS

Juvenile sauropod bones and dozens of shed Allosaurus teeth were recently found preserved in a dinoturbated, carbonate mudstone in the Morrison Formation near Thermopolis, Wyoming. The unusual combination of teeth, bones, and tracks led paleontologists to interpret the site as a record of predation activity, behavior not well documented in the literature.

Traditional mapping methods were initially used at the site but failed to supply adequate chronological constraints on the taphonomy of the assemblage. Consequently, more advanced technology was employed to document geospatial data and create a 3-D map of the quarry. Geospatial

data collected from each element with a Total Station was compiled in new 3-D mapping software. ArcView GIS was used to map outcrops in the immediate area and link corresponding geochemical, ichnological, and sedimentary attributes. Query information from the linked data led to a detailed paleoenvironmental reconstruction.

Synthesized data revealed two distinct bone and track-bearing units in the quarry that were preserved in palustrine-lacustrine deposits during transgressive events. Chronological constraints documented by independent lines of evidence support one near shore scavenging event followed by a regression in a shallow lake system.

The combination of paleontological field methods used in the taphonomic and paleoenvironmental evaluation of this assemblage allows the unique opportunity to compare traditional field methods with innovative technological techniques. Results of this study indicate that technology improves our ability to integrate taphonomic and paleoenvironmental information in complex assemblages and significantly enhance our understanding of paleobiota.

**SATURDAY AFTERNOON, NOVEMBER 6, 2004**

**TECHNICAL SESSION XVII  
PLAZA BALLROOM A/B**

**MODERATORS: THOMAS MARTIN AND ROBIN O'KEEFE**

**1:30 Martin, T. and Averianov, A.: MIDDLE JURASSIC VERTEBRATES FROM KYRGYZSTAN (CENTRAL ASIA)**

MARTIN, Thomas, Freie Universitaet Berlin, Berlin, Germany; AVERIANOV, Alexander, Russian Academy of Sciences, St. Petersburg, Russian Federation

Large areas of the Central Asian terrestrial Mesozoic are still poorly known. One important source of new information is the Middle Jurassic (Callovia) Sarykamyshsai locality within the Balabansai svita near Tashkumyr in the northern Fergana valley (Kyrgyzstan). This locality has yielded a rich vertebrate assemblage consisting of abundant teeth of hybodontid sharks, holostean and teleostean fishes, a dipnoan, a brachyopoid labyrinthodont, a xinjiangchelyid turtle, a possible eosuchian, lizards, pterosaurs, dinosaurs, the goniopholidid *Sunosuchus*, a possible thalattosuchian crocodyliform, dinosaurs, and mammals. In the northern Fergana region, the Balabansai svita is composed of alternating terrestrial to marginal marine sandstones, siltstones, and claystones with rare conglomeratic and marly intercalations. The greyish to reddish claystone sequences contain lenses with concentrations of mainly isolated vertebrate remains that can be recovered by screen washing.

The pterosaurs are represented by isolated teeth of Rhamphorhynchinae indet. and the dinosaurs by teeth of a large theropod (Tetanurae indet.) and a sauropod (Neosauropoda indet., possibly *Ferganasaurus*). A metatarsal I and a first phalanx of the fifth digit can also be attributed to the sauropod. A new pachycephalosaur has been described on the base of teeth that expand the fossil record of this group by 10-20 m.y.

The mammals are represented by a new docodont, *Tashkumyrodon desideratus* Martin and Averianov 2004. Together with *Tegotherium* from the Upper Jurassic of Mongolia and *Siberotherium* from the Lower Cretaceous of Siberia, *Tashkumyrodon* represents an Asian lineage of docodonts that is separate from the Euro-American clade. Additionally to *Tashkumyrodon*, isolated teeth of a yet undescribed smphilestid ("Triconodonta") have been found. A slender premolar and an isolated unicuspid talonid indicate the presence of Holotheria that were unknown from the Middle Jurassic of Central Asia so far.

**1:45 Mueller, J. and Reisz, R.: THE SKULL OF *BELEBEY VEGRANDIS* AND THE PHYLOGENETIC POSITION OF BOLOSOURIDS**

MUELLER, Johannes, REISZ, Robert, Univ. of Toronto Mississauga, Mississauga, ON, Canada

One of the most enigmatic clades of early amniotes is surely the Bolosauridae, an assemblage of small reptiles from Permian strata of North America and Eurasia. Originally known only on the basis of isolated jaw material and fragmentary skulls, the recent discovery of an almost completely preserved bolosaurid skeleton from the Lower Permian of Germany revealed that these animals were apparently very agile little hunters with the ability to run bipedally. Bolosaurids are characterized by a unique dentition, consisting of relatively few teeth that are strongly expanded and with complex crown morphology, suggesting very specialized nutrition habits and the capability for strong dental occlusion. For a long time, the phylogenetic position of bolosaurids remained controversial, but recent investigations indicated that this clade might be nested within the Parareptilia, which would make bolosaurids the currently oldest-known members of this group.

Despite their wide stratigraphic range, the number of bolosaurid taxa is surprisingly low. In total, only three valid genera are currently recognized, *Bolosaurus* from the Lower Permian of Oklahoma and Texas, *Eudibamus* from the Lower Permian of Germany, and *Belebey* from the Upper Permian of Russia and China. The cranial osteology of most of these taxa is only poorly known, but several comparatively well-preserved skulls have been reported for *Belebey vegrandis*, representing the best cranial material so far available.

We present a reinvestigation of the cranial anatomy of *Belebey vegrandis*, which shows that these animals were characterized, among other features, by the development of a secondary palate and the presence of a lower temporal fenestra whose ventral border was exclusively formed by the elongate quadratojugal. These new data are used to incorporate bolosaurids into a phylogeny of early amniotes in order to evaluate their relationships to parareptiles in detail.

2:00 **Fraser, N., Nosotti, S. and Rieppel, O.:** A RE-EVALUATION OF TWO SPECIES OF *TANYSTROPHEUS* (DIAPSIDA, PROTOROSAURIA), FROM MONTE SAN GIORGIO, SOUTHERN ALPS

FRASER, Nicholas, Virginia Museum of Natural History, Martinsville, VA; NOSOTTI, Stefania, Museo Civico di Storia Naturale, Milano, Italy; RIEPPEL, Olivier, Field Museum of Natural History, Chicago, IL

The extraordinarily long-necked protorosaurian *Tanytropheus longobardicus* was originally described on the basis of a number of specimens with an extensive size range from the Grenzbitumenzone (Anisian/Ladinian) of Monte San Giorgio. A second species, *T. meridensis*, was described on the basis of a single specimen from slightly younger (lower Ladinian) strata. A re-examination of all this material indicates the single specimen of *T. meridensis* cannot be distinguished from the smallest specimens of *T. longobardicus*, and it is here included within this taxon. On the other hand, it is possible that there are two separate taxa represented among the Grenzbitumenzone material. In one the premaxilla has a relatively long posterolateral process articulating with the maxilla, and pronounced tricuspid teeth. In the second the posterior process of the premaxilla is short, and the marginal teeth are, at best, only very weakly tricuspidate. While all the largest specimens fall into the second group, there are also smaller examples of this form indicating that the differences may not be ontogenetic, as previously supposed. The occurrence of postcloacal bones in some specimens is indicative of sexual dimorphism.

2:15 **Casey, M., Kowalewski, M. and Fraser, N.:** MORPHOMETRICS AND TAPHONOMY OF *TANYTRACHELOS AHYNIS* FROM THE UPPER TRIASSIC COW BRANCH FORMATION, SOLITE QUARRY, VIRGINIA

CASEY, Michelle, KOWALEWSKI, Michal, Virginia Tech, Blacksburg, VA; FRASER, Nicholas, Virginia Museum of Natural History, Martinsville, VA

The Solite Quarry, Virginia, (Upper Triassic Cow Branch Formation, Dan River Basin) is known for its soft-bodied preservation of insects and abundant, small (<50 cm) aquatic reptiles (*Tanytrachelos ahynis*). The presence of two distinct morphotypes - one with and one without paired heterotopic bones associated with the proximal caudal region - suggests a sexually dimorphic population. The numerous, well preserved, partly-to-completely articulated skeletons occur in two distinct, well-laminated organic-rich cyclic lacustrine horizons separated by ~350 ky. This provides a unique opportunity for a thorough morphometric evaluation of allometric patterns, sexual dimorphism, taphonomic overprints on morphology, and morphological trends through time.

This study combines morphometric and taphonomic methods to study over 200 specimens from two horizons. A total of 30 morphometric variables are analyzed based on linear dimensional measurements of skeletal elements, which are most commonly found articulated (pelvic girdle, hind limbs, and associated vertebrae). The classificatory variables regarding sexual dimorphism (presence/absence of heterotopic bones), extent of weathering, burial orientation (ventral or dorsal), and other taphonomically and anatomically relevant data are also recorded. By combining multivariate morphometric analyses of linear dimensions with taphonomical and biological grouping variables, we aim to (1) identify possible sex-associated skeletal differences; (2) test for the presence of multiple taxa; (3) assess morphometric signatures of taphonomic patterns; (4) recognize and correct for any deformational biases; (5) establish an appropriate proxy for overall (latent) body size (i.e., a commonly preserved, size-correlative, element); (6) compare size distributions across morphotypes and horizons; and (7) assess allometric differences among horizons (heterochrony) and morphotypes (dimorphism/polymorphism).

The analyses should provide rigorous insights into the biology and evolution of this species, as well as help establish guidelines for subsequent morphometric comparisons of this species with other protorosaurs.

2:30 **Nesbitt, S. and Thiessen, K.:** A BIZARRE NEW, BASAL DIAPSID REPTILE FROM THE LOWER MOENKOPI FORMATION (LOWER TRIASSIC) OF NORTHERN ARIZONA

NESBITT, Sterling, Mesa, AZ; THIESSEN, Kenneth, Winzler and Kelly Consulting, Eureka, CA

Fossil reptiles are poorly known from the lower Moenkopi Formation of Arizona. In the mid 1940s, Samuel P. Welles of the Univ. of California Museum of Paleontology discovered a small pocket of fifteen articulated diapsid reptiles in the lower Moenkopi. Because the skeletons are poorly preserved, preparation of most of the specimens did not take place until recently. Here, we present this new taxon and comment on its phylogenetic relationships.

The skull of this new taxon is represented by five specimens. The premaxilla, maxilla, and dentary are edentulous and a system of foramina and fossae on the lateral surface of the premaxilla suggesting the presence of a rampithecium in life. A foreshortened face, large orbits, and large upper temporal fenestra characterize the skull. Ten cervical vertebrae are present, and all are slightly elongated. The limbs are poorly developed, and the foot and hand retain a basal diapsid phalangeal formula. Both dorsal and proximal caudal vertebrae have extremely long transverse processes. The ribs are holocephalous and expand five times their original width distally. The distal ribs overlap each other laterally to form an inflexible flank.

The skeletons represent adults, as all of the vertebrae have closed sutures. Yet many juvenile features are present. For example, the carpals and tarsals have not ossified. This suite of adult and juvenile characters suggests that this new diapsid may be paedomorphic. In addition, the skull is remarkably similar to that of embryonic *Sphenodon punctatus*. The phylogenetic position is difficult to determine because of the poor preservation. However, a basal position among the archosauromorphs is hypothesized.

2:45 **Gottmann-Quesada, A.:** THE EARLY DIAPSID *PROTOROSAURUS SPENERI* MEYER 1856 AND ITS SYSTEMATIC POSITION

GOTTMANN-QUESADA, Annalisa, Institut fuer Palaeontologie Universitaet Bonn, Bonn, Germany

As the first fossil remains of *Protorosaurus speneri* were discovered already in 1706 and published in 1710, it is one of the first fossil reptiles ever having been described. However, its systematic position remains unclear. Most commonly, *Protorosaurus* has been regarded as an early member of the

archosauromorph group Prolacertiformes. However, today the systematics of the Prolacertiformes is discussed controversially, the group either constituting a clade, or forming a grade, or a polyphyletic assemblage.

Although many additional specimens of *Protorosaurus* have been collected during the last 300 years, skull remains are rare. A detailed cranial reconstruction had not been possible due to the incomplete preservation of the only skeleton with an almost complete skull preserved, the holotype. However, the excellent preservation of a second, still undescribed specimen with a skull, found in the Richelsdorfer Mountains (Hesse, Central Germany) in 1972, reveals nearly all cranial sutures.

The analysis of the skull characters gathered from the new specimen, as well as a major revision of the postcranium, the first since 1856, provide crucial information about the taxonomic position of *Protorosaurus*. Although most characters indicate archosauromorph affinities (e.g. the ankle joint), others, such as the lack of the posterior process of the premaxilla, resemble the condition in Lepidosauromorpha. A preliminary analysis, with some postcranial characters not yet revised, put *Protorosaurus* at the base of a paraphyletic Prolacertiformes. *Protorosaurus* hence will provide important clues for resolving interrelationships of the Prolacertiformes.

3:00 **Modesto, S.:** NEW INFORMATION ON THE SKULL OF THE EARLY PERMIAN REPTILE *MESOSAURUS TENUIDENS* AND ITS PHYLOGENETIC IMPLICATIONS

MODESTO, Sean, Univ. College of Cape Breton, Sydney, NS, Canada

Three species of the amniote clade Mesosauridae are currently recognized, but the only the type species, *Mesosaurus tenuidens*, is represented by relatively abundant cranial remains. Redescription of specimens assigned to this mesosaurid clarifies numerous aspects of its skull structure. There is no evidence of temporal fenestration in *M. tenuidens*. The rostrum and the marginal teeth are relatively longer than in other mesosaurids. Marginal tooth orientation changes serially from vertical posteriorly to procumbent anteriorly. The combination of tooth length, tooth orientation, and the narrowly tapering aspect of the alveolar arcade result in an effective bite width that is roughly equivalent to gullet breadth (as inferred from the reconstructed distance between the jaw articulations). The morphology and the organization of the marginal teeth suggests that they were used to capture small, individual prey, rather than for filter feeding. The latter hypothesis was based on the erroneous interpretation that *M. tenuidens* possessed almost double the number of marginal teeth than can be accounted for with the available materials. The new anatomical data permits a reappraisal of several cranial characters that have appeared in phylogenetic analyses of early amniotes. Emendation of these characters and reanalysis of early amniote phylogeny corroborates the hypothesis that Mesosauridae is the most basal taxon of a clade (Parareptilia of some authors) that also includes Millerettidae, Pareiasauria, and Procolophonoidea.

3:15 **BREAK**

3:30 **Wu, X.-C. and Dong, Z.-M.:** A POLYDACTYLOUS SKELETON OF HUPEHSUCHIA (DIAPSIDA) FROM CHINA

WU, Xiao-Chun, Canadian Museum of Nature Dept of Paleobiology, Ottawa, ON, Canada; DONG, Zhi-Ming, Institute of Vert. Paleontol. & Paleoanthropol., Beijing, China

Despite ever increasing knowledge of vertebrate history, new higher-level taxa are still being discovered. One such group, the Hupehsuchia, is characterized by many features associated with an aquatic way of life. The highly specialized morphology of the Hupehsuchia is clearly demonstrated by a recent discovered specimen, SSTM (Shanghai Science and Technology Museum) 5025 comprising a nearly complete skeleton from the upper Lower Triassic of China. The most striking feature of SSTM



5025 is that its limbs have more than five digits (seven in the forelimbs and six in the hindlimbs). Unlike the supernumerary fins of Mesozoic ichthyosaurs or populations in some extant species, these digits are composed of fully-developed carpals/tarsals, meta-carpals/tarsals, and phalanges and clearly display a truly preaxial polydactyly comparable with the current limb developmental model. In overall morphology, the digits of SSTM 5025 resemble those of the earliest tetrapods and are also similar in general shape to the limb-like paired fins of extant frogfishes. These indicate that the limbs of SSTM 5025 may have functioned similarly as in the earliest tetrapods or to the paired fins in frogfishes when moving across underwater substrates. The discovery of SSTM 5025 provides not only a good example of convergence but also a good example of analogy in vertebrate evolution.

The limbs of a second specimen, IVPP (Institute of Vertebrate Paleontology and Paleoanthropology) V4070 (previously referred to *Hupehsuchus*) closely resembles those of SSTM 5025. These specimens may pertain to adults of the *Nanchangosaurus* (the type genus of the Hupehsuchia), but this cannot be certain because of the fragmentary nature of the latter.

3:45 **O'Keefe, F., Sidor, C. and Larsson, H.:** MORPHOLOGY AND ONTOGENY OF THE HINDLIMB OF THE LARGE CAPTORINID *MORADISAURUS GRANDIS*

O'KEEFE, Frank, SIDOR, Christian, NYCOM, Old Westbury, NY; LARSSON, Hans, Redpath Museum, McGill Univ., Montreal, QB, Canada

The large moradisaurine captorhinid *Moradisaurus grandis* was named by Taquet in 1969 based on a mandible discovered in the Upper Permian Moradi Formation of north-central Niger. Postcranial material of this taxon was later reported, but not described. Recent field work in the Moradi Formation around Arlit has yielded new material of *Moradisaurus grandis*, including an essentially complete adult hindlimb and a complete juvenile pes. The adult specimen consists of the right mandible, several vertebrae, fragments of the pelvic girdle, and well-preserved hindlimb elements. The jaw ramus is approximately 75% of the length of the holotype. The right femur is a robust element, and its proximal articulation is oriented medially, unlike the postero-medially oriented articulations displayed by other captorhinids. The femur also lacks the large internal trochanter found in *Labidosaurus*, and the fourth trochanter is very large. The well-preserved astragalus is very unusual, being relatively short proximodistally with a short fibular process. The tibial facet is large and makes a relatively shallow angle with the body of the astragalus. The tibial facet is extended medially by a rugose flange projecting from the body of the element. The calcaneum possesses an unusually well-developed articulation for the astragalus, and is apparently co-ossified with distal tarsal five. *Moradisaurus* is the most common large animal in the Moradi Formation, and was probably a herbivore. The fauna of the Moradi Formation is therefore more similar to the captorhinid-dominated uppermost Lower Permian fauna of America rather than the dicynodont-dominated Upper Permian fauna of South Africa. The second, juvenile specimen is a complete pes preserved in articulation, establishing that that phalangeal formula was 2,3,4,5,4, and also preserves several sesimoid ossifications. The juvenile astragalus is partially ossified, and shows at least three and possibly four discreet ossification centers. This material supports the view that the captorhinid astragalus ossified from at least three discreet centers, unlike extant diapsids or turtles.

4:00 **Reisz, R. and Mueller, J.:** AMNIOTE PHYLOGENY AND THE INITIAL GEODISPERSAL OF SYNAPSIDS

REISZ, Robert, MUELLER, Johannes, Univ. of Toronto at Mississauga, Mississauga, ON, Canada  
Synapsids were the first amniotes to diversify extensively near the end of the Carboniferous, and during the rest of the Paleozoic they became the most commonly found and most conspicuous terrestrial vertebrates. The fossil record indicates that synapsids first showed up in North American sediments, but

also appear in slightly younger sediments in western and central Europe. Only much later, in the Middle Permian can they be found in Eastern Europe, and in the Late Permian in Southern Africa. In order to resolve the pattern of origination and geodispersal of a particular group of animals, we require a robust phylogeny of the group, a prolonged temporal framework, and at least two outgroups with good evolutionary histories. For evaluating the initial evolutionary radiation of synapsids we need a clade that has at least a modest level of diversity, and one that has a fossil record that extends from the Carboniferous into the Late Permian. The phylogeny of reptiles and diadectomorphs, the sister taxa to synapsids, and their first appearance in North American strata, support the hypothesis that synapsids originated along the equatorial regions of this part of Pangaea. However, most synapsid clades are not useful for evaluating the pattern of dispersal of this group because their temporal range does not cover the known history of the initial pattern of diversification. Ophiacodontids, edaphosaurids, and even sphenacodontids have modest taxic diversity, and a limited temporal range.

Recent work indicates that varanopids and captorhinid eureptiles have surprisingly high diversity and long fossil records, extending from the Late Carboniferous into the Late Permian. Varanopid synapsids first appear in Carboniferous sediments of Kansas. This group of agile predators diversified rapidly, with small and medium sized species in Lower and Middle Permian sediments in North America. Middle and Upper Permian sediments in the Mezen River Basin and South Africa provide the evidence of geodispersal of this group, with possible multiple invasions of Eastern Europe, and at least one for South Africa.

4:15 **Froebisch, J. and Reisz, R.:** A REEVALUATION OF *KOMBUISIA* AND THE SURVIVORSHIP OF DICYNODONTS ACROSS THE PERMO-TRIASSIC BOUNDARY

FROEBISCH, Joerg, REISZ, Robert, Univ. of Toronto at Mississauga, Mississauga, ON, Canada

The monospecific genus *Kombuisia*, a small dicynodont that lacks a pineal foramen, is known from the Early and Middle Triassic of southern Gondwana. The type specimen of *K. frerensis* from the *Cynognathus* Assemblage Zone of the South African Beaufort Group comprises a nearly complete skull and lower jaw that has been distorted by dorsoventral flattening. A second specimen from the same strata consists of a snout and dentaries only. Two additional specimens have been reported from the Fremouw Formation of Antarctica, thought to be equivalent in age to the *Lystrosaurus* Assemblage Zone of South Africa. Thus, with only four specimens *Kombuisia* is one of the rarest and least known dicynodonts.

Several authors recognized *Kombuisia*'s close relationship to *Kingoria*, but *Kombuisia* has never been included in a phylogenetic analysis. In addition, the specific phylogenetic relationships within the emydopoids are currently not resolved, since different synapomorphies support conflicting patterns of phylogenetic relationships. New information, made available by further preparation of the holotype and a first-time consideration of the material from Antarctica, has been included into a data matrix for the Emydopoidea. In addition to *Kombuisia*, three additional taxa (*Kawingasaurus*, *Cistecephaloides*, and *Myosauroides*) are for the first time included into a phylogenetic analysis.

The resulting phylogenetic hypothesis confirms the sister-taxon relationship of *Kombuisia* and *Kingoria*. It also shows that multiple dicynodont lineages cross the Permo-Triassic Boundary, and these include *Myosaurus*, *Lystrosaurus*, *Kannemeyeria* as well as *Kombuisia*. This pattern is paralleled by other groups such as diapsids and procolophonoids, supporting a higher estimation of survivorship across the Permo-Triassic Boundary than previously suggested.

4:30 **Botha, J. and Smith, R.:** *LYSTROSAURUS* SPECIES COMPOSITION ACROSS THE PERMIAN/TRIASSIC BOUNDARY IN SOUTH AFRICA

BOTHA, Jennifer, SMITH, Roger, Iziko: South African Museum of Cape Town, Cape Town, South Africa

The end-Permian extinction, dated at approximately 251 Ma, is considered to be the most catastrophic of the five major Phanerozoic mass extinctions. The dicynodont, *Lystrosaurus*, is one of the few therapsid genera to have survived the end-Permian extinction, and the only genus to have done so in abundance. However, it is currently unknown which of the four *Lystrosaurus* species survived the extinction.

In this study, the various *Lystrosaurus* species from Permian to Triassic strata in the Karoo Basin of South Africa were identified to determine any changes in species composition across the Permian/Triassic boundary. Data generated from museum collections and fieldwork were used to stratigraphically arrange 142 *Lystrosaurus* specimens and thus determine which species survived the extinction. Results reveal that *L. curvatus*, *L. maccaigi* and *L. murrayi* were present during the Late Permian in South Africa. *Lystrosaurus maccaigi* remains have thus far not been found in Lower Triassic strata. *L. curvatus* specimens were found in the Lower Triassic portion of the Palingkloof Member, Balfour Formation, but have yet to be recovered from the overlying Lower Triassic Katberg Formation.

*Lystrosaurus murrayi* and *L. declivis* are the most abundant *Lystrosaurus* species and the only two species whose ranges extend into the Lower Triassic Katberg Formation. They may have had an adaptational advantage or may have occupied different niches to *L. maccaigi* and *L. curvatus*, which were advantageous in an Early Triassic environment.

These results support earlier proposals that *Lystrosaurus*, as a genus, should not be used as an indicator of Triassic-aged strata. However, we suggest that the *Lystrosaurus* species, *L. maccaigi*, may be used as a biostratigraphical marker to indicate uppermost Permian strata in South Africa.

#### 4:45 **Angielczyk, K.:** BIOGEOGRAPHIC IMPLICATIONS OF A NEW, ENDEMIC PERMIAN DICYNODONT (SYNAPSIDA, THERAPSIDA) FROM TANZANIA

ANGIELCZYK, Kenneth, California Academy of Sciences, San Francisco, CA

Upper Permian dicynodont therapsids have been known from the Ruhuhu Valley of Tanzania since the first half of the 20th century. Although specimens from Tanzania have been the focus of several papers, this fauna has received notably less attention than the coeval fauna from the Karoo Basin of South Africa. However, despite its close geographic proximity, the Ruhuhu Valley dicynodont fauna is an interesting contrast to that of the Karoo because it includes endemic taxa, such as the specialized burrower *Kawingasaurus*, as well as an assemblage of taxa that do not co-occur stratigraphically in South Africa.

Here I describe a new dicynodont known from two skulls that were collected by F. R. Parrington in 1933 in the Kawinga Formation of the Ruhuhu Valley. Both specimens are of moderate size (snout-occiput length approximately 150mm), and are noteworthy for the relative shortening of the pre-orbital region of the skull. This pre-orbital shortening gives the new taxon a general resemblance to the Russian dicynodont *Elph borealis*, although a preliminary phylogenetic analysis suggests it may be a member of the clade including *Delectosaurus*, *Dicynodon*, and *Kannemeyeria*.

The discovery of a new, apparently endemic Tanzanian dicynodont contributes to a seemingly more complex pattern of Permian dicynodont distribution than generally has been recognized. Some faunas, such as that of the Kundaram Formation of India, show a relatively high degree of similarity to the well-studied fauna of the Karoo Basin, whereas others, including those of the Ruhuhu Valley and Russia, show varying degrees of dissimilarity. Although these patterns are becoming better documented, their causes remain obscure. Despite some speculation, little is known about the factors that controlled

dicynodont distributions. Addressing this issue rigorously is the next important step to be taken towards understanding the biogeography of dicynodonts and other Permian vertebrates.

5:00 **Jacobs, L., Winkler, D., Gomani, E. and Newman, K.:** A NEW BURNETIAMORPH THERAPSID FROM THE PERMIAN CHIWETA BEDS, MALAWI

JACOBS, Louis, WINKLER, Dale, Southern Methodist Univ., Dallas, TX; GOMANI, Elizabeth, Dept. of Antiquities, Lilongwe, Malawi; NEWMAN, Kent, Southern Methodist Univ., Dallas, TX

A joint Malawi Department of Antiquities-Southern Methodist University field crew discovered three therapsid skulls, among other vertebrates, in the Upper Permian Karoo Supergroup rocks near Chiweta, northern Malawi. Two of the skulls from the Chiweta beds pertain to the dicynodont *Oudenodon* sp. and one represents a new burnetiamorph biarmosuchian. Shared burnetiamorph characters of the Malawi skull include the presence of a supraorbital boss, median frontal ridge and antorbital pit on the lacrimal. It is distinguished from other burnetiamorphs by its facial region, large orbit, and shape of the frontal and supraorbital bosses. Phylogenetic analysis places this new Malawi form with the burnetiids, a clade more derived than *Lemurosaurus*.

Collections from Malawi's Chiweta beds made in the 1920's produced the dicynodont *Endothiodon*, at or below the level of our collections. This and the co-occurrence of the Malawi burnetiamorph with *Oudenodon*, imply a correlation of these therapsids with the *Cistecephalus* Assemblage Zone (Late Permian: Tatarian).



and dietary accommodation to arid vegetation. Evolutionary changes in dietary adaptations are also expected.

We evaluated these two models with data about stable-isotopic composition of mammalian teeth, microwear, relative abundance of taxa in the Siwalik sequence, and geographic range outside the Potwar Plateau for lineages occurring between ~10-6 Ma. Preliminary data indicate that some lineages follow the predictions of the first model (dietary adaptations do not change, species disappears), while other lineages follow the predictions of the second model (dietary adaptations change, species persists locally). We suggest refinements to the models based on the Siwalik record.

2:00 **MacPhee, R.:** REPEATED MEGAFUNAL COLLAPSE AND RECOVERY IN NORTHERN ASIA DURING THE PLEISTOCENE/ HOLOCENE TRANSITION

MacPHEE, Ross, American Museum of Natural History, New York, NY

Although the use of chronometric records to determine extinction times is often confounded by sampling inadequacies, Signor-Lipps effects, and other problems, <sup>14</sup>C date distributions are consistent with the argument that large mammals may have virtually disappeared from northernmost Asia for a time during and immediately after the Pleistocene/ Holocene transition (PHT). Date distributions help not only to constrain extinctions, long linked notionally with the PHT, but also to identify major local population crashes among those megafaunal species that did not become extinct at this time. In some cases catastrophe was followed by recovery, with abandoned ranges eventually being restocked from populations persisting elsewhere. However, the picture is more complex than usually realized.

Among megafaunal species known to have survived into the Holocene, mammoths made a very limited recovery, repopulating Wrangel Island (?from the mainland) during the period 7700 to 3700 BP only. Others such as woolly rhinos (*Coelodonta antiquitatis*; ?last occurrence, ca. 11,000 BP) evidently did not recover at all.

Of great interest is the pattern seen in <sup>14</sup>C records for muskox (*Ovibos moschatus*) and horse (*Equus* cf. *caballus*). Both disappear from the high Arctic during or just after the PHT, then reappear almost simultaneously shortly after 4000 BP. By 2000 BP, muskox were extinct in Eurasia; horses survived.

Although aspects of this pattern (PreBoreal disappearance, late Hypsithermal reappearance) correlate well with climate change, the role of factors such as overhunting and emerging infectious diseases ought to be considered as well. Ancient DNA evidence increasingly supports the inference that megafaunal species experienced repeated crashes before susceptibles finally became extinct.

2:15 **Deng, T.:** MAMMALIAN FAUNAL CHANGES DURING THE LATE CENOZOIC IN THE LINXIA BASIN OF NORTHWESTERN CHINA

DENG, Tao, Chinese Academy of Sciences, Beijing, China

A continuous sedimentary sequence of the late Cenozoic is well developed and exposed in the Linxia Basin (Gansu, China), in which very abundant mammal fossils are discovered. The late Oligocene *Dzungariotherium* fauna, the middle Miocene *Platybelodon* fauna, the late Miocene *Hipparion* fauna, and the early Pleistocene *Equus* fauna are the most representative in the Linxia Basin. The strong uplift of the Tibetan Plateau during the late Cenozoic greatly influenced climate and environment, which would be reflected from the mammalian faunal changes. In the important period of the uplift of the Tibetan Plateau in the late Cenozoic, the Linxia Basin has the mammal fossil assemblages, which can exactly determine geological ages, and the thick deposits, which can accurately reflect climatic variations. As a result, the Linxia Basin is a best site to study the uplift process of the Tibetan Plateau and its influence to climate and environment. For the study to the Tibetan Plateau, the Linxia Basin can correspond to or be better than the classical Siwaliks on the south margin of the

Tibetan Plateau. The ecological features of the distinct faunas indicate that the Linxia Basin came through great climatic and environmental changes: warm and humid forest mixed with some open lands in the late Oligocene, denser forest with richer water bodies in the middle Miocene, tropical semiarid savanna with strong seasonal variation in the late Miocene, until cold and arid climate with high elevation in the early Pleistocene. The particular geographical position of the Linxia Basin implies that the evolution of its mammalian faunas is tightly related to the uplift of the Tibetan Plateau in the late Cenozoic. The uplift of the Tibetan Plateau is not enough to baffle the dispersal of large mammals between north and south of this plateau in the late Oligocene, but it became an obvious barrier for the mammal migration in the middle Miocene and more obvious in the late Miocene. The Linxia Basin reached a relatively high elevation in the early Pleistocene, so that a plateau or alpine mammalian fauna appeared in this area.

2:30 **Missiaen, P. and Smith, T.:** THE LATE PALEOCENE SITE OF SUBENG (INNER MONGOLIA, CHINA): COMPLETING AND CHALLENGING MAMMAL BIOGEOGRAPHY IN ASIA

MISSIAEN, Pieter, Univ. Gent, Gent, Belgium; SMITH, Thierry, Royal Belgian Institute of Natural Sciences, Brussels, Belgium

The Subeng mammal site was briefly mentioned in literature some 20 years ago, but none of the few collected specimens have yet been described. During the Sino-Belgian Dinosaur Expeditions in 1995, 2000 and 2001, the upper Paleocene Nomogen Formation in the Subeng area was prospected and sampled. Here this formation consists of a lower lacustrine unit containing palynomorphs, charophytes and abundant ostracods, and an upper fluvial unit dominated by charophytes but poor in ostracods. A new level rich in mammal remains was discovered in channel-fillings of the fluvial unit. Screenwashing of 500 kilos of sediment yielded 251 identifiable mammal teeth, making Subeng one of the richest Paleocene sites. Material from at least 17 mammal taxa was collected, mainly isolated teeth from animals of small to very small size. No indisputable modern taxa were found and most of the identified taxa are shared with the well-known Bayan Ulan site. These include important Gashatan markers such as the rodentiform *Tribosphenomys*, the arctostyloid *Paleostylops*, the taeniolabidid *Lambdopsalis* and the mixodont *Eomylus*. Preliminary results of microfossil studies indicate affinities to the Gashatan site in Mongolia. Therefore the Subeng mammal fauna is considered to be Gashatan in age, traditionally correlated to the North American Clarkforkian and the European upper Thanetian. These correlations however are not undisputed and our results also indicate interesting relations to other land mammal ages. The recently described *Subengius mengi* is the oldest Asian plesiadapiform known and resembles Torrejonian-early Tiffanian *Elphidotarsius*, suggesting an early Tiffanian migration into Asia. Next to this, the morphology of a new nyctitheriid insectivore indicates a certain period of isolation from American and European nyctitheriids. The cimolestid *Naranius* and the ptilodontid *Mesodmops*, both previously only known from the Bumbanian, now have their oldest record in the Gashatan. Clearly the history of Paleocene Asian mammals is complex and more detailed research is required before pending biogeographic problems can be resolved.

2:45 **Smith, R. and Haarhoff, P.:** TAPHONOMY OF AN EARLY PLIOCENE SIVATHERE BONEBED AT LANGEBAANWEG, CAPE PROVINCE, SOUTH AFRICA

SMITH, Roger, Iziko: South African Museum, Cape Town, South Africa; HAARHOFF, Phillippa, Iziko: West Coast Fossil Park, Langebaanweg, South Africa

Late Pliocene vertebrates were first discovered at Langebaanweg on the West Coast of South Africa during phosphate mining operations in the late 1950's. Since then over a million bones of at least 150 different taxa have been collected, representing the terrestrial, freshwater and marine animals that lived

in and around the Proto-Berg River estuary approximately 5 million years ago. Most of the specimens were excavated from a 0.75m-thick bonebed that was intersected some 20m below surface on the seaward side of a water worn phosphate rock outcrop. Sedimentological and taphonomic analysis of a newly exposed 35m<sup>2</sup> portion of this bonebed is used to reconstruct the sequence of events that led to the accumulation and burial of this unique deposit.

The bonebed lies at the base of the Pelletal Phosphorite Member, a phosphate rich sand interpreted as having accumulated in shallow lagoon and estuarine environments during still stand and early transgression. Spatial distribution of numerous sivathere bones confirms that they were concentrated in a sinuous scour pool extending around one side and 60m downstream of the phosphate rock. Most of the bones are “fresh” and were sub-aerially exposed for less than a year before final burial. Element associations and partial articulations suggest that at least 10 sub-adult sivathere skeletons arrived at the site as floating complete carcasses during a single flood event. Some were grounded on the rock and others became trapped within turbulent eddies in the lee of the obstruction. Mandibles are common although skull roofs (with horn cores) are under-represented in the sampled portion of the bone bed. Bone “trains” that appear to originate from individual skeletons indicate a style of disarticulation and dispersal that is mainly governed by gravity rather than hydraulic sorting. Bone damage patterns on scapulae and limb bones show numerous point compression fractures, scratch marks and arcuate “greenstick” breaks interpreted as the result of trampling by hooved animals during and immediately after burial, whilst the sediment was still unconsolidated.

3:00 **Gaudin, T.:** PHYLOGENETIC ANALYSIS OF EXTINCT AND EXTANT PANGOLINS (MAMMALIA, PHOLIDOTA) AND RELATED TAXA USING POSTCRANIAL DATA

GAUDIN, Timothy, Univ. of Tennessee Chattanooga, Chattanooga, TN

Although the fossil record of the mammalian Order Pholidota (including the modern pangolins, or scaly anteaters) is sparse, it includes a number of extinct genera represented by relatively complete skeletal remains. Unfortunately, most of this material is devoid of significant skull material. A previous collaborative effort by the present author to elucidate the taxonomy and phylogenetic history of this order using cranial morphological characteristics failed to provide any information on the relationships among the early, well-preserved fossil genera, or their relationships to the living taxa. Therefore, a new analysis has been undertaken, examining the relationships among the seven living species of pangolins, the extinct pangolin genera *Necromanis*, *Patriomanis*, *Cryptomanis*, and *Eomanis*, the enigmatic edentate *Eurotamandua*, and the Palaeanodonta, using 289 morphological characters drawn from the postcranial skeleton. Characters are polarized via comparison to successive outgroups represented by the extant hedgehog genus *Erinaceus*, and the extant opossum *Caluromysiops*. Depending on the manner in which multistate characters are weighted, the analysis yields 1-3 most parsimonious trees (CI = 0.54-7, RI = 0.62). These trees corroborate the monophyly of the extant pangolins as a whole and the Asian pangolins in particular, but the manner in which the African pangolins are related to the Asian forms varies from tree to tree. The monophyly of Patriomanidae, including the extinct taxa *Necromanis*, *Patriomanis*, and *Cryptomanis*, is supported, and this clade is the sister group to modern pangolins. *Eomanis*, *Eurotamandua*, and the Palaeanodonta form a basal assemblage whose relationship to other undisputed pangolins is not unambiguously resolved, but it is of particular interest that in some trees the Messel taxa *Eomanis* and *Eurotamandua* are united as sister taxa.

3:15 **BREAK**

3:30 **Williamson, T. and Carr, T.:** *MICROCLAENODON* (MAMMALIA) REVISITED



WILLIAMSON, Thomas, New Mexico Museum of Natural History, Albuquerque, NM; CARR, Thomas, Royal Ontario Museum, Toronto, ON, Canada

*Microclaenodon assurgens* (Cope, 1883) is an early Paleocene (Torrejonian) mammal known only from the San Juan Basin, New Mexico. New material, including NMMNH P-22043, an associated upper (C1, P<sub>3</sub>-M<sub>3</sub>) and lower (c1, p2, p<sub>4</sub>-m<sub>3</sub>) dentition, adds significant new information for *M. assurgens* and allows a revision of its taxonomy and phylogeny.

A significant outcome is the recognition that *Oxyclaenus* is a synonym of *Microclaenodon*. In 1883, Cope erected *Triisodon assurgens* for the holotype AMNH 3215, a partial dentary with portions of p<sub>4</sub>-m<sub>3</sub>. In the same publication, he erected *Mioclænus (Oxyclaenus) cuspidatus* for the holotype AMNH 3252, a maxilla with a partial P<sub>3</sub> and M<sub>4</sub>-M<sub>3</sub> and dentary with obscured teeth. In 1892, Scott erected the genus *Microclaenodon* for *M. assurgens* and the family Oxyclaenidae to include *Oxyclaenus* and several other genera. The holotype of *O. cuspidatus*, a specimen with poor provenance, was considered “atypical” for the taxon. Nevertheless, numerous specimens of Puercan age were referred to it. A comparison with new specimens of *M. assurgens* show that the genoholotype of *Oxyclaenus cuspidatus* is a junior synonym of *M. assurgens*. This necessitates a revision of the taxonomy of the “Oxyclaenidae.”

Recent phylogenetic analyses posit a close relationship between *Microclaenodon* and Mesonychia. Dental characteristics of *Microclaenodon* include a large stylar shelf with an unreduced parastylar region and connate primary cusps on M1-3 and m1-3 that are trenchant with a high trigonid. However, unlike “triisodontines” or mesonychians, the upper and lower canines possess sharp, serrated distal carinae. Our phylogenetic analysis incorporating the new information agrees with other analyses that indicate that the Triisodontinae is paraphyletic and *M. assurgens* is the sister species of Mesonychia.

### 3:45 **Hoffman, J.:** PRACTICAL APPLICATION OF THE MESOWEAR METHOD ON UNASSOCIATED TEETH

HOFFMAN, Jonathan, Univ. of Florida, Gainesville, FL

The mesowear method of Solounias and coworkers was proposed as a relatively quick and efficient method of paleodiet analysis for mammalian herbivores. It originally focused on examining cusp shape and occlusal relief of the upper second molar (M2). This method has been extended, using hipparionine and extant equids, to include the combination of P4, M1, M2, and M3 positions, which is the most consistent permutation with the original M2 model. Both the extended and original models, however, rely on positive identification of tooth position. Since fossilized teeth are often found unassociated, it can be difficult to attain such identification. It is not always possible to distinguish between a P4 and M1 or between a M1 and M2 based solely on the inclination of the teeth. In the interest of assessing the practical applications of the mesowear method, this study applies the method to P3s, P4s, M1s, and M2s, and simulates random sampling. Additionally, this study uses a broader taxonomic range, consisting of equids from multiple tribes displaying morphological and temporal diversity. The specimens vary in tooth morphology from mesodont to hypsodont and span an age range of 18 Ma. Statistical goodness of fit (c2) tests were done on observed cusp shape and occlusal relief of the M1, P3, and P4 of six fossil equids to their respective observed M2 values. The same tests were conducted on sets of 20 randomly chosen teeth from each taxon in order to simulate realistic sampling of unidentified isolated teeth. Additionally, the paleodiet classification of each equid was determined, using each tooth type separately in cluster analyses, as well as combinations of different tooth types. For each taxon, the M1 and P4 fit well with the M2 observations, and yielded the same paleodiet classification. The P3 was inconsistent with both the c2 tests and paleodiet classification (a discrepancy in one of six taxa). This study has determined that, while positive identification of teeth is obviously preferred, a general paleodiet

classification can be obtained from any combination of unidentified P4/M1/M2 teeth, requiring only the exclusion of more easily identifiable P3s.

4:00 **Stucky, R.:** EVOLUTION OF THE EOCENE HERBIVORE GUILD IN NORTH AMERICA: METHODS OF ANALYSIS

STUCKY, Richard, Denver Museum of Nature & Science, Denver, CO

During the Eocene, mammalian herbivores underwent profound evolutionary change in North America. Key morphological shifts include an overall expansion of the size range (size increase), greater tooth crown height, greater shearing lengths on molar dentitions, and changes in the postcranial skeleton that suggest adaptations to more open habitats. These changes occurred in a number of independent lineages of different orders of mammals including artiodactyls, perissodactyls, rodents, primates and other groups. Analytical methods will be presented which examine the overall structure of the herbivore guild including analyses of niche breadth, community dynamics, and impacts of changing climate. The methodology uses a principal component and canonical analysis of dental measurements that predict resource use. This analysis provides for discrete analysis of species attributes that are comparable to analyses of modern living guilds. The objective of this approach is to determine how much variance in herbivore guild evolution is controlled by species interaction and how much is controlled by environmental factors.

4:15 **Libed, S.:** LATE PALEOCENE *NACIMIENTOTHERIUM SILVESTREI* (MAMMALIA), FROM THE SAN JUAN BASIN OF NEW MEXICO, AND THE ORIGIN OF TILLODONTS

LIBED, Shirley, University of New Mexico, Rio Rancho, NM

The historical consensus regards *Deltatherium* (a problematic mammal long-restricted to the Torrejonian of New Mexico's San Juan Basin), as an arctocyonid. But the transitional morphology of recently discovered *Nacimientotherium silvestrei*, from the earliest Tiffanian of New Mexico, supports a minority view—*Deltatherium* as a basal deltatherine tillodont. The holotype of *Nacimientotherium* (NMMNH P-38701), a crushed maxillary fragment with LP2 partial-M2, is largely only comparable in size to several Asian alleged tillodonts (e. g. late Paleocene *Meiostylodon*), but structurally intermediate between similarly sized *Deltatherium*, and larger-sized, earliest undisputed tillodont, North American late Paleocene *Esthonyx xenicus*. In premolar morphology, *Nacimientotherium* is advanced over *Deltatherium* in its subtriangular outline, distinctly bicuspid P3, greater P4 protocone development, metastylar lobe reduction, and parastyle augmentation in P3-4. In *Nacimientotherium*'s molar morphology, *Deltatherium*'s long, triangular molars, with their asymmetrical, wing-like stelar shelves, are superseded in five derived tillodont characters: subrectangular outline; labially migrated protocones; anteroposteriorly-compressed, symmetrical, dilambdodont crown; crown hypsodonty; and posterolingually-flared hypoconal postcingulae. Little fossil evidence prior to *Nacimientotherium* was available to clarify the controversial phylogenetic position of *Deltatherium* or its relationship to Tillodontia. But while late Paleocene North American and Asian faunal interchange is irrefutable, corroboration of North American *Nacimientotherium* as a late Paleocene basal tillodont transitional to *Esthonyx* confounds *Esthonyx*'s derivation from oldest putative tillodont—Asian, early Paleocene *Lofochaius*. Hence, *Nacimientotherium* supports *Deltatherium*'s inclusion within Tillodontia, but inadvertently defies the tillodont identities of aforementioned Asian forms, resuscitates a North American origination of the order, as well as complicates interrelated theories of speciation, radiation, and timing during the Paleocene-Eocene faunal turnover.

4:30 **Marcot, J.:** ESTIMATING THE HISTORY OF TAXONOMIC EVOLUTION IN RUMINANT ARTIODACTYLS USING FOSSIL AND MOLECULAR DATA

MARCOT, Jonathan, Duke Univ., Durham, NC

The study of taxonomic diversification is a fundamental line of research in evolutionary biology. Traditionally, it has been studied by paleontologists using the stratigraphic occurrence of fossils. Recently, neontologists have inferred patterns of taxonomic evolution using molecular phylogenies. If these molecular methods produce meaningful results, they hold promise for the study of countless taxa with depauperate fossil records. To date, molecular phylogeny-based analyses have been restricted to taxa lacking a robust fossil record.

For the first time, I compare the taxonomic patterns produced by molecular methods to those generated by traditional, fossil-based analyses using ruminant artiodactyls as a test case. Ruminants are an ideal group with which to do this because they have a robust fossil record and numerous extant representatives from which molecular data have been derived.

I inferred the fossil-based pattern of origination and extinction rates using a modified survivorship method. This analysis indicates two distinct intervals of increased origination in the Miocene, and no significant changes in extinction rate.

To determine the molecular-based pattern, I generated a phylogeny of extant ruminants using previously published DNA sequence data. I obtained divergence times with a penalized likelihood method using multiple calibration points. I then created a lineages-through-time plot to show the pattern of reconstructed lineage richness. In a novel approach, I plotted deviations of this pattern from a constant-rate, pure-birth null model against time for comparison with the fossil-derived time-series of rates. This method indicates a single peak in origination rate during the early Miocene, which matches the first suggested by the fossil-based approach. However, the second peak from the fossil-based method was not apparent. This discrepancy may be due to the extinction of large portions of several clades with low extant diversity.

These results suggest that molecular methods can reliably reconstruct some evolutionary patterns, but also underscores the importance of fossil-based analyses, where feasible.

4:45 **Feranec, R. and MacFadden, B.:** ISOTOPIC DISCRIMINATION OF RESOURCE PARTITIONING AMONG UNGULATES IN C<sub>3</sub>-DOMINATED COMMUNITIES FROM THE MIOCENE OF CALIFORNIA AND FLORIDA

FERANEC, Robert, Univ. of California Berkeley, Berkeley, CA; MacFADDEN, Bruce, Florida Museum of Natural History, Gainesville, FL

Stable isotope analyses of mammal teeth are commonly used to examine resource partitioning in environments characterized by a mixture of C<sub>3</sub> and C<sub>4</sub> plants. However, isotopic discrimination of resource partitioning has rarely been shown in C<sub>3</sub>-dominated paleocommunities, even though analysis of modern ecosystems from Africa and North America has shown that this type of partitioning is detectable. We explored resource use and niche partitioning in three ancient, C<sub>3</sub>-dominated, Miocene communities from California and Florida: Barstow (CA), Blackhawk Ranch (CA), and the Love Bone Bed (FL), each of which predates the C<sub>4</sub> global carbon shift 7 million years ago.  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  values were obtained from the tooth enamel of six ungulate genera from Barstow, eight from Blackhawk Ranch, and 14 from the Love Bone Bed. Results from 226 bulk isotope samples showed no significant differences among taxa at Blackhawk Ranch, but significant differences were observed among taxa within both the Barstow and Love Bone Bed localities. At each locality, equids generally had more positive  $\delta^{13}\text{C}$  values, which suggests their use of more open habitats, while antilocaprids, camelids, and proboscideans had more negative values, implying residence in closed habitats. Notably, *Pediomeryx*

(*Yumaceras*) sp. from the Love Bone Bed exhibited positive  $\delta^{13}\text{C}$  values, corroborating that more fiber, possibly grass, was incorporated into its diet, similar to the horses from the same locality. The lack of significant differences among taxa at Blackhawk Ranch may indicate either a relatively homogeneous flora, or presence of abundant resources permitting niche overlap, while the opposite is implied by the presence of significantly different isotope values among taxa at Barstow and Love Bone Bed. This study highlights the ability of this technique to discern resource partitioning for the millions of years before the  $\text{C}_4$  global carbon shift that occurred during the late Miocene.

5:00 **Clementz, M., Domning, D., Barnes, L. and Beatty, B.:** EOCENE AND OLIGOCENE EVOLUTION AND STRUCTURE OF THE AQUATIC HERBIVORE ADAPTIVE ZONE IN THE WEST ATLANTIC AND CARIBBEAN

CLEMENTZ, Mark, Smithsonian Institution Marine Station, Fort Pierce, FL; DOMNING, Daryl, Howard Univ., Washington, DC; BARNES, Lawrence, Natural History Museum of Los Angeles County, Los Angeles, CA; BEATTY, Brian, Univ. of Kansas, Lawrence, KS

Modern marine ecosystems support fewer herbivorous mammals than their terrestrial counterparts, and include only four non-sympatric species of Sirenia (i.e., sea cows, dugongs, and manatees). Yet, the diversity of aquatic herbivores through most of the Cenozoic was typically higher, there being many periods when multiple species co-inhabited the same regions, including species other than sirenians (i.e., desmostylians, xenarthrans). With so many large mammal species foraging within a single locality, available resources of aquatic vegetation were likely to have been finely partitioned among herbivores, creating several distinct feeding niches. We have begun to define these feeding niches using features of cranial morphology, enamel carbon isotope values, and dental microwear as evidence of dietary preferences. Together, these independent lines of dietary evidence allow us to explore long-term patterns in the appearance and diversification of these niches, providing insight into the development and structure of ancient aquatic communities. Three key regions we plan to study include the West Atlantic-Caribbean, Tethys-Mediterranean, and Eastern Pacific, all of which were regions of diverse aquatic herbivore faunas throughout most of the Cenozoic. Here we present initial data collected from Eocene and Oligocene fossil localities in the West Atlantic and Caribbean region. Fossils of aquatic herbivores collected from these deposits include multiple species from three separate families of Sirenia, including the earliest and most primitive family, the Prorastomidae. Morphological evidence suggests that the locomotor capabilities, habitat preferences, and dietary preferences of these species were quite distinct and, when combined with carbon isotope evidence collected from tooth enamel, may reflect differences in the amount and type of seagrass included in each species diet.

5:15 **Heaton, T. and Grady, F.:** DETAILED VERTEBRATE HISTORY OF SOUTHEAST ALASKA DURING THE LAST GLACIAL MAXIMUM

HEATON, Timothy, Univ. of South Dakota, Vermillion, SD; GRADY, Frederick, Smithsonian Institution, Washington, DC

Excavations of cave faunas in Southeast Alaska during 12 field seasons have produced a collection of 41,000 cataloged specimens (mammals, birds, and fish) from >42,000  $^{14}\text{C}$  yr B.P. to the present. Results from 176 dated samples (121 of them from On Your Knees Cave, Prince of Wales Island) have permitted an increase in resolution of the vertebrate history beyond four zones reported earlier. The period of greatest interest is the Last Glacial Maximum (LGM) because of the extirpation of some mammals in coastal Alaska and its importance to the archaeological history of North America.

*Phoca hispida* is an indicator of local sea ice and therefore of cold (glacial) conditions. Radiocarbon dates of 25 specimens range from 24,150 to 13,690 with a significant gap between 17,130 and 14,520

14C yr B.P. No other species have been dated to this time gap, which is by far the longest in the suite of dates. Since there is evidence that glaciers covered the region during the LGM, it must have been during this relatively brief interval.

*Alopex lagopus* and several pinnipeds and sea birds survived the LGM on coastal islands, and it is possible that *Ursus arctos*, *Ursus americanus*, and *Rangifer tarandus* did as well (their remains have been dated to before and after the LGM). But several rodent genera were extirpated during the LGM, most of which have never recolonized the coastal islands. New evidence suggests that they were extirpated during the date gap between 17,130 and 14,520 14C yr B.P. rather than earlier in the LGM. A date on *Marmota caligata* of 17,850 14C yr B.P. shows that it survived to this period (other marmot dates precede 22,670 14C yr B.P.). In the stratigraphic zonation at On Your Knees Cave, *Phenacomys intermedius* and *Lemmus trimucronatus* show an increase in abundance relative to *Marmota caligata* and *Microtus longicaudus* in the early LGM.

This data documents that bitter Ice Age conditions were short lived in coastal Alaska and that only rodents were seriously affected. A community of Arctic mammals thrived there during the LGM. Therefore it is possible that humans could have made use of a coastal route between Alaska and the lower 48 states during most or all of the LGM.

5:30 **Rivals, F. and Solounias, N.: BISON DIETARY CHANGES IN NORTH AMERICA DURING THE PLEISTOCENE-HOLOCENE TRANSITION**

RIVALS, Florent, SOLOUNIAS, Nikos, New York College of Osteopathic Medicine, Old Westbury, NY

Bison is a common fossil taxon in North America. *Bison* inhabited large regions of North America south of the margin of the Pleistocene ice sheets. Because of the widespread distribution of *Bison*, some differences should exist during the Pleistocene from the northern to the southern habitats. Four samples of *Bison* from Pleistocene localities were studied: Fairbanks Area (Alaska), Folsom Quarry (New Mexico), Seminole Field (Florida) and Dalhart Sideroad Pit (Texas). They in turn were compared to a mixed sample of extant *Bison* from the central plains. A dietary study was performed using tooth mesowear and microwear of the upper second molars.

Mesowear: All extinct samples had mainly rounded molar apices (between 93 and 100%). This mesowear signature is strongly different from that of modern *Bison* where it is 26.6% rounded and 73.3% blunt and most similar to *Hippotragus equinus* and *Kobus ellipriprymnus* (African bush and water margin grazers).

The microwear analysis shows that *Bison* from New Mexico, and Texas were grazers similar to *Equus burchelli*. *Bison* from Florida was similar to *Gazella granti* (a mixed feeder) or fruit dominated browsers. The extinct Alaska *Bison* had a diet similar to recent *Cervus canadensis* (a mixed feeder). Elk graze part of the time as mixed feeders. Two additional observations are possible. (1) Because of the high longitude of Alaska and the Pleistocene temperatures, the fine scratches observed on this sample suggest this extinct *Bison* population was grazing on C3 grasses. (2) Such C3 grasses produce very fine microwear scratches.

The results show geographically variable diets for the extinct *Bison*. This study reveals the importance of such analyses which are necessary to understand the dietary breadth of species and escape uniformitarian assumptions based upon the well-known but in certain cases unrealistic Holocene scenarios.

5:45 **Wang, X. and Wallace, S.: TWO NEW IMMIGRANTS FROM THE OLD WORLD: THE EARLIEST AND MOST PRIMITIVE RED PANDA (*PARAILURUS*) AND A NEW EURASIAN BADGER**

(*ARCTOMELES*) FROM LATE MIOCENE/EARLY PLIOCENE GRAY FOSSIL SITE, EASTERN TENNESSEE

WANG, Xiaoming, Natural History Museum of Los Angeles County, Los Angeles, CA;  
WALLACE, Steven, East Tennessee State University, Johnson City, TN

Two new carnivorans with clear Eurasian affinities were recently recovered from the late Miocene/early Pliocene Gray Fossil Site, Tennessee. These forest-adapted forms offer a rare glimpse into the late Cenozoic of eastern North America, which is traditionally under-sampled because of a general lack of suitable deposits. New faunal information therefore fills an important gap in our knowledge of the history of the eastern deciduous forest. The new red (lesser) panda (family Ailuridae) is based on an upper canine and an M1, which represent only the second record after its first reported occurrence in the early Pliocene Taunton fauna of Washington (a highly derived species of *Parailurus*). Dental morphology of the new Gray panda is very primitive, with poorly developed styler cusps (such as para-, meso-, and metastyles), small protoconule, small accessory cusps, and a low length/width ratio. This suite of characters places the Gray panda at the base of the red panda phylogeny, indicating a new stem genus, and on the opposite end of the tree from the Taunton panda. Such a relationship suggests that the two North American records of red panda represent separate dispersal events—the Gray form comes from a more primitive stock, whereas the Taunton form occupies a terminal position of the *Parailurus* clade. A new highly derived species of Old World badger (*Arctomeles*, subfamily Melinae) from the Gray site is only the second record of melines in North America, after a recent discovery of a similar form from Ellesmere Island. Represented by a premaxillary and maxillary fragment with I1-M1, it has an expanded P4 lingual cingulum, reduced P4 protocone, a large trailing talon on M1, and well-developed accessory cusps on M1. Phylogenetically, the Gray badger is highly derived, very distant from the more basal Ellesmere Island form (which probably does not belong to *Arctomeles*), indicating once again a unique dispersal event.

**TECHNICAL SESSION XIX**  
**GOVERNOR'S SQUARE 14**  
**MODERATORS: TOMAKI SATO AND H. TODD WHEELER**

1:30 **Ross, M. and Fastovsky, D.:** QUANTITATIVE APPROACHES TO LATE CRETACEOUS SHALLOW-MARINE AND SHELF STRATIGRAPHY OF MARINE VERTEBRATES

ROSS, Marcus, FASTOVSKY, David, Univ. of Rhode Island, Kingston, RI

The record of marine vertebrates in Upper Cretaceous deposits is excellent both in North America and throughout the world. High eustatic sea level and expansive epicontinental seas produced thick packages of sediment with high preservation potential in comparison to contemporaneous terrestrial deposits. Aggressive collection of marine vertebrates since the mid-1800's (particularly from classic lithologic units such as the Niobrara Chalk and Pierre Shale) has generated tens of thousands of specimens.

Here we introduce a series of stratigraphically correlated assemblages (SCA) for the Late Cretaceous, most of which span approximately 2 million years. Mosasaurs are an ideal group to track using the SCA's, because they are abundant, globally distributed, readily identified, and taxonomically stable at the generic level. Rarefaction is the primary statistical analysis available for comparison of generic richness between SCA's. Rarefaction calculates 1) the expected number of genera for a given sample, and 2) the confidence intervals with which to bracket statistical expectations of mosasaur generic richness.

The SCA's provide an important tool with which to chart the overall contours of mosasaur evolution, richness, and extinction. An important result of the construction and subsequent refinement of the SCA's is the potential to chart the interplay of marine vertebrate evolution with various abiotic and biotic factors, including coordinated evolutionary events, changes in ocean chemistry and eustatic sea level, and climatic fluctuations. Additionally, since the youngest SCA is coincident with the Cretaceous-Tertiary boundary, we can quantitatively test the null hypothesis that mosasaur generic richness was unchanged during the last few million years of the Cretaceous.

1:45 **Patrick, D., Martin, J., Parris, D. and Grandstaff, D.:** DETERMINATION OF PROVENIENCE AND THE STRATIGRAPHIC SIGNIFICANCE OF *MOSASAURUS MISSOURIENSIS*

PATRICK, Doreena, Univ. of Pennsylvania, North Wales, PA; MARTIN, James, South Dakota School of Mines and Technology, Rapid City, SD; PARRIS, Dave, Natural History Bureau, Trenton, NJ; GRANDSTAFF, David, Temple Univ., Philadelphia, PA

The first mosasaur from the American West was taken from the Missouri River area to Germany by Prince Maximilian of Weid in the 1830's. Early records indicate the specimen was collected from the Big Bend area of the Missouri River in central South Dakota. However, the precise stratigraphic position of the specimen was unknown. Preservation of the fossil and associated invertebrates were suggestive, but an independent means of deriving the stratigraphic position was desirable. Rare earth elements (REE) in fossil apatite may be used to determine or limit provenience of such fossils. REE concentrations in the specimen were measured and compared with those of previously analyzed mosasaur bones collected from five members of the upper Cretaceous Pierre Shale at localities near the Missouri River. Fossils from each member of the Pierre Shale have REE signatures similar to one another over large areas of central South Dakota, but different from those of other members. Fossils collected from the Sharon Springs Member have distinctive REE signatures that may be further subdivided statistically into three superposed groups that correspond with the upper, middle, and lower Sharon Springs Member. Because REE signatures differ between units, fossil bones removed from

stratigraphic context may be assigned to their original members based on visual and statistical comparisons of REE signatures. Discriminant analysis was used to predict the original stratigraphic origin of the fossil. The historic sample grouped statistically with fossils from the DeGrey Member. Therefore, the provenience of this fossil could be assigned to the DeGrey Member based on REE analyses.

2:00 **Schulp, A.:** FEEDING THE MECHANICAL MOSASAUR: WHAT DID *CARINODENS* EAT?

SCHULP, Anne, Natuurhistorisch Museum Maastricht, Maastricht, Netherlands

*Carinodens* is amongst the smallest mosasaurs known, and one of the most elusive at that. This enigmatic taxon is known from just two dentary fragments and a dozen or so of isolated teeth, mainly from the Maastrichtian type area (SE Netherlands and NE Belgium). There are additional records, all based on isolated teeth, from Brazil, Morocco and Bulgaria.

Based on this limited material, an attempt has now been made to improve our understanding of the species' dietary habits, by comparing tooth and jaw morphology to extant analogues, and by matching a biomechanical model with 'feeding' experiments using an artificial mosasaur jaw equipped with a force gauge.

*Carinodens* appears to have been a durophagous mosasaur, capable of crushing small molluscs and arthropods, but its dietary habits may not necessarily have been limited to hard-shelled food. Contrary to what has been suggested previously, the experiments do suggest that *Carinodens* was poorly equipped for feeding on squid.

2:15 **Sato, T., Eberth, D., Nicholls, E. and Manabe, M.:** PLESIOSAUR ASSEMBLAGE FROM THE DINOSAUR PARK FORMATION (CAMPANIAN) AT DINOSAUR PROVINCIAL PARK, ALBERTA, CANADA

SATO, Tamaki, Canadian Museum of Nature, Ottawa, ON, Canada; EBERTH, David, NICHOLLS, Elizabeth, Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada; MANABE, Makoto, National Science Museum, Tokyo, Japan

The vast majority of plesiosaurian fossils come from marine deposits, but in a few instances they are known from non-marine sediments. We studied geological and taxonomic aspects of a plesiosaurian assemblage from Upper Cretaceous sediments at Dinosaur Provincial Park, southern Alberta, Canada. All specimens with precise locality information are either from the non-marine-to-paralic Dinosaur Park Formation (DPFm) or the overlying marine Bearpaw Formation (BFm). Specimens from the DPFm dominate the record and typically consist of isolated and worn elements from multitaxic bonebeds that are hosted by paleochannel lags. We propose that these plesiosaurian remains are parautochthonous, and that their stratigraphic distribution pattern has been strongly influenced by sedimentological and taphonomic factors, and collecting biases.

Elasmosaurid remains dominate in the DPFm and, at the family-level, this assemblage is similar to the Bearpaw plesiosaurian fauna. However, specimens are too fragmentary for identification at lower taxonomic levels, thus precluding more precise comparisons. DPFm plesiosaurian vertebrae are generally small and therefore similar to a subadult elasmosaur known from the Pembina Member of the Pierre Shale.

2:30 **Sanders, F., Carpenter, K., Reed, B. and Reed, J.:** PLESIOSAUR SWIMMING RECONSTRUCTED FROM SKELETAL ANALYSIS AND EXPERIMENTAL RESULTS

SANDERS, Frank, CARPENTER, Kenneth, REED, Brian, REED, Julia, Denver Museum of Natural History, Denver, CO



Three basic hypotheses have been proposed for the swimming locomotion of plesiosaurs: rowing motion in which the flippers move primarily in a horizontal plane; figure-eight motion (underwater flight) in which the flippers move primarily in a vertical plane while continuously being rotated on their longitudinal axes so as to generate thrust in a manner roughly analogous to that of penguins or sea turtles; and a sea lion stroke in which the flippers move downward (and backward (belly-ward)) to produce thrust. Within these hypotheses various proposals have been made for synchronicity of the fore and rear flippers, as well as front flippers propelled while the back flippers were passively employed for stabilization/steering. These models for flipper motion have not been adequately constrained by limits of joint articulation of fossil specimens. Furthermore, the proposed models for plesiosaur propulsion have not previously been experimentally tested; given the inherent complexities of underwater propulsion it is important that conclusions regarding plesiosaur swimming should be confirmed by successful physical demonstrations.

We have reconstructed plesiosaur swimming by firstly taking into account constraints on plesiosaur shoulder and hip joint articulation, and secondly by testing (within the available range of motion) a variety of strokes with human swimmers equipped with facsimile plesiosaur fins, including paired swimming to replicate the action of four flippers at once. Significant results include: plesiosaur limbs are constrained to mostly vertical motion with relatively less fore and aft freedom; in *Plesiosaurus* fore flippers could move through a 55 deg arc and hind flippers only 35 deg below horizontal; and back flippers did assist propulsion. Synchronous or near synchronous movement of the front and back flippers has been found to work best. Propulsion is very sensitive to details of flipper rotation during each stroke as well as small motions at the flipper tips.

2:45 **Bennett, S. C.:** NEW INFORMATION ON THE PTEROSAUR *SCAPHOGNATHUS CRASSIROSTRIS* AND THE PTEROSAURIAN CERVICAL SERIES

BENNETT, S. Christopher, Univ. of Bridgeport, Bridgeport, CT

A third specimen of *Scaphognathus crassirostris* from the Upper Jurassic Solnhofen Limestone of southern Germany adds new information about the rare taxon. The specimen is a juvenile with unfused girdles, carpals, and tarsals, and is slightly smaller than the Maxberg specimen. It is complete, fully articulated, and less crushed than is typical of Solnhofen specimens. The specimen, along with a reexamination of the holotype specimen, provides information leading to a new reconstruction of the skull that shows that the snout was broader than previously thought. Reinterpretation of the dentition shows that there were only 2 premaxillary teeth, 6 maxillary teeth, and 5 mandibular teeth; additional small teeth are replacement teeth. The bone of the skull has a dense, convoluted pattern of grain suggesting that the bone was thicker and heavier than is seen in other similarly sized Solnhofen pterosaurs. Taken together the skull shape, dentition, and robust bone suggest that the pterosaur was adapted for preying on larger fishes than other Solnhofen pterosaurs. Adjacent to the skull is an articulated partial vertebral column of a relatively large fish, which probably was regurgitated around the time of death. The tail is slightly shorter than that of the Maxberg specimen, but it appears that the tip was lost and healed sometime before death.

The cervical series of the specimen consists of 9 vertebrae if the first vertebra that bears a large rib that articulates with the sternum is interpreted as the first dorsal vertebra. Traditionally, it has been thought that rhamphorhynchoids had 8 cervicals, Jurassic pterodactyloids such as *Pterodactylus* had 7 cervicals, and large pterodactyloids had 9 cervicals, the latter resulting from the cervicalization of the anterior two dorsal vertebrae. However, if the above definition is used, then *Scaphognathus* and other rhamphorhynchoids and all pterodactyloids had 9 cervicals. Thus, the number of cervicals remained constant throughout the evolution of pterosaurs.

3:00 **Meredith, R., Martin, J. and Case, J.:** NEW CHELID TURTLE MATERIAL FROM THE OLIGO-MIOCENE ETADUNNA FORMATION OF SOUTH AUSTRALIA

MEREDITH, Robert, Riverside, CA; MARTIN, James, SD School of Mines and Technology, Rapid City, SD; CASE, Judd, Saint Mary's College of California, Moraga, CA

The Etadunna Formation, Lake Eyre Basin, is the oldest fossiliferous Tertiary formation in South Australia. The clay and sand sequences were deposited during the late Oligocene and early Miocene. The formation has been divided into five faunal zones (zones A-E, oldest to youngest) consisting of nine members (1-9, oldest to youngest). However, due to the environment of deposition most of the material is highly fragmentary and unidentifiable.

The most common elements recovered from all faunal zones of the Etadunna Formation are fragmentary chelid turtle shells. Unfortunately, the vast majority of the shell material is unidentifiable past the family level and no complete shells are known from the formation. However, two nearly complete carapaces and plastrons are known from the slightly younger Wipajiri Formation. All of the known fossil chelid shell material from these two formations has been referred to the living genus *Emydura*. Skull material, unknown from the Wipajiri Formation, is extremely rare in the Etadunna Formation being known only from one locality in Zone A and has likewise been referred to *Emydura*.

Recent fieldwork over last decade has more than doubled the amount of known chelid turtle material including the first nearly complete specimen consisting of both cranial and postcranial material. Several cranial elements including a partial skull have now been recovered from all faunal zones of the Etadunna Formation as well as the Wipajiri Formation. In addition, a nearly complete carapace is now known from faunal Zone A. All of the new material is referable to the genus *Emydura* and supports the hypothesis that there is only one genus present in the Etadunna and Wipajiri formations. Unfortunately, specific identification is not possible at this time because most of the living species of *Emydura* do not have good osteological descriptions and the validity of some species is questionable.

3:15 **BREAK**

3:30 **Metzger, C., Terry, Jr., D. and Grandstaff, D.:** THE ROLE OF PEDOGENESIS IN SETTING THE RARE EARTH ELEMENT SIGNATURE OF FOSSIL BONE FROM BADLANDS NATIONAL PARK, SOUTH DAKOTA

METZGER, Christine, Univ. of Oregon, Eugene, OR; TERRY, JR., Dennis, Temple Univ., Philadelphia, PA; GRANDSTAFF, David, Temple Univ., Philadelphia, PA

The rare earth element (REE) geochemistry of fossil bones from several locations in the Orellan Scenic Member of the Oligocene Brule Formation in Badlands National Park, South Dakota, was analyzed and compared to the degree of pedogenesis at each site. Paleosols from Chamberlain Pass, Heck Table, and Sheep Mountain Table ranged from weakly developed entisols to more strongly developed inceptisols, all typical of a fluvial environment and possibly indicative of systematic paleocatena variation. The paleosols were alkaline and well-drained, as shown by molecular weathering ratio and trace element data. Sediments with sparse soil features from an oxbow-lake site suggest that conditions were too waterlogged and sedimentation rates too rapid for much, if any, pedogenesis to occur. The variance of REE signatures in fossil bones from the paleosol sites was significantly greater than that of fossils from the unpedogenically altered sediments at the oxbow-lake site. Cerium anomalies (Ce\*) were well correlated with uranium concentration, with positive Ce\* values associated with low uranium, and were used to indicate paleoredox conditions. The degree of pedogenesis, regardless of the soil horizon in which the bone was found, systematically affected the REE signature preserved in the

fossil bones, with heavy rare earth enrichment characteristic of the more developed paleosols. The REE signatures of bone from the different paleosols and sedimentary environments were significantly different and distinguishable.

3:45 **Rothschild, B. and Panza, R.:** THE PIVOTAL ANKLE DETERMINANT OF DINOSAUR AND BIRD OSTEOARTHRITIS

ROTHSCHILD, Bruce, Arthritis Center of Northeast Ohio, Youngstown, OH; PANZA, Robin, Carnegie Museum, Pittsburgh, PA

Notation of osteoarthritis in dinosaurs, limited in distribution to their ankle joints, stimulated search for related pathology in their perceived descendants. Dinosaur and bird skeletons were examined in North American, Belgique, Italian and Swiss osteologic collections for the appendicular joint remodeling with spur (osteophyte) formation pathognomonic for osteoarthritis.

Such osteophytes were found among dinosaurs only in two *Iguanodon* (with an additional example of injury-related osteoarthritis in an *Apatosaurus*), but were also present in 5% of birds. Vertebral osteophytes (characteristic of spondylosis deformans, not osteoarthritis) were common in dinosaurs, but only rarely noted in birds. The frequency of osteoarthritis in birds was independent of captive or wild-caught status. It was invariably limited in distribution to the ankle in the latter. Osteoarthritis in aviary and caged birds predominantly affected the ankle, with only isolated examples of knee, shoulder or elbow involvement. Variation in frequency of osteoarthritis was noted among bird morphotypes (e.g., averages of 11% in hawks, 17% in pigeons, but less than 3% in ratites). Significant variation was also noted even within genera (e.g., ranging from 26% in *Accipiter cooperii* to 0 of 106 *Accipiter gentilis*).

It is intriguing that only relatively small dinosaurs were affected by primary osteoarthritis. Osteoarthritis complicating an injury in an *Apatosaurus* was the sole example in Sauropoda, related to biomechanical gait alteration from a stress fracture. The frequencies of osteoarthritis in *Iguanodon* (although not considered a direct bird ancestor) and one of the basal bird groups (ratites) were comparable. Curiously, the frequency was greater in more derived birds (e.g., hawks and pigeons) and analogous to that noted in two very derived mammals, Diprotodon and macropods. Similarities and differences between dinosaurs and birds will be explored to address selective susceptibility.

4:00 **Parker, W. and Irmis, R.:** A REVISION OF THE PHYTOSAUR SPECIES *PSEUDOPALATUS MCCAULEYI* (ARCHOSAURIA: PSEUDOSUCHIA), BASED ON TWO NEW SPECIMENS FROM PETRIFIED FOREST NATIONAL PARK, AZ

PARKER, William, Petrified Forest National Park, Petrified Forest, AZ; IRMIS, Randall, Northern Arizona Univ., Flagstaff, AZ

*Pseudopalatus mccauleyi* is a poorly known phytosaur collected from the Upper Triassic Chinle Formation just east of Petrified Forest National Park, Arizona. Known from a single incomplete skull lacking much of the rostrum, the validity of this taxon has been contested in the literature. Recently, however, two new specimens have come to light from inside the park that can be referred to this taxon, including one specimen consisting of a complete skull associated with much of the postcranial skeleton. This first individual, more popularly known as the "Petroglyph Phytosaur" specimen, is almost identical to the type specimen regarding the shape of the squamosals, shape of the exoccipitals, position of the nares relative to the skull roof, and the degree of heterodonty. In addition, the rostral crests of this new specimen and the holotype are identical showing that *P. mccauleyi* was fully crested. The association of postcranial material with this skull provides the first description of non-cranial material for this taxon.

The second specimen consists of a skull roof complete from the squamosal tips to the posterior nares. This specimen can also be referred to *P. mccauleyi* based upon the position of the nares,

squamosals that are not “knob-like” and thin exoccipitals that are not oar-shaped. Both the holotype of *P. mccauleyi* and the second specimen are from the base of the Sonsela Member of the Chinle Formation, while the “Petroglyph Phytosaur” is from the Petrified Forest Member. The referral of these two new specimens changes the status of *P. mccauleyi* from one of the most poorly known to one of the more completely known phytosaur taxa.

4:15 **Spearing, K. and Behlke, A.:** PHYLOGENY OF THE MOSASAURINAE AND THE MONOPHYLY OF THE GENUS *CLIDASTES*

SPEARING, Kurt, Northern Illinois Univ., De Kalb, IL; BEHLKE, Adam, Univ. of Wisconsin-Madison, Madison, WI

There have been several phylogenetic analyses of the mosasaurs. The two most comprehensive previous studies were the pre-cladistic work of Russell in 1967, and the cladistic analysis by Bell in 1997, in which all North American members of the Mosasauroidae were examined. Since then, several new taxa have been discovered, and many of these discoveries were evaluated by various authors using the 1997 study as a basis upon which to evaluate the phylogenetic position of their new taxa. In these studies, the genus *Clidastes* has consistently been shown to be a paraphyletic group, usually near the base of the subfamily Mosasaurinae. Presented here is a recently revised phylogenetic analysis of this subfamily, building upon the 1997 study, but removing or revising several characters to provide a more effective examination of the phylogeny. Additional taxa are included in the analysis; several that have been coded in various publications since 1997, as well as taxa from other regions of the world. Also included is a new *Clidastes* specimen from the University of Wisconsin Geology Museum, which appears to be a basal member of the genus. In this phylogeny of the Mosasaurinae, the data show support for the tribes Plotosaurini and Globidensini, as well as a monophyletic clade of the genus *Clidastes*.

4:30 **Adams, T., Breithaupt, B., Shinn, J., Southwell, E. and Matthews, N.:** THE SUNDANCE VERTEBRATE ICHNOFAUNAL PROVINCE: EVIDENCE FOR POPULATION STRUCTURES OF BATHONIAN DINOSAURS FROM TRACKSITES IN THE BIGHORN BASIN, WYOMING

ADAMS, Thomas, BREITHAUPT, Brent, SHINN, Jerome, SOUTHWELL, Elizabeth, Geological Museum, Univ. of Wyoming, Laramie, WY; MATTHEWS, Neffra, National Science and Technology Center, Denver, CO

Near the town of Shell in the northeastern Bighorn Basin, Wyoming, sporadic exposures of a limestone facies at the top of the Canyon Springs Member of the Lower Sundance Formation (i.e., “Sundance Footprint Bed”) preserve thousands of footprints of tetanurine theropod dinosaurs. These tracks are tridactyl, digitigrade, pes impressions in concave epirelief, representing a large assemblage of small-to-medium sized carnivorous dinosaurs indicating a single and possibly new ichnotaxon. Exhaustive documentation of multiple tracksites within the Bighorn Basin reveals a complex interrelationship between track morphologies, track densities, and microenvironments, providing a unique glimpse of Middle Jurassic paleoecology and paleobiology. Due to common ichnofaunal content, similar depositional environment, and correlative stratigraphic position, these tracksites are grouped into a newly defined “Sundance Vertebrate Ichnofaunal Province.” This province is the most extensive area of dinosaur footprints in Wyoming and may represent an endemic fauna of theropod dinosaurs in North America during the Bathonian. The monospecific ichnocoenoses of these combined tracksites (Red Gulch Dinosaur Tracksite, Yellow Brick Road Dinosaur Tracksite, Flitner Ranch Dinosaur Tracksite, and Melinda 2 Dinosaur Tracksite) allows for the intensive study of a large vertebrate ichnology data set consisting of detailed measurements, descriptive observations, statistical calculations, and extensive

graphic documentation. Analysis of this important data set supports interpretations about the family structure and community dynamics of gregarious, theropods interacting on the Sundance tidal flats approximately 167 million years ago.

4:45 **Milner, A. R., Lockley, M., Kirkland, J., Bybee, P. and Mickelson, D.:** ST. GEORGE TRACKSITE, SOUTHWESTERN UTAH: REMARKABLE EARLY JURASSIC (HETTANGIAN) RECORD OF DINOSAURS WALKING, SWIMMING, AND SITTING PROVIDES A DETAILED VIEW OF THE PALEOECOSYSTEM ALONG THE SHORES OF LAKE DIXIE

MILNER, Andrew R., City of St George Utah, Parowan, UT; LOCKLEY, Martin, Univ. of Colorado at Denver, Denver, CO; KIRKLAND, James, Utah Geological Survey, Salt Lake City, UT; BYBEE, Paul, Utah Valley State College, Orem, UT; MICKELSON, Debra, Univ. of Colorado at Boulder, Boulder, CO

Abundant body fossils are being collected in close association with dinosaur traces from the lacustrine Whitmore Point Mbr., Lower Jurassic Moenave Fm. The mudflats and beaches surrounding Lake Dixie were an oasis during deposition of the Wingate erg to the northeast, and preserve evidence of a diverse array of dinosaur behaviors. The traces at the base of the main track sequence are preserved as natural casts in a beach-deposited sandstone that overlies a basal mudstone. Laterally, the sole of this bed records a transition from an exposed mudflat with deep distinct tracks on the east side of the site to subaqueous mud scoured by longshore currents with hundreds of swim tracks to the west. Swim-track preservation is exceptional, showing details of claws, scale scratch lines, and rare skin impressions. The majority of these casts preserve pes claw scratch marks in sets of three, or rarely two, with casts of many digits and claws extending completely out of the sandstone. The vast majority of the traces are oriented parallel to scour marks, suggesting that the animals may have been reacting to being swept off-balance by the N-S currents and that the sand deposited simultaneously with the formation of the traces. These swim (or floundering) tracks are of the same size as *Grallator*, and were probably produced by coelophysoid theropod dinosaurs. Abundant *Grallator*, *Eubrontes*, and *Batrachopus* footprints on the rippled surface of the beach-deposited sandstone show a N-S (or vice versa) trend of travel paralleling the beach. A *Eubrontes* trackway approximately 21 meters long has a tail drag mark and a squatting or resting trace along its path. Apparently the animal stopped and placed both feet parallel as it lowered its body, impressing its metatarsals and resting on its ischial boot. Unique left and right manus impressions a short distance in front of the feet show claws and fingers turned medially. The animal staggered forward about 30 cm and sat once more, impressing its metatarsals and ischial boot, but not its forefeet, before walking across the remainder of the exposed surface.

5:00 **Agnolin, F., Apesteguia, S. And Chiarelli, P.:** THE END OF A MYTH: THE MYSTERIOUS UNGUAL CLAW OF *NOASAURUS LEALI*

AGNOLIN, Federico, APESTEGUIA, Sebastian, CHIARELLI, Pablo, Museo Argentino de Ciencias Naturales, Ciudad de Buenos Aires, Argentina

One of the most striking aspects of abelisaur anatomy is the claimed presence of the raptorial second toe unguinal claw reported for the noosaurid *Noasaurus leali*, an adaptation that resembles dromaeosaurids. The re-study of the putative 'raptorial claw' of *Noasaurus* permitted to recognize the following features: Ungual claw with a strong lateral compression and abnormally curved in lateral view. The articular medial keel is strongly developed as well as the proximo-ventral process. The lateral sulci are symmetrical. These features strongly suggest that this claw is from the manus, and that *Noasaurus* bore sharp and well-developed prehensile manual claws. Furthermore, the absence of a dicotomized lateral sulcus and the lateral bump, rather than autapomorphic features, mostly support the

manual nature of the claws. The observed symmetry in the proximal articular facets suggest its pertaining to a non-lateral digit, perhaps the second one. A second undescribed claw bear the same features and size, except for the, perhaps pathological, absence of the lateral sulcus. As a *Noasaurus* unique feature, both sides of the claws are sub-parallel in dorsal view. Abelisauroid claws were described from pedes material. The *Noasaurus* pedes are unknown, but as suggested by their closely related velocisaurines (e.g. *Velocisaurus*, *Masiakasaurus*, *Santanaraptor*), were probably non-raptorial, but cursorial. The presence of a deep excavation in the ventral side of the *Noasaurus* manual claw as well as the lack of flexor tubercle show abelisauroid affinities. The mentioned features suggest that the claimed ‘velocisaurid’- noasaurid lineage show a good development of the forelimbs whereas the lineage that drove to *Carnotaurus* shows the opposite trend.

- 5:15 **Denton, R., Nesbitt, S., Wolfe, D. and Holtz, T.:** A NEW SMALL THEROPOD DINOSAUR FROM THE MORENO HILL FORMATION (TURONIAN, UPPER CRETACEOUS) OF NEW MEXICO  
DENTON, Robert, Specialized Engineering, Winchester, VA; NESBITT, Sterling, Univ. of California, Berkeley, CA; WOLFE, Douglass, Mesa Southwest Museum, Mesa, AZ; HOLTZ, Thomas, Univ. of Maryland, College Park, MD

The Zuni Basin Dinosaur Site (Turonian, Late Cretaceous) of western New Mexico, has produced a number of new dinosaur taxa, including the therizinosaur *Nothronychus* and ceratopsian *Zuniceratops*. A third proposed taxon is a new small theropod. Discovered in 1997, the new taxon is described on the basis of an articulated and well preserved anterior skull section, including premaxillae, maxillae, partial lacrimals and dentaries. Referred material discovered in 2000 includes a second specimen with a nearly complete posterior appendicular skeleton, partial forelimbs and vertebrae.

Originally considered a putative dromaeosaur, the Zuni small theropod is revised as a basal tetanurine on the presence of the following character states: maxillary antorbital fossa short compared to length of antorbital fenestra; femur with prominent fourth trochanter, lesser trochanter large and developed distal to greater trochanter; craniodistal femoral sulcus absent; cervical centra weakly opisthocoelus; premaxillary and maxillary teeth isodont and laterally compressed with finely serrate anterior and posterior carinae.

- 5:30 **Minjin, B., Rougier, G., Chuluun, M. and Geisler, J.:** NEW EARLY CRETACEOUS GOBICONODONT MAMMAL FROM OSHIH, MONGOLIA

MINJIN, Bolortsetseg, American Museum of Natural History, New York, NY; ROUGIER, Guillermo, Univ. of Louisville, Louisville, KY; CHULUUN, Minjin, Mongolian Univ. of Science and Technology, Ulaanbaatar, Mongolia; GEISLER, Jonathan, Georgia Southern Univ., Statesboro, GA

In the summer of 2003, a partial dentary of a “triconodont” was found in the Cannonball Member of the Oshih/Ashile area (Ovorkhangai Province). These beds are thought to be Early Cretaceous in age. The only mammals previously reported from this locality are gobiconodontid triconodonts, including the type of *Gobiconodon hopsoni* and fragments of another gobiconodont indet. species. Our new specimen (i.e. RCSP03-22) consists of a partial right dentary with a lower incisor, canine, two premolariform teeth, and three molariform teeth; this is so far the best mammalian specimen from Oshih.

We identify RCSP03-22 as a gobiconodontid based on an enlarged i1; absence of accessory cusps on p1; procumbent incisor, canine, and p1; and premolariform teeth with crowns higher than their mesiodistal diameters. Comparison of our specimen to other gobiconodontids indicates that it represents a new species. Our specimen differs from *G. hopsoni* by its small size, in having a mesially positioned cusp e, and in having longer roots. Our specimen is unlike *G. ostromi* in being smaller and in having a more robust dentary ventral to the anterior premolariform teeth. Unlike both *G. zofiae* and *G. borissiaki*

the meckelian groove in RCSP03-22 does not extend as far anteriorly. It appeared that our specimen differed from other Asiatic gobiconodontids in lacking a p4; however, an X-ray photo revealed a double-rooted alveolus for p4 that is partially filled with bone, a condition also reported in *G. ostromi*. Our specimen also differs from *G. borissiaki* in having cusp b higher than cusp d on m1, and it differs from *G. hoburensis* in having a smaller cusp b on m1. A phylogenetic analysis of triconodonts and other basal mammals is underway to establish the affinities of this specimen and the interrelationships of gobiconodontids. Our find adds to the recent discoveries of gobiconodontids, or related forms from China, Russia, Spain and possibly Japan. Gobiconodontids are one of the most conspicuous Early Cretaceous groups of mammals with a remarkable diversity and geographical distribution.

5:45 **Wheeler, H. T.:** MACHAIRODONT CANINE FUNCTIONAL MORPHOLOGY IS ABOUT MORE THAN SABER SHAPE: THE VARIED ROLE OF THE INCISORS IN DIFFERENT KILLING BITE MODELS

WHEELER, H. Todd, Daedalus Paleoengineering, West Linn, OR

The terms scimitar and dirk-tooth are widely understood for saber shape. Apart from having nothing in common with the properties of the weapons from which the words derive, nothing would be gained by inventing new terms. Our bite research however, does show a distinction between the first order bite in which the canines cut on the down stroke, and require opening to release; and the more sophisticated second order bite, in which the sabers cut their way out of the prey in one continuous arc without the cat ever having to open its mouth.

Dirk-toothed Machairodonts of similar lateral saber profile have other dramatic variations. The canine width to thickness ratio (APD/LLD) for felids, and some nimravids, is around 2:1. These cats have bell curve shaped cemento-enamel junctions (CEJs) comparable in height to the APD of the tooth, mildly prognathous incisor arcades, and deciduous canines of scimitar shape half the length of the secondaries. However Barbourfelids and Eusmilids have much thinner sabers approaching a 4:1 ratio, extremely prognathous and/or procumbent incisors, and deciduous canines approaching the size of the secondary teeth. Our existing dirk-toothed felid bite model will not apply to these Nimravids.

There are also some interesting considerations with respect to the scimitar-tooth bite. In lateral profile, APD to length, APD/LLD ratio, and general CEJ shape, the sabers of Machairodus are the same as *Homotherium*. Scimitar-toothed felids in general have incisors that are much larger and more prognathous than other saber-toothed cats. In the Homotherini however, the CEJ is higher, and the incisors are larger and more prognathous, with serrated margins, and may be able to cut their way out of some prey; something our testing has shown the other incisor arcades cannot do.

The Homotherini and Barbourfelid bites will remain speculative until experimentally verified, but at this point we can quantitatively distinguish four unique combinations of saber shape, CEJ, and incisor morphology.

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