THE XENARTHRA FROM THE ITABORAÍ BASIN (ITABORAIAN, UPPER PALEOCENE) RIO DE JANEIRO, BRAZIL

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The discovery of xenarthran remains in Itaboraí Basin was reported in 1949, but they were only formally studied in the mid-seventies. Two osteoderms were first assigned to *Prostegotherium astrifer* Ameghino, 1902, but latter reviewed and considered a new taxon—*Riostegotherium yanei* Oliveira & Bergqvist, 1998—based on the presence of more than ten pits in the groove around the central figure of fixed scutes.

In the early eighties, two cingulate astragali were described and assigned to a dasypodid (the larger) and to a glyptodontid. A posterior review of those astragali suggested that the features argued as suggestive of glyptodontid affinities are also presented in several other "edentate" tarsals.

In the nineties, new xenarthran remains were discovered among the fossils recovered from the basin. The revision and description of the postcranium are the goals of this contribution.

As in other xenarthrans, the humeri presents a developed deltopectoral shelf, a prominent supinatory crest and a broad distal end, but also bear several features shared by other "edentates": a pectoral crest medially directed, pectoral and deltoid tuberosities developed, deltopectoral shelf extending more than halfway of total length, supinatory crest with a straight border and wide and shallow bicipital groove. The ulna preserved only the proximal part. As in most Dasypodidae, the olecranon is long in thin, but the epiphysis is transversely large and curved, as in *Metacheiromys*. Two different patterns of xenarthrans astragali are confirmed for Itaboraí. The smaller has a more primitive morphology—body and neck slender and longer, though lacking astragalar foramen. The larger resembles dasypodids with a broad and short trochlea and a more oblique neck. Both bear sustentacular and ectal facets aligned on the same axis of rotation, considered by some authors as a synapomorphy of Xenarthra and Palaeonodonta.

Although the scutes surely indicate the presence of cingulates in Itaboraí, the same cannot be assumed by the limb bones, as several features are shared by other "edentates". A careful review is urged for a better definition of each edentate-like group.

THE BRAINCASE AND EAR REGION OF *ICHTHYOSTEGA*: A UNIQUELY SPECIALISED EAR IN AN EXCEPTIONALLY PRIMITIVE TETRAPOD BRAINCASE

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Surface preparation and CT scanning of new *Ichthyostega* specimens has allowed the first anatomically plausible interpretation of the braincase and ear region. The highly autapomorphic otic structure suggests specialisation for underwater audition, but it also shows some very primitive features. The otoccipital region is unusually long for a stem tetrapod but the saccular chambers are remarkably small and anteriorly placed. The combination of a tiny ear and long hindbrain is unique among tetrapods. The otoccipital bears deep posterior flanges suturing to the skull roof and there are no posttemporal fossae. The vestibular fontanelle is not confluent with the fenestra vestibuli; this may be a primitive trait, but is unique among early tetrapods.

Large chambers on each side of the braincase, constrained by flanges of the braincase and skull roof, extend above the otic capsules almost to the midline. With its reinforced walls, the chamber is unique to *Ichthyostega*, but may correspond in part to a spiracular recess identified in other early tetrapods. The stapes appears to have two heads separated by large stapedial foramen. The ventral head articulates with the basioccipital, while the dorsal head inserts into a hole in the braincase wall near the saccular chamber. The stapedial shaf" is an almost circular, anterodorsally curved lamina of very thin bone projecting dorsolaterally into the chamber alongside the braincase, almost contacting the transverse proötic buttress. The chamber likely housed a diverticulum of the spiracular tract (or middle ear). If air-filled but sealable, it could have acted as a transducer for water-borne sound, transmitting it to the stapes if the latter were incorporated into a ventral, soft tissue wall to the chamber. This would be functionally comparable to ear function in underwater sound reception in *Xenopus* and ostariophysans. The specialised ear of *Ichthyostega*, apparently adapted for aquatic hearing, provides clues to the origin of the tetrapod auditory system. We cannot assume that the transformation of the fish spiracular region into the tetrapod ear involved a direct conversion to aerial hearing.

HOW AND WHY DO SOME SHREWS HAVE RED TEETH?

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Enamel coloration has long been used to distinguish the two living subfamilies of shrews: Soricinae (red-toothed) and Croidurinae (white-toothed). While known to contain iron, neither the composition nor the function of the red enamel has been fully established. X-ray diffraction and SEM studies of *Blarina* enamel after EDTA and nitric acid extraction conclusively demonstrate that the red parts consist of discrete layers of goethite, FeO(OH), crystallites (herein termed siderose enamel) deposited externally to white hydroxyapatite enamel by the interrod clefts between the Tomes processes of ameloblasts. As the interrod clefts change from depositing hydroxyapatite to goethite interprismatic crystallites, the Tomes processes continue to deposit hydroxyapatite prisms but the processes and the prisms gradually attenuate and disappear as amelogenesis progresses.

Several lines of evidence demonstrate that siderose enamel is harder than hydroxyapaptite enamel and it is distributed where resistance to dental abrasion would be critical to maintenance of puncturing and shearing functions. This appears to contradict the fact that the majority of shrew prey items are soft bodied invertebrates. However, scattered data indicate that soricine shrews not only ingest a larger percentage of earthworms and subterranean larvae but also chew them more thoroughly than do crocidurine shrews. We believe that siderose enamel serves to minimize dental abrasion during mastication of prey items with silt and sand adhering to them or in their guts.

It is difficult to trace similar iron mineralization in fossil teeth because seconday iron staining is so common but numerous examples of *Lambdopsalis bulla*, a Paleocene multituberculate, bear bright red enamel on their incisors and second molars and the color of fossil rodent incisors and soricine teeth can persist for millions of years. Various iron oxide compounds have been reported in ectodermally derived dental cuticle or in the outermost dental layers of extant fish, salamanders, snakes and rodents suggesting that iron compunds were important throught much of vertebrate history.

CRANIAL STRUCTURE AND AFFINITIES OF THE LOWER PERMIAN CAPTORHINID REPTILE *CAPTORHINIKOS PARVUS* (REPTILIA, CAPTORHINIDAE)

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The cranial morphology of the Lower Permian captorhinid reptile *Captorhinikos parvus* (Reptilia, Captorhinidae) is re-interpreted. Re-examination and further preparation of 7 specimens from the original study characterizing the species, as well as preparation and examination of 16 new specimens, all from the Hennessy Formation of Central Oklahoma provide significant new information bearing on the characterization of *C. parvus*. This study shows it to be a valid and distinct taxon based on very small adults with multiple maxillary and mandibular tooth rows. This determination supports Olson's original characterization in the broadest sense, but significant revision and additions to cranial morphology and relationships can now be offered. Fine scale preparation of these excellently preserved specimens has yielded one of the most complete pictures of cranial structure in a basal reptile, including the morphology and interrelationships of palatal as well as braincase, and stapedial elements. Three single rows of small palatal teeth radiate anteriorly, anterolaterally, and laterally from the medial edge of the transverse flange. In addition, the suture connecting the vomer and palatine bones bisects the facet marking the contact between the palate and the maxilla anterior-posteriorly. Visualization of individual braincase elements, including opisthotic, basioccipital, and stapes bones allows for a much more complete braincase reconstruction. Preliminary phylogenetic analysis reinforces the validity of the taxon and hints at possible affinities with the small, single rowed captorhinid reptile *Saurorictus australis*. Confirmation that *C. parvus* is indeed based on adult specimens also invites speculation that the taxon represents an example of miniaturization within the Captorhinidae.

THE PHYLOGENETIC RELATIONSHIPS OF MEGALOSAURIDAE WITHIN BASAL TETANURINE THEROPODS (DINOSAURIA).

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The discovery of *Poekilopleuron? valesdunensis* from the Middle Bathonian of Normandy provides us cranial and postcranial characters that are crucial for reconstructing the phylogeny of basal tetanurine theropods commonly related to poorly known Megalosauridae.

Phylogenetic analyses of a data matrix of 107 characters and 22 ingroup taxa (including 9 European taxa) in a branch and bound search in PAUP support the monophyly of Megalosauridae within a monophyletic Spinosauroidea (Megalosauridae + Spinosauridae + *Torvosaurus*) which is the sister taxon to Neotetanurae (Allosauroidea + Coelurosauria). *Ceratosaurus* lies closer to Tetanurae than to *Coelophysis*. *Poekilopleuron? valesdunensis*, *Eustreptospondylus*, *Streptospondylus* and *Afrovenator* are united within Megalosauridae. *Lourinhanosaurus* is found to be another Megalosauridae, while *Metriacanthosaurus* and *Erectopus*, commonly referred to that clade, are more closely related to Allosauroidea. *Neovenator* is a basal allosauroid.

The resulting strict consensus tree superimposed on the geochronologic time scale suggests that Ceratosauria, Spinosauroidea, Allosauroidea and Coelurosauria were distinct as early as the Early Jurassic. With nine valid taxa, the Middle to Late Jurassic European large theropod fauna thus appears to be more diversified than what has previously been recognized. It is dominated by spinosauroids while these are greatly outnumbered by allosauroids in the North American Morrison Formation.

MUSCULOSKELETAL CORRELATES AND CONSEQUENCES OF CHANGES IN STANCE AND GAIT DURING SYNAPSID EVOLUTION

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A general trend in several synapsid lineages was from the primitive obligate sprawling locomotion of pelycosaurs, with horizontal excursions of the humerus and femur and enhancement of stride length by horizontal undulations of the trunk, toward increasingly upright stance and gait, with more sagittal motion of these bones and enhancement of stride length by vertical movements of the trunk. Major changes in skeletal structure accompanied and permitted these changes. The present study is primarily an analysis of the actions and roles of major proximal muscles on the shoulder joint and hip joint about each of three orthogonal axes: anteroposterior (abduction and adduction), dorsoventral (horizontal protraction and retraction), and mediolateral (sagittal protraction and retraction), as well as the nonorthogonal proximodistal axis (long-axis rotation and derotation). The change in limb posture imposed functional changes on certain muscles but not others. Compensatory alterations in attachments or in skeletal configuration allowed some muscles to continue functioning as they did before. In early cynodonts the scapulocoracoid had, in my opinion, become quite moblile, contributing to stride

length by anteroposterior rocking on a flexible acromioclavicular joint. This mobility was secondarily lost in monotremes but greatly increased in therians by the addition of considerable flexibility of the sternoclavicular joint. Thus, muscles such as levator scapulae that had previously stablized the pectoral girdle, but not significantly moved it, became important movers of the girdle.

EXTRATERRESTRIAL BOLIDE IMPACTS AND BIOTIC CHANGE IN NORTH AMERICAN MAMMALS

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Large bolide impacts are surprisingly frequent, and the Cretaceous-Tertiary mass extinction of mammals and other vertebrates is incontrovertibly linked to one of the largest known impact structures. Could impacts also drive smaller-scale episodes of change? Fortunately, Cenozoic impact structures from the northern continents are so well documented that this record can be subjected to time series analysis. I binned craters into 1.0 m.y.-long intervals to match the quantitative biochronological time scale of North American mammals, and then found the largest crater in each bin. About half the bins included at least one crater >1 km. Maximum crater sizes were cross-correlated with origination rates, extinction rates, total and net turnover rates, changes in body mass distributions, and rates of taxonomic replacement independent of background turnover. No convincing correlations were found, even after lagging the data sets relative to one another. Likewise, Mann-Whitney U-tests show that bins with and without medium- to large-sized craters have indistinguishable rates of biotic change. Furthermore, there are no close (<5 m.y.) temporal matches between key biotic events, such as the Paleocene-Eocene, mid-Eocene, and mid-Oligocene faunal reorganizations, and the very largest craters, most importantly the geographically proximate late Eocene Popigai and Chesapeake structures. Genuine extinction pulses are rare to start with in the mammalian record: the only clear-cut post-K-T example is the Mio-Pliocene extinction episode, which may or may not be linked to the Messinian Salinity Crisis. Previous studies also failed to find any rigorous, consistent link between climate change and large-scale changes in the North American mammal biota. Nonetheless, we do have good evidence that such non-random patterns as a dynamic equilibrium in taxonomic diversity do result from biotic interactions. Thus, the results emphasize the point that intrinsic dynamical laws related to ecological processes such as competition may have done more to shape mammalian evolution than abiotic, extrinsic environmental forcing factors.

THE FOSSIL FISHES FROM PLIOCENE LOCALITIES NEAR TULA DE ALLENDE, HIDALGO, MEXICO.

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The recent field works on the Pliocene lake deposits in Hidalgo state, central Mexico, composed of clay-volcanic sand, and ashes, mainly in “La Cementera”, “Las tortas” and “La Viga de Tula” localities, near Tula de Allende city, revealed the presence of at leas two fossil fish taxa. The most abundant and best preserved vertebrate remains are belong to a Catostimid form, including complete bones of the opercular series, jaws, skull, tails, parts of the Weber apparatus, and pharyngeal teeth. These bones are identified as *Ictiobus* in base of their characters, such as the presence of strong striated opercular, frontal-parietal fontanelle, frontal-ethmoid fontanelle, and rounded and laterally compressed pharyngeal teeth. This is the first fossil of *Ictibus* in Mexico; the only one previous record of ctostomid in the country is the “Moxostoma” of the Pleistocene deposits of Lake Chapala, Jalisco state. Also catfish remains were found including pectoral and dorsal spines and tail elements, pectoral girdle and Weber apparatus fragments, and bones of the lower jaw. The pectoral spine dentition is similar to *Ictalurus spodius* and allows to confer this record to that species described on base of its fossil from Pleistocene sediments of Chapala Lake. This is the older record for a catfish known in Mexico and the second for this catfish species. Additional fossil found in “La cementera” comprise undescribed ostracods, large mammal bones fragments, and horse upper teeth of *Nannippus cf. peninsulatus* (Blancan index fossil for North America) which confirm the Late Tertiary age. The sequence of these lacustrine localities in Hidalgo state can be related to other localities in this area of the country with pluvio-lacustrine sediments, such as “Zacualtipan”, “Las Golondrinas”, “Actopan” and “Tepexi del Río”, where remains of *N. peninsulatus* had been recovered. Desirable future paleontological and geological studies in Tula de Allende and other areas of Hidalgo state and the Mexican transvolcanic belt will show the characteristics of these ancient Lakes and its paleobiota.

3-D SCAN OF A *TYRANNOSAURUS REX* SKULL

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The challenge of three dimensionally scanning large fossils has often led to expensive solutions usually not affordable by many researchers. We present a cost effective alternative that yielded impressive results. The fossil scanned in this case is a complete skull of an adult *Tyrannosaurus rex* from a specimen housed in the Black Hills Institute of Geological Research, often referred to as Stan. It is largely disarticulated with all elements preserved with minimal distortion. CT scanning the original was dismissed as a viable option because of vastly increased shipping costs and significant risks of specimen damage during shipping and scanning. Many of the original, fossil bones also were extremely dense and prone to X-ray artifacts and would yield little, if any, internal information if used. Optical scanning also was rejected due to the numerous undercuts present in many of the bones. To extract this complex morphology with the least amount of effort, significantly reduce the overall costs of the project, and eliminate all risks to the specimen, we decided to CT scan polyurethane casts of the original cranial elements. Each cast skull bone was scanned on a GE Medical CT scanner with 1 mm slice resolution. Using MIMICS software we were able to quickly create very accurate 3-D virtual models. These virtual models were easily reduced in scale for the rapid prototyping of accurate 1/6th scale replicas of the individual bones or the complete, assembled skull. Accurate digital files were constructed that provide a permanent archive of the fossils in high resolution. These files can then be used to make accurate measurements, and instantaneously calculate volumes of selected bones, and make digital comparisons with other specimens. The virtual model also will be very useful for biomechanical modeling.

LEPOSPONDYL DIVERSITY IN THE EARLY PERMIAN AND LATE PENNSYLVANIAN

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Lepospondyls are small anamniotes united by simple, spool-shaped vertebrae, a lack of labyrinthine in-folding of tooth enamel, reduced number of cranial ossifications, and a general tendency towards elongation. Lepospondyli includes five distinct orders, Microsauria, Aïstopoda, Nectridea, Lysorophia, and Adelospondyli, which may or may not be monophyletic groups. Recent phylogenetic analyses and developmental studies have suggested that lepospondyls gave rise to some, or all, of the extant modern amphibians (Lissamphibia). Understanding patterns of diversity of lepospondyls through time and space may provide clues to whether such hypotheses are likely.

Using a newly assembled database of Pennsylvanian and Permian fossil vertebrate localities, we examined every occurrence of lepospondyls, with a particular focus on differences of lepospondyl abundance in the Pennsylvanian and Early Permian. Lepospondyl diversity appears to be greatest in the Pennsylvanian. Lepospondyls are represented predominantly in the Early Permian by three taxa: *Diplocaulus*, *Lysorophus*, and *Pantylus*, and are usually outnumbered by other anamniotes, especially dissorophoids. The species richness (numbers of different species at a single locality) of the Pennsylvanian is matched in the Early Permian only at Fort Sill, Oklahoma, which suggests that other factors (e.g., environmental, taphonomic) may be biasing the taxa present. These factors are examined in detail. Collecting biases may also be present; microfossils found at several localities suggest that application of techniques commonly used at Mesozoic and Cenozoic localities (i.e., screen washing) may change our perception of the relative abundance of small vertebrates like lepospondyls in Permian deposits.

A PHYLOGENETIC ANALYSIS OF RODENT GENERA IN THE FAMILY ISCHYROMYIDAE

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An analysis of taxa currently included in the family Ischyromyidae was undertaken to study relationships among taxa known to be closely related evolutionarily. Descriptions of all known material for each genus were reviewed and/or observations were made and a data matrix of 30 dental characteristics was generated and subjected to phylogenetic analysis using parsimony. Results of the analysis confirm outgroup placement of *Eurymylus,* and *Tribosphenomys,* with the latter most closely related to the ischyromyid clade. Other results indicate that *Knightomys*, a sciurid, may be more closely related to the ischyromyids than previously thought. Overall, results of the phylogenetic analysis are consistent with the stratigraphic data currently known for each taxa and a number of useful synapomorphies which divide the genera into several distinct clades have been identified. There are two distinct clades which include genera that appear early in the fossil record and three clades include general that appear later. These results suggest that while the inclusion of skull features would provide for a more robust test of phylogeny, some information can be gained via an analysis of dental features alone, which is the type of fossil material most abundantly found.

A LATE CRETACEOUS ASSOCIATION FROM ALTARES, CHIHUAHUA, MÉXICO.

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The Mesozoic terrestrial fauna of México is poorly know, and the record consists mainly of isolated finds of dinosaurs. Several localities bearing continental Late Cretaceous fossil vertebrates were located in the northeastern corner of Chihuahua. The fossils were recovered from a sequence of yellow clays and sandstones. No geological and stratigraphic framework exist that allows a detailed correlationship with the outcrops of the Javelina and Aguja formations; but these units have been tentatively identified on the Mexican side.

This study refers to one fossiliferous site where a ceratopsians and pollen were recovered from the clay, and petrified wood found in growth position was collected in the sandstone. The ceratopid includes a left squamosal of 770 mm length, 290 mm width, preserving five epoccipitals; and a supraorbital horncore of 420 mm length. The material is referred to *Chasmosaurus mariscalensis*. The pollen was identified as *Tricolpites* and *Tricolporites*(angiosperms) and *Pinuspollenites* (gymnosperm). A kind of monolete echinated spore was also recovered. The pollen diversity is low in comparasion with that described from the Aguja Fm.

The morphological characters present in the wood suggests it belongs to the extant family Podocarpaceae, and shows similarities with *Podocarpoxilon*, described for the Late Cretaceous flora of the Olmos Fm., Coahuila. Conifers podocarpaceae-like were the dominant group during the Campanian in southwestern Texas, suggesting woodlands.

The pollen taxa and the chasmosaurinae are the same as those present in the Big Bend National Park, extending their distribution southwardly and suggesting a continuum in the depositional conditions, maybe a floodplain.

The study of this association would provide information for a better understanding of the paleobiogeography during the Late Cretaceous.

PERMIAN DICYNODONTS IN THE TWENTY-FIRST CENTURY

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Dicynodonts were the most abundant and diverse group of Late Permian terrestrial vertebrate herbivores. Although the study of dicynodonts dates to the time of Owen, new research is changing our view of dicynodonts and their place in the Permian world. The phylogeny of dicynodonts is now better known than at any previous time, thanks to recent cladistic studies. This increasing phylogenetic knowledge provides a framework for testing evolutionary, biogeographic, and biostratigraphic hypotheses. The discovery of several new, basal dicynodonts from the *Tapinocephalus* Assemblage Zone of South Africa supports a Gondwanan origin for the group, which fits well with recent challenges to the traditional hypothesis of a Laurasian origin of most major therapsid clades. Six new dicynodont genera also have been described recently from Russia. Among the new Russian taxa may be the Permian sister taxon of the Kannemeyeriiformes, suggesting that this important Triassic clade may have originated in Laurasia. The success of dicynodonts in the Permian has been attributed largely to their complex masticatory system, based on a propalinal jaw movement. However, new studies have shown that at least one non-dicynodont anomodont also possessed propaliny, and there is evidence that this feature may have evolved twice within Anomodontia. Finally, dicynodonts continue to be used extensively in Permian biostratigraphy. As our understanding of dicynodont phylogeny and stratigraphy improves, we may need to reassess some previously recognized biostratigraphic correlations and divisions. For example, the well known genus *Dicynodon* may be paraphyletic, and careful biogeographic, stratigraphic, and phylogenetic research will be necessary to determine whether it can be used for correlations across widely separated basins. Much of the new research on dicynodonts challenges traditional ideas, and demonstrates the importance of new methods and new discoveries to our understanding of extinct synapsids. Only through similarly detailed consideration of other terrestrial organisms will an accurate picture of the Permian world and the extinction that ended it emerge.

FRESHWATER FISHES OF THE LOS RASTROS FORMATION (MIDDLE TRIASSIC) ISCHIGUALASTO-VILLA UNION BASIN, ARGENTINA

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The continental Triassic deposits of the Ischigualasto-Villa Unión Basin in northwestern Argentina yield pivotal tetrapod faunas, but fish remains are rarely described, and are only known from lacustrine facies of the Los Rastros Formation (Ladinian?). The fishes described here are preserved in a mass kill layer in the fifth lacustrine hemicycle of Los Rastros Formation near Cañón del Gualo (La Rioja Province). Prior to our work, only one fish taxon had been described from the Los Rastros Formation. This fish was referred to the Australian genus *Myriolepis*, and biogeographic relationships were proposed on the basis of this assignment. However, the material is poorly preserved, and the assignment to the Australian genus is questionable. Based on five new specimens, we have identified three additional basal actinopterygian fishes in the Los Rastros Formation. Unfortunately, because of the preservation of the material only one of the new taxa can be diagnosed. This specimen represents the first record of the Redfieldiiformes in South America, and it is characterized by its strikingly large body size. Interestingly, the other two new taxa from the same bed are also represented by large specimens (400-600 mm estimated total length). The close association of these relatively large specimens in a single bed is suggestive of some type of event mortality. Selective preservation, in turn, might have biased the sample with regard to the preservation of smaller forms. A preservation bias might also explain the absence of ceratodont dipnoans, which tend to occur with redfieldiiforms in other Triassic sediments of Gondwana.

CHEIROLEPIFORM FISH FROM THE DEVONIAN OF RED HILL, NEVADA

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Middle-Late Devonian actinopterygians were poorly diversified and represented by only seven genera (*Cheirolepis, Howqualepis, Mimia, Moythomasia, Osorioichthys, Stegotrachelus*, and *Tegeolepis*). Although complete specimens are rare, scales are found world-wide. The Cheirolepididae, representing one of the oldest actinopterygian groups, is a monogeneric family known from *Cheirolepis canadensis* (Frasnian; Miguasha, Canada), *C. trailli* (Givetian; Scotland), and questionably by *C. gaugeri* (Givetian; Germany), and *C. gracilis* (Givetian; Germany). A few years ago, additional cheirolepid remains (lower jaw, scales) from the Middle-Upper Devonian boundary of Red Hill, Nevada, were identified as *Cheirolepis* sp. cf. *C. canadensis*. Currently, *Cheirolepis* is interpreted as basal actinopterygian, and one of the oldest actinopterygians for which articulated specimens are known.

New material recovered from Red Hill, Nevada, includes a well preserved specimen with head and anterior part of body (part and counterpart). This material provides significant, additional information on *Cheirolepis* such as the absence of the pineal plate and pineal foramen and the presence of a very deep anterior operculum, extending close to the anterodorsal margin of the preoperculum, a palatoquadrate covered by dentition, and small teeth extending below the parasphenoid. The dermal pectoral girdle consists of a small posttemporal, a large, elongate supracleithrum, a short and massive cleithrum, and a long, robust, triangular clavicle. The ornamentation of cranial bones consists of very regularly distributed ridges of ganoine and a few tubercles that are also ordered in lines. Although the fish from Red Hill shares some similarities with *C. canadensis*, it also differs from this taxon and *C. trailli*, and a unique combination of characters shows that it represents a new species.

PHYLOGENETICS OF LIVING AND EXTINCT INSECTIVORAN MAMMALS: APPLYING TOTAL EVIDENCE AND SUPERCOMPUTING

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One of the more intriguing proposals in higher mammalian phylogenetics during the last decade concerns the affinities of the endemic African insectivoran groups Tenrecidae and Chrysochloridae. For most of the 20th century, tenrecs and golden moles were considered to be part of the Lipotyphla, along with shrews, hedgehogs, moles, and solenodons. More recently, a large amount of sequence data has been interpreted to support a close relationship among tenrecs, golden moles, elephants, sea cows, hyraxes, elephant shrews, and aardvarks, collectively known as the Afrotheria. Here, we test the support for Afrotheria from approximately 20kb of sequence data using several distinct analyses that vary statements of sequence homology and character transformation weights (including gaps). We combine the molecular data with a new morphological matrix that samples extinct insectivorans, condylarths, anagalids, embrithopods, desmostylians, proboscideans, and Cretaceous eutherians, all of which have been hypothesized either to nest within Afrotheria or influence the position of placental root.

Our results indicate that the Afrotheria as a group is relatively robust to changes in molecular sequence alignment and transformation weights, and is much better supported by molecular data than the Lipotyphla. On the other hand, parsimonious trees derived from morphological data that sample both living and extinct taxa contradict monophyly of the Afrotheria; and the combined topologies vary considerably depending on initial assumptions about homology and weighting. Methods for identifying an optimal parameter combination are discussed, as are the implications for inferring an accurate phylogeny of placental mammals.

HOW MUCH DID *ARCHAEOPTERYX* AND *QUETZALCOATLUS* WEIGH? MASS ESTIMATION BY MULTIVARIATE ANALYSIS OF BONE DIMENSIONS

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Body mass is an important aspect of the biology of an organism. Many methods have been proposed to estimate body mass from skeletal measurements. Most have been based on univariate regression of the mass of specimens against single measurements, usually of limb bones, and subsequent use of the regression relationship to predict specimens of unknown mass. Although the measures used are often based on functional criteria (e.g., diameters of weight-bearing bones), typically no attempt is made to compare the degrees of correlation of these measures with body mass against other possible skeletal measures. Another class of body-size estimates has been based on volumetric models of reconstructed body forms. These models are advantageous for fossil organisms with no modern analogs, but require complete skeletons to allow for reconstruction and involve various conjectures about the anatomy of soft tissues.

We describe the use of a simple multivariate method (principal component analysis) to predict body mass from sets of log-transformed skeletal measurements, and compare the results of these predictions with mass estimates based on univariate regression of a variety of elements. The multivariate method has the advantages of using measurements that provide information on both body size and shape, of averaging the predictive values of all individual measures and their prediction errors, and of not requiring complete skeletons.

We used both ontogenetic and interspecific data on modern birds, bats, and crocodilians to test the predictive abilities of univariate versus multivariate estimates of body mass and to compare the predictive values of individual measurements. Different bone measurements varied widely in their ability to predict body mass, but in all cases a multivariate approach gives a much better estimate than any univariate method. We then applied the multivariate and volumetric methods to estimate body sizes of three species of pterosaurs, including the giant *Quetzalcoatlus*, and of *Archaeopteryx*. Depending on the body density used to scale volume to mass, we estimate the body mass of *Quetzalcoatlus* to be 90-120 kg.

A PHYLOGENETIC APPROACH TO GONDWANA BIOGEOGRAPHY

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Widespread use of cladistic methodology during the last decades has made it possible to compile enough phylogenetic data to test biogeographic hypotheses using parsimony methods. Here we attempt a cladistic reconstruction of the Gondwana breakup. We analyze eleven vertebrate phylogenetic data sets using Brooks Parsimony Analysis in order to produce a comprehensive hypothesis of the historic relationships. Our data include phylogenies of Cichlidae (freshwater fishes), Dipnoi (lungfishes), "peirosaurids" and Araripesuchidae (extinct Crocodylomorpha), Neoceratosauria and Spinosauroidea (theropod dinosaurs), "Titanosauria" and Dicraeosauridae (sauropod dinosaurs), Ratites (ostriches and relatives), Nataloidea (bats), and Gondwanatheria (extinct mammals) obtained from the literature. To produce a matrix of areas versus taxa, ancestral and terminal taxa specified by the phylogenies were coded according to the presence of their descendants in each presumptive area of endemism. A single most parsimonious area cladogram was selected using global parsimony analysis (127 steps; consistency index = 0.74; retention index = 0.61). The following set of area relationships was specified: (Mongolia ((New Zealand, Australia), (Africa (India (Madagascar (Argentina, Brazil)))))). According to this hypothesis, the first vicariant event associated with the break up of the Gondwanan supercontinent was the separation of Australia and New Zealand from the remaining landmasses (Upper Jurassic-Early Cretaceous). The formation of the South Atlantic Ocean and the Strait of Mozambique subsequently lead to isolation of Africa from surrounding continental plates (Albian-Aptian). According to our data set, India, Madagascar and South America share a common history subsequent to the isolation of Africa. Such relationship may be explained by a lasting connection of the southern tip of South America to Antarctica, Madagascar, and the Indian subcontinent. We predict that further fossil discover-

ies in Antarctica will reveal taxa closely related to species in India, South America and Madagascar.

SHOULDER MECHANICS IN GLIDING BIRDS: IMPLICATIONS FOR THE EVOLUTION OF FORELIMB AERODYNAMICS

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The avian shoulder joint is highly mobile to permit flapping, yet also stable enough to prevent dislocation. Bony and soft tissues making up the joint must accommodate loads to balance muscular, aerodynamic, gravitational, and inertial forces on the wing. The simplest scenario for understanding this force balance is steady-speed gliding. Classical models hypothesize that the upward aerodynamic force on the outstretched wing is balanced by a downward pectoralis force. These opposing torques require the coracoid to be loaded by the humeral head as a compressive strut. However, the saddle-shaped glenoid provides no articular surface ventrally to prevent dislocation by the massive pectoralis. A ligament spanning from the acrocoracoid process to the humerus (the acrocoracohumeral ligament) is well positioned to act as a tensile brace and counter dislocation. We propose that this ligament is a critical structural component that maintains integrity of the shoulder joint.

On the line to birds, the glenoid reoriented from its ancestral archosaurian condition and aerodynamic forces became increasingly important. Understanding the relative magnitudes and balance among internal and external forces will help constrain scenarios for the origin of flight.

MIDDLE MIOCENE PIKAS (LAGOMORPHA, OCHOTONIDAE) FROM NORTH AMERICA: INTRASPECIFIC VARIATION, PALEOHABITAT, AND DIVERSITY

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Fossil pikas have been reported from many North American faunal assemblages of middle Miocene age, but because most samples contain only a few isolated teeth, variation within species and overall diversity of the group have been difficult to assess. Recent work on a large sample of the archaic ochotonids *Russellagus* and *Hesperolagomys* from Barstovian and Clarendonian localities of Nebraska and reexamination of material from the Barstovian Wood Mountain Formation of Saskatchewan has provided information on intraspecific variation in dental and cranial features of these taxa. *Russellagus vonhofi* from all studied sites shows cranial and dental variation expected for a single species. Dentitions of *Russellagus* are slightly larger than those of the modern North American pika *Ochotona princeps*. Comparison of material attributed to *Hesperolagomys* from the Barstovian Valentine Railway Quarries of Nebraska with type material of *Hesperolagomys fluviatilis* from Wood Mountain, however, indicates that the Railway Quarries sample represents a separate, previously undescribed species. This new species of *Hesperolagomys* is larger than both *H. fluviatilis* and the type species *H. galbreathi* from Clarendonian localities of Nevada and Nebraska, and is near *Ochotona princeps* in size of jaws and teeth.

Russellagus and *Hesperolagomys* share several characteristics with the fully hypsodont *Oreolagus*, known from the early to middle Miocene of the Great Plains and Rocky Mountains, but also possess many primitive lagomorph characters. Whereas *Oreolagus* is rarely found with archaic ochotonids, *Russellagus* and *Hesperolagomys* are commonly sympatric and seem to have lived in lower relief, more mesic environments than *Oreolagus*.

The diversity of ochotonids rivaled that of leporids in the middle Miocene of North America. Archaic ochotonids maintained relatively high diversity until they disappeared from the North American record at the end of the Clarendonian.

SPEED IN TYRANNOSAURS

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Competing theories about speed in giant theropods can be tested with combinations of scaling parameters, Recent analogues, and fossil footprints. Models based on elephant analogues are inferior to those based on rhinos, because all theropods agree with all rhinos in possessing: high flexure at all joints, permitting elastic rebound during fast runs; large cnemial crest, affording high leverage for knee extension during rebound; long, compact metatarsus with large calcaneum tuber or hypotarsus tuber, providing high leverage for ankle extension and long ankle-segment contribution to the stroke. For a given body mass, giant theropods possess greater strength to resist bending in the limbs than do elephants because the cross-section of the femur is greater than that of the elephant femur and humerus combined.

Tyrannosaurid footprints from the Lance Formation at Glenrock, Wyoming, show a cruising speed as high or higher than that of small theropods. There is no evidence that large theropods were slower, on average, than small theropods. Large theropod footprint speeds are much higher than those of mammoths and mastodons. Tyrannosaurs were not bipedal elephants.

OSTEOLOGICAL DESCRIPTION OF AN ELEPHANT BIRD EMBRYO USING COMPUTED TOMOGRAPHY AND RAPID PROTOTYPING, WITH A DISCUSSION OF GROWTH RATES IN *AEPYORNIS*

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Very little is known regarding the embryonic skeleton of the extinct elephant bird, *Aepyornis*, largely due to our hesitation in breaking open intact eggs of this taxon. High resolution x-ray computed tomography (CT), however, provides a non-destructive method for viewing the internal structures of such eggs. The combination of CT and three-dimensional rapid prototyping technology made possible the description and reconstruction of a disarticulated embryonic skeleton of *Aepyornis* preserved within a complete egg. Skeletal elements digitally retrieved from the egg include: the braincase, palate, rostrum, vertebral column, and both fore- and hindlimbs. A surprising number of detailed cranial characteristics are preserved. For example, the path of the cranial carotid artery through the basisphenoid into the dorsum sellae is clearly visible with the aid of CT images. The tuba auditiva can also be observed in the basisphenoid just dorsal and posterior to the basipterygoid process. Due to the early ontogenetic stage of the specimen, development of the postcranial skeleton is less advanced. This specimen in conjunction with adult *Aepyornis* material was used to construct a growth trajectory to compare with those of extant ratites. These comparisons offer new insight into the question of how the world's largest bird got so big.

MAMMALIAN BIODIVERSITY RESPONSE TO MIDDLE PLEISTOCENE CLIMATE CHANGE AT PORCUPINE CAVE PIT LOCALITY, COLORADO

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Porcupine Cave, Colorado, is the richest Irvingtonian-age vertebrate site known in the world. Recent compilations of 17 years of research by several different workers have verified >13,000 curated, identified specimens representing ~150 species of vertebrates, including new Irvingtonian species and the oldest records for several extant taxa. The most clearly stratified of the 26 sites known in the cave is the Porcupine Cave Pit Sequence (PCPS), which has yielded >7000 specimens, most of them mammals. The PCPS spans from <900 to >250 Ka including at least two glacial-interglacial transitions. Specimen-count data from the PCPS, in concert with independent proxies of climate change indicated by the sediments, were used to explore the effect of orbital-scale climate change (glacial-interglacial transitions) on mammalian biodiversity patterns. Rarefaction and other statistical techniques were used to understand the relationship between numbers of specimens per stratigraphic level and number of species, and anomalies from the expected species accumulation curves were used to identify times of particularly high or low species diversity within major taxonomic groupings of mammals. Overall mammalian diversity may not have differed much from the present. Some groups (such as *Spermophilus)* demonstrate remarkable stability in diversity for the past 800 Ka. Other groups, such as arvicolines and *Neotoma,* fluctuate in diversity coincident with at least one glacial-interglacial transition. These data imply a certain amount of stability in mountain ecosystems. Resulting predictions of how ongoing global climate change might be expected to affect biodiversity patterns in western U.S. mountains are important, in that these regions today hold some of the least disturbed temperate latitude ecosystems on Earth.

OBSERVATIONS ON THE POSTERIOR TIP OF THE NOTOCHORD OF *PROTOPTERUS AETHIOPICUS* (SARCOPTERYGII: DIPNOI)

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The heterocercal tail of Paleozoic dipnoans such as *Dipterus valenciennesi* is well known. Since the 19th century work of Louis Dollo, it has been generally agreed that post-Paleozoic lungfishes such as *Neoceratodus, Protopterus*, and *Lepidosiren* have a secondarily symmetrical tail, in which the dorsal and the anal fins are confluent at the posterior tip of the body. This external symmetry is reflected internally by the nearly symmetrical arrangement of neural and hemal elements that support the continuous median fin. However, examination of sagittal sections through the posterior tip of the notochord of specimens of Protopterus aethiopicus reveal a striking asymmetry, with the notochordal tip sharply upturned. This observation confirms and extends early reports in the literature concerning notochordal asymmetry in living lungfishes and reinforces Dollo's basic observation regarding irreversibility of evolutionary change. This paper is a contribution to a symposium honoring Hans-Peter Schultze and his many contributions to the anatomy and sytematics of fossil and living sarcopterygian fishes.

NEW MAMMAL FINDS AND THE EARLY MIOCENE AGE OF THE ASKAZANSOR LOCALITY, KAZAKSTAN

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The Askazansor locality, in the southern Betpak-Dala (eastern Golodnaya Steppe) of central Kazakstan, was discovered by the geologist D. I. Jakovlev in 1929. The bone-bearing interval is in the Askazansor Formation in coarse sand with strongly marked, steeply inclined cross bedding. The argillaceous sands (fine-grained and micaceous with hematitic interbeds) that overlie the bone-bearing stratum have very thin horizontal bedding. Askazansor is principally a locality of large mammals, having yielded fossils of the chalicothere *Borissiakia*; the rhinoceri *Brachypotherium* Roger (=*Diaceratherium* Dietrich), *Dicerorhinus* Cloger, and *Aceratherium* Kaup; the anthracotheres *Anthracotherium* Cuvier and *Brachyodus* Deperet; and the carnivore *Amphicyon* Lartet. Varied opinions of the age of Askazansor locality are: (1) it corresponds to the fauna of the Harrison in North America so is early Miocene; (2) late Oligocene?; or (3) late Oligocene-early Miocene. The late Oligocene age assignments seem tenuous as they are based on identification of the giant rhinoceros *Paraceratherium* and the chalicothere *Schizotherium* from isolated and/or fragmentary postcrania.

Fieldwork at Askazansor in 2001 produced new fossil material that can define more precisely the age of this locality, including teeth and postcranial bones of the early Miocene rhinoceros *Protaceratherium* Abel. This material suggests that earlier reports of *Dicerorhinus* or *Ceratorhinus* may have been based on specimens of *Protaceratherium*. Furthermore, we recovered specimens of *Sinolagomys* cf. *S. minor* Bohlin, and Tachyoryctoididae gen. et sp. indet. Similar lagomorphs and rodents occur in lower Miocene deposits elsewhere in Kazakstan (Akespe, Altynshokysu, Ajakoz, and the Akzhar svita in the Zaysan basin) and in China (Xining basin, Qinghai). So, we conclude that all reliable evidence indicates an early Miocene age for the Askazansor locality.

CORNWALLIUS SOOKENSIS (DESMOSTYLIA, MAMMALIA): A RE-EVALUATION OF A LATE OLIGOCENE DESMOSTYLIAN FROM THE EASTERN NORTH PACIFIC COAST

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Cornwallius sookensis is one of the oldest known but most mysterious members of the order Desmostylia. It was previously known only as teeth from the Alaska, British Columbia, and Mexico, but is now described from adult and juvenile skulls as well as mandibulae, more dentition, and postcranial material.

Based on this new material, *C. sookensis* is determined to belong to the monophyletic group including *Desmostylus* and *Vanderhoofius*. The *Paleoparadoxia* species remain sister taxa to this crown group and *Behemotops* remains basal to them.

Desmostylians are often characterized as hippo-like semiaquatic mammals similar in habits to their close tethytherian cousins, *Moeritherium* and *Pezosiren portelli*. Based on newly described cranial characteristics, postcranial material, and taphonomic associations, the interpretation of *C. sookensis* and other desmostylians as semiaquatic, but not hippo-like, is supported.

FUNCTIONAL INTEGRATION OF THE LOCOMOTOR SYSTEM IN NON-MAMMALIAN SYNAPSIDS DURING THE PERMIAN

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During the Permian, the locomotor system of non-mammalian synapsids changed from a morphology typical of sprawling reptiles to a morphology indicating a more upright posture typical of most mammals. We used multivariate analyses of linear and angular morphological measurements from the humerus, scapula, femur, and ilium of Permian „pelycosaurs" and therapsids to test the extent to which changes in several parts of the locomotor system were integrated during this major functional transition. In our analyses, we divided the Permian into six time intervals to examine morphospace usage and changes in mean limb element shape through time. Results of principal components analyses and MANOVAs show substantial changes in femur shape through the Permian, consistent with previous studies. However, contrary to previous suggestions, our results also indicate large changes in synapsid forelimb morphology through the Permian. In addition, the timing of changes in girdle element shape and in limb element shape do not coincide. Thus, during the evolution of the locomotor system in Permian non-mammalian synapsids, morphological change may have been more coordinated between forelimb and hindlimb elements than previously recognized, but evolutionary changes in the girdle and limb bones of each limb appear not to have been well-integrated.

EXCEPTIONALLY LARGE SPECIMEN OF *CLIDASTES* (MOSASAURIDAE) FROM THE LATE CRETACEOUS NIOBRARA FORMATION OF WESTERN KANSAS

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A large, nearly complete skeleton of the mosasaur *Clidastes* was collected in 1991 from the Niobrara Formation of Logan County, Kansas. Preparation revealed that the specimen is of unusual size (seven meters), and does not conform morphologically to either species of *Clidastes* (*C. propython* or *C. liodontus*) known from the Niobrara Formation. Stratigraphic data indicates the specimen is of Early Campanian age.

Comparison of the new specimen to *Clidastes "moorevillensis"* from the Selma Formation of Alabama yields a close morphological match. Further investigation into *Clidastes "moorevillensis"* must be accomplished before the taxonomic position of this specimen can be defined. The Mooreville member of the Selma Formation is stratigraphically equivalent to the upper portion of the Niobrara Formation, and there were no paleogeographic barriers preventing migration between the two areas.

TAPHONOMIC IMPACT OF PREDATORS IN THE AMBOSELI ECOSYSTEM, KENYA

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Predators are known to have significant effects on bone assemblages that typically are apparent in patterns of damage to bones and alteration of skeletal part ratios. Such taphonomic features have been documented for mammalian, reptilian, and avian carnivores at specific sites (e.g., dens, caves) or using controlled feeding experiments with modern species. Recent dramatic changes in the predator diversity of Amboseli Park, Kenya, provide a unique opportunity to test the impact of such changes on the potential fossil record of this ecosystem and to understand possible broader-scale effects of predators on the vertebrate fossil record. In the 1970s and 1980s, abundant bones of both large and small mammals occurred throughout Amboseli, and there was a diverse community of living predators (lion, hyena, cheetah, jackel, many smaller mammal and avian predators and scavengers). An explosive increase in the hyena population (*Crocuta crocuta*) during the 1990s, accompanied by a decline in other predators, is likely correlated with a marked decrease in the number of bones available for fossilization. The current macro-mammal bone assemblage is biased toward remains of animals of Cape Buffalo size and larger (>400 kg), apparently as a result of intense intraspecific competition by *Crocuta*, resulting in nearly total consumption of carcasses of animals 15-400 kg body weight. During the past several decades, Amboseli has lost much of its tree cover and now is mostly open grassland and swamp, in contrast to extensive areas of acacia woodland that formerly provided cover and roosting sites for a variety of predators and scavengers. These ecological changes also have affected predator and prey diversity. Similar fluctuations in the populations of ancient predators and bone consumers could have had major consequences for the fossil record. Based on the modern analogue provided by Amboseli, it should be possible to specify types of taphonomic evidence that might indicate variations in predator/scavenger diversity and pressure on ancient herbivore populations and their skeletal remains.

NORTH AMERICAN QUATERNARY SQUAMATA: RE-EVALUATION OF THE STABILITY HYPOTHESIS

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The last four decades saw a dramatic increase in knowledge of Quaternary squamate reptiles in North America. Initial research centered on primary descriptive accounts of faunas, but these were recently supplemented by synthetic regional summaries, and efforts to place the reptiles in a broader context of faunal dynamics in the Pleistocene and Holocene. The picture that emerged from these studies suggests that squamate reptiles were taxonomically and geographically stable throughout much of the Quaternary. In stark contrast to the mammals and birds, few extinctions and no significant geographic range adjustments are reported for reptiles at the end of the Pleistocene.

Phylogenetic systematics has yet to play an important role in Quaternary vertebrate paleontology, but it presents a potentially fruitful alternative philosophical and methodological approach. Our recent re-evaluation of the stability hypothesis was based on this approach and leads to several important conclusions: 1. This hypothesis suffers from circularity because many fossil identifications ultimately are based on the modern geographic distribution of taxa; 2. Due to their incomplete nature and our current understanding of morphological synapomorphies for squamates, species-level taxonomic resolution is not possible for the majority of Quaternary fossils; 3. Geographic and taxonomic stability is demonstrable at more-inclusive taxonomic levels, but is not particularly informative with respect to questions typically asked by Quaternary paleontologists; 4. To answer species-level questions, we must seek synapomorphies in the isolated skeletal elements commonly preserved in Quaternary deposits.

Utilization of phylogenetic systematics in Quaternary studies will require an effort to seek synapomorphies in materials typically recovered from Quaternary deposits, acceptance of the taxonomic limitations of the data with which Quaternary paleontologists work, and a willingness to frame questions in a phylogenetic context.

THE QUESTIONABLE MONOPHYLY OF MOSASAURIDAE

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The transition of mosasaurs to large, fully marine forms through the small plesiomorphic aigialosaurs is a long accepted model of a major evolutionary development. It is generally conceded that the small aigialosaurs with only slightly shortened terrestrial limbs and a somewhat compressed swimming tail are excellent examples of an intermediate evolutionary lineage leading from terrestrial anguimorphs to cosmopolitan marine mega-lizards. However, newer specimens from the late Cenomanian and middle Turonian of Texas call this concept into doubt. Specimens of aigialosaur-grade mosasauroids (Mosasauroidea = Aigialosauridae + Mosasauridae) from central and west Texas exhibit character conditions that are diagnostic of taxa currently referable to mosasaur-grade clades, Mosasaurinae and Halisaurus. One new taxon from the middle Turonian Arcadia Park Fm. near Dallas is very well represented by most of the osteological anatomy and is distinctively a functional aigialosaur. It exhibits several character conditions used previously to diagnose Mosasaurinae. Vertebrae of another aigialosaur-grade mosasauroid from latest Cenomanian to middle Turonian parts of the Boquillas Fm. in Big Bend have character conditions comparable to a clade of mosasaurs including Halisaurus. Associated with these middle Turonian Texas specimens are vertebrae comparable to Cenomanian-Turonian aigialosaurs from the Aegean and Israel. These aigialosaurs from the Mediterrainean possess several character conditions found also in Plioplatecarpinae and Tylosaurinae. Mosasaur-grade specimens occuring with the aigialosaurs in two middle Turonian localities in central Texas and one in Big Bend are definitively referable to the latter two mosasaurid taxa. The total evidence available better supports a hypothesis that the current concept of Mosasauridae is a polyphyletic grouping and that Aigialosauridae is likewise paraphyletic. The possibility that this new arrangement could have significant implications for sauropterygians should be examined.

EARLY OLIGOCENE RODENTS FROM THE RODENT HILL LOCALITY IN THE CYPRESS HILLS FORMATION, SOUTHWEST SASKATCHEWAN

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The Cypress Hills Formation of southwest Saskatchewan preserves fossils that range in age from Uintan to Hemingfordian. Sampling of probable Orellan and Whitneyan microvertebrate localities, including Rodent Hill, has produced large numbers of mammal teeth and other fossils, but to date the taxonomic work on this material has been preliminary. The Rodent Hill Locality has been described as Whitneyan based on the presence of the lagomorph *Paleolagus* cf. *P. burkei*. This conclusion may be inconsistent with the possible occurrence of the aplodontid rodent *Prosciurus relictus*, which is known only from Orellan sites. Additional collecting and more detailed analysis of the rodents from the Rodent Hill Locality has revealed a larger number of taxa than previously reported, including the aplodontid *Prosciurus* cf. *P. magnus*, sciurids including ?*Cedromus* sp., and heliscomyids including ?*Heliscomys* sp., as well as representatives of the families Castoridae, Eutypomyidae, Florentiamyidae, and Geomyidae. Cricetid and eomyid taxa are also present and have been studied by another worker. Several lithostratigraphic units have been identified at the Rodent Hill Locality and, while they are all fossiliferous, they differ in the nature and quantity of fossil material. A better understanding of the rodents from this locality will not only better constrain the age of the fauna, but will also improve our overall knowledge of early Oligocene biodiversity in the northern plains.

STRUCTURE AND DEVELOPMENT OF TRUNK SCALES OF THE LONGNOSE GAR, *LEPISOSTEUS OSSEUS* (GINGLYMODI: LEPISOSTEIDAE).

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Using cleared and stained specimens, ground sections of scales and scanning electron microscopy, we conducted new studies of scale development in the longnose gar, *Lepisosteus osseus*. The materials examined included samples drawn from a frequently sampled growth series ranging from early embryos to young juveniles; scales of adult specimens also were studied. These materials allow us to document not only patterns of scale formation and growth but also to describe new histological details of scale formation and the relationship of mineralized tissues in the scales to surrounding soft tissues. We propose a new terminology for scale structure of gars based on recognizable landmarks in adult scales. The pattern of distribution of denticles on the scales is described as well as its relationship to the adult distribution of ganoin on the surface of the scales. This paper is a contribution to a symposium honoring our colleague and friend, Hans-Peter Schultze and his many contributions to the anatomy and systematics of fossil and living actinopterygian fishes.

A SECOND SPECIMEN OF *ANUROGNATHUS* FROM THE SOLNHOFEN LIMESTONE OF SOUTHERN GERMANY

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A new specimen of *Anurognathus ammoni* from the Upper Jurassic Solnhofen Limestone of southern Germany is only the second known specimen of the species. It provides much more anatomical information than the fragmentary, disarticulated holotype. The specimen is about 55% the size of the holotype. It is preserved in dorsal view with the wings folded along the sides of the body and includes impressions of the wing membrane. The specimen is fully articulated except for minor disarticulation and distortion of cranial elements due to post-mortem compression of the highly arched skull.

The specimen demonstrates that several interpretations based on the holotype specimen are incorrect: the wing finger consisted of only three phalanges and so was not abnormally long; the short tail was composed of simple vertebrae like those of pterodactyloids and was not in any way pygostyle-like; and pedal digit V bore only two elongate phalanges, not four. In addition, the excellent preservation of the skull demonstrates that the skull was quite different from previous reconstructions of anurognathid skulls. A sclerotic ring preserved *in situ* demonstrates that the eye and orbit were much larger than previously thought, and as a consequence of the large orbit, the preorbital part of the skull was much smaller than previously thought.

THE ASTRAPOTHERIA OF ITABORAÍ BASIN (ITABORAIAN, UPPER PALEOCENE), RIO DE JANEIRO STATE, BRAZIL.

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The Itaboraí basin is famous for its abundant and diversified mammal fauna. The order Astrapotheria is represented in the basin by *Tetragonostylops apthomasi* (Price & Paula-Couto, 1983), a very common ungulate of a fox-terrier size.

Although the Itaboraí skeletons are disarticulated, it is possible to assign some bones to the Itaboraí species using a “combo” of different methodologies. A humerus, astragalus and calcaneum were the first bones assigned to *T. apthomasi*. The humerus retain the primitive pattern seen in ungulates; the astragalus present a secondary facet on the fibular shelf, continuous with the ectal facet, as in latter Astrapotheria; the most diagnostic feature of the calcaneum is the development of peroneal tubercle into a large shelf.

As in *Trigonostylops wortmani* Ameghino, 1897, the teeth of *T. apthomasi* present a great morphological and biometric variation. A careful study and measurements undertaken on more than 500 dental specimens (most isolated teeth) has quantified the size variation and the amount of variability present in this species. The tooth length was the most variable dimension, being higher on the upper teeth, in which the range of variation goes from 10% (P4) to 46% (M1). However, this great size variation is continuous, not forming clusters in any statistical treatment. There is also a great morphological variation, noticed in the last two premolars and in all molars (the first two premolars are unknown and the incisors and canines were not taken into account for this analysis). The upper molars are the most variable and the major variability is found on M^3, where the hypocone, metaconule, metaloph, parastyle and/or cingulum can be present or absent, more or less developed, etc., in different teeth. Previous authors suggested that the genus *Tetragonostylops* should comprises more than one species, but the continued size variation and the absence of patterns of dental variation, support that *Tetragonostylops apthomasi* is a single, although greatly variable, species.

VARIATION IN THE ANURAN ILIUM AND ITS IMPLICATIONS FOR SPECIES-LEVEL IDENTIFICATION OF FRAGMENTARY FOSSIL SPECIMENS

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The anuran ilium is widely considered to be the single best element upon which to base identifications when only disarticulated individual bones are available. The purported utility of the ilium for identifying fossil anurans derives from both its relatively high percentage of recovery and the range of morphological characters it is reported to contain. Approximately 40% of fossil frog species are named based on the purported distinctiveness of their ilial morphologies. While it certainly may be true that when only disarticulated bones are available, the ilium is the most diagnostic element, the taxonomic level to which confident allocation of anuran ilia can be made is not thoroughly tested.

I assessed intra- and interspecific variation for both qualitative and quantitative characters from the ilium of Recent species of North American *Bufo*. The level of polymorphism and quantitative overlap indicates that, at least for *Bufo*, species-level identifications based entirely on the ilium are tenuous due to the current lack of discrete, apomorphic characters. Apomorphy-based identifications need to be applied to fragmentary specimens to test the validity of our current understanding of the anuran fossil record.

OLD AND NEW VERTEBRATE FOSSIL SITES IN THE UINTA BASIN, UTAH

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The Uinta Basin of northeastern Utah has been a major area of focus for paleontological investigations of Eocene rocks since the late 1800s. Due to recent significant increases in petroleum exploration activity, there is renewed interest in the fossil resources of the Uinta and Duchesne River formations. Literature and museum searches have revealed only vague descriptions of classic sites like the Myton Pocket, *Dolichorhinus* Quarry, Skull Pass Quarry, Leota Quarry, and Well #2. Stratigraphic control has been based largely of fossil assemblages rather than detailed lithologic and paleoenvironmental descriptions. Use of GPS technology and aerial reconnaissance has aided our efforts in determining the precise identification of old localities and discoveries of new ones.

Particularly important are new vertebrate fossil sites very near the formational boundary. Deposition environments and provenance change across the boundary, but similar faunas survived at least through the lower 300 feet of the Duchesne River Formation. However, the preservation of the fossils is radically different. Whereas Uinta Formation mammals and turtles are well preserved, Duchesne River Formation faunas are rarely found. Freshly exposed rocks produce a variety of new fossils that essentially disappear with the first precipitation.

THEROPOD DINOSAURS FROM THE UPPER JURASSIC LITHOGRAPHIC LIMESTONES OF WESTERN EUROPE: AN UNEXPECTED BIODIVERSITY REVEALED BY TRACKS

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Few theropod dinosaur remains are known in the Late Jurassic of Western Europe, especially in littoral environments linked to lithographic limestones. Only the two small theropod skeletons belonging to *Compsognathus longipes* Wagner, 1861 have been unearthed from the Tithonian lithographic limestones of Western Europe (from Solnhofen, Bavaria, Germany and from Canjuers, Var, France). It is noteworthy that a new small theropod, which could be a new species of *Compsognathus*, has been recently reported from the silicified, laminated limestone of Schamhaupten (Late Kimmeridgian, Bavaria, Germany). In addition, the only track formerly reported to a theropod was that of *Saltosauropus* from Cerin (Late Kimmeridgian, Ain, France), which has been reinterpreted as chelonian in origin.

Here we report several theropod tracks from the intertidal environment of Crayssac (Early Tithonian, Lot, France), ascribed to four ichnospecies with track-makers ranging from chicken to ostrich in size. The morphological variation between the pes prints of these ichnospecies reflects a significant difference in the autopod anatomy of the track-makers, what clearly demonstrates the presence of four different theropod species. Nevertheless, it is not possible to link one of these ichnospecies to *Compsognathus*. This ichnological discovery underlines that the Late Jurassic theropod biodiversity in the Western Europe littoral environments was greater than what has been expected until now from bone remains.

Moreover, tracks are first hand evidence of biological activity owing to their autochthony, hence this find will also shed light on theropod ecology. It will be possible to evaluate the trophic relationships of these terrestrial carnivorous in the Late Jurassic littoral ecosystems. Predators or scavengers, they were surely in the intertidal area of Crayssac at low tide to feed on mudflat- and aground-preys.

AUGMENTED PALEONTOLOGY: MERGING FOSSIL SPECIMENS WITH COMPUTER GENERATED INFORMATION FOR ANALYSIS AND EDUCATION

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Augmented Reality (AR) is a revolutionary interface that enhances the real world with synthetic supplements. AR allows virtual data, such as 3-D computer graphics, to be presented directly within a real environment rather than on a flat monitor. Over the last 40 years, technological advances have continued to blur the boundary between real and computer generated worlds. We have coined the term Augmented Paleontology to refer to the application of AR to paleontology. The goals of this technology are twofold: 1) to support paleontologists in their research, and 2) to communicated the results of these studies to museum visitors in an exciting and effective way.

Two case studies that combine physical fossil specimens with computer graphics will be presented. First, a cast skull of *Deinonychus* has been augmented with 3-D computer models of reconstructed soft tissues and missing bones. The real and virtual components can be perceived together in stereo from any perspective using a special high-resolution AR display device—the Virtual Showcase. AR provides the opportunity to test models of soft-tissue anatomy by assessing the conformational relationships (packing) of reconstructed components. Second, a cast dinosaur footprint has been augmented by an animated 3-D model of a theropod foot skeleton. This example illustrates how the distinctive shape of the track was likely produced and allows foot motion to be reconstructed.

DINOSAUR SOCIAL LIFE: EVIDENCE FROM SHED-TOOTH DEMOGRAPHY

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Shed teeth offer quantitative insight into social structure and survivorship. Late Jurassic beds at Como Bluff have been sampled for croc and theropod shed teeth at wet floodplain sites and peri-lacustrine sites. Since Como crocodilians are very close in adaptive geometry to extant crocodilians, the Jurassic crocs can be used to calibrate the theropod sample. Hatchling croc teeth should be concentrated in sheltered spots where the mother protected the young; this is the case at Como. In open-water sites, croc shed teeth should represent mostly older juveniles and young adults; this too is the case at Como. Since few crocs survive to older adulthood, large croc shed teeth should be rare; this is the rule in all sites at Como.

If theropods had societies and parental care like those of predatory birds, hatchlings should leave teeth at the same sites with older juveniles and adults. This is the case for Como allosaurs, ceratosaurs, and megalosaurs. The shed-tooth demography indicates that theropods had much higher survivorship than in crocs all through life, so the average theropod hatchling would have a probability of reaching adulthood 100 times greater than would the average crocodile hatchling.

AN ANALYSIS OF DISARTICULATED JUVENILE *EOLAMBIA* BONES IN THE CEDAR MOUNTAIN FORMATION OF EASTERN UTAH.

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The *Eolambia* II (Eo2) site is in the Cedar Mountain formation in Eastern Utah. The site contains multiple disarticulated juvenile individuals of varying sizes in a lacustrine deposit. This site is part of a larger on going multi-disciplinary study of the flora, fauna and paleoenvironment of the Cedar Mountain formation by the College of Eastern Utah and its partners. The Eo2 site is important for the bones of *Eolambia*. The abundance and good quality of the fossil bones makes ratio comparisons and other studies possible increasing our knowledge of *Eolambia* growth patterns. Crocodile teeth have been found with the bones indicating a predator/prey situation and turtle shell has also been found at the site. A carbonacious layer is one meter above the bone bed, samples have been gathered and are being analyzed for spores and pollen. A volcanic ash layer is associated with the bone bed, samples are being analyzed to determine its age. The bone bed postdates the ash layer and is located in a scoured out portion of the ash layer.

CRETACEOUS SEA TURTLE NESTING STRUCTURES FROM THE FOX HILLS FORMATION, ELBERT COUNTY, COLORADO

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Sedimentary structures preserved in the Fox Hills Formation, Elbert County, Colorado are interpreted as Cretaceous analogs to Recent loggerhead sea turtle nests studied on St. Catherines Island, GA.

Loggerhead sea turtles nesting on Georgia beaches construct elliptical nest structures which mask underlying body pits and egg chambers with a thin veneer of bioturbated sand of the covering activity. Study and documentation of over 600 nests and associated crawlways, with detailed trenching of 40 of these, has led to a stratigraphic model of the sedimentary structures produced by nesting of *Caretta caretta* Linnaeus, 1758. Measurements on loggerhead nests (n=70) show them to consist of an elliptical covering pit averaging 2.24 m by 1.98 m, below which lies a body pit approximately the size of the nesting turtle and within which lies an urn-shaped egg chamber averaging 26.8 cm deep and 23.1 x 18..52 cm in diameter.

The Cretaceous Fox Hills Formation in Elbert County, Colorado preserves a sequence of foreshore, backshore, and eolian sediments associated with an ancient shoreline. Preserved within the backshore facies are four biogenic sedimentary structures representing a body pit (with no exposed egg chamber), two preserved egg chambers (one containing egg molds), and a crawlway in close association with one another and with laminated heavy mineral backshore deposits, fossilized root traces, and possible desiccation features. The morphology and proximity of the structures, their sizes, and their association with other sedimentary structures and sediments of the strand facies are consistent with interpretation as nesting structures of an ancient sea turtle approximately the size of *Protostega gigas*.

TWO EARLY CRETACEOUS PTEROSAURS FROM AFRICA

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The Aptian-aged Elrhaz Formation of Niger has yielded many fossil vertebrates, including dinosaurs, crocodyliforms, turtles, and fish. Recent excavations produced two new pterodactyloid pterosaur specimens. These represent the only documented pterosaurian appendicular material from Africa. Both specimens are uncrushed. One specimen, a fairly complete left humerus, resembles those of tapejaroids such as *Quetzalcoatlus*, *Tapejara*, *Bennettazhia*, and a form from the Glen Rose Formation of Texas. The other specimen is an incomplete right wing. Characters such as an "ornithocheiroid" carpus and reduced metacarpals II and III suggest that the wing specimen be assigned to the Anhangueridae. African pterosaurs are mostly represented by teeth, cervical vertebrae, and very fragmentary cranial remains. These two appendicular specimens provide the best evidence for the African presence of tapejaroids and anhanguerids during the Early Cretaceous. As both clades are known from the Early Cretaceous of South America, this new evidence supports the idea of faunal continuity of vertebrate taxa between Africa and South America during the Early Cretaceous.

ORIGIN AND RELATIONSHIPS OF ARCHONTA (MAMMALIA, EUTHERIA): RE-EVALUATION OF EUDERMOPTERA AND PRIMATOMORPHA

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W. K. Gregory pioneered the concept of Archonta, which has been central to the debate on the origin of Primates. As currently conceived, Archonta includes extant Primates, tree shrews (Scandentia), flying lemurs (Dermoptera), and bats (Chiroptera). The earliest uncontroversial record of one of these groups dates to the beginning of the Eocene (ca. 55 Ma), when euprimates appear in North America, Europe, and Asia. One of the major issues in archontan systematics is how to tie Paleocene groups such as Nyctitheriidae, Plagiomenidae, and Plesiadapiformes to fossil representatives of extant archontan clades. The fossil record supports either North American or Asian origins for Archonta in the earliest Paleocene or latest Cretaceous. Studies utilizing molecular data and evolutionary models suggest a much earlier Cretaceous origin of this clade.

Recent hypotheses of archontan relationships include a close association between Euprimates and a revised Dermoptera that includes certain plesiadapiforms (Primatomorpha). Within this modified Dermoptera, paromomyid and micromomyid plesiadapiforms are thought to be the sister taxa to extant dermopterans (Eudermoptera). A collaborative project including new plesiadapiform fossil material, a more phylogenetically relevant sample of scandentians, and a new phylogenetic analysis that includes cranial, dental, and postcranial data, is pointing towards a new consensus on archontan systematics. Plesiadapiforms lack morphological evidence for a close relationship with dermopterans. Instead, plesiadapiforms share characteristics with Euprimates that are both adaptively and phylogenetically significant, indicating that they should be classified in the order Primates. The presence of "primatomorphan" characters in the postcranium of *Ptilocercus lowii* weakens evidence for a dermopteran-euprimate clade. Both morphological and molecular analyses suggest that dermopterans are more closely related to Scandentia than to Primates, but this issue is complicated by differing opinions on the position of Chiroptera. The phylogenetic position of bats remains the biggest question in archontan systematics.

VERTEBRAL DEVELOPMENT AND ITS EVOLUTION IN MODERN SALAMANDERS

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The origins of salamanders and their interrelationships with frogs and caecilians have long been questioned. An approximately 100 million year gap separates the oldest unquestionable salamander fossil in the Middle Jurassic and their putative ancestors in the Paleozoic. No adult Paleozoic amphibian shows any derived features in common with salamanders, but ontogeny sheds a different light on the matter. I am investigating vertebral development in modern salamanders to help establish interrelationships between modern and Paleozoic amphibians. The sequence of ossification of vertebral elements is known in lepospondyls, labyrinthodonts, frogs and caecilians and is consistent within each group. Salamanders are a challenge since preliminary studies show that vertebral development is not consistent within the order. *Ranodon* sp., a member of the most primitive family (*Hynobiidae*), chondrify and ossify the arches before the centra but *Salamandrella keyserlingi*, another member of the *Hynobiidae*, chondrifies the centra before the arches. Members of the *Sirenidae*, *Salamandridae*, *Ambystomatidae* and *Proteidae*, moderately derived families, all chondrify the centra first and then the arches. The ossification sequence, when it is known, closely follows the pattern of chondrification. Within the more derived family *Dicamptodontidae*, *Dicamptodon ensatus* ossifies centra and arches simultaneously. All *Plethodontidae*, the most derived family, ossify the arches and centra almost simultaneously, but some chondrify the centra slightly before the arches. *Ranodon* sp. shows a vertebral development pattern similar to that of labyrinthodonts and modern frogs, but the remainder of the order resembles lepospondyls and caecilians in their vertebral development. Coupled with studies of ontogeny in Paleozoic and other modern amphibians, this research should make a significant contribution in resolving the question of monophyly of modern amphibians and in establishing sister-group relations between salamanders and a particular group of Paleozoic amphibians.

PHYLOGENETIC POSITION OF *TIJUBINA PONTEI* BONFIM & MARQUES, 1997 (LEPIDOSAURIA, SQUAMATA), A BASAL LIZARD FROM THE SANTANA FORMATION, LOWER CRETACEOUS OF BRAZIL.

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Tijubina pontei features among the few taxa of Squamata described for the Mezosoic of South America. The single, nearly complete skeleton was discovered in the laminated limestones of the Crato Member, Santana Formation, which bears one of the most spectacular fossil assemblages of the world. This formation is one of the few known *lagerstätten*. Its excellent preservation allows the three-dimensional study of its fossils, often including their soft parts. In this study, we access the phylogenetic relationships of this species within the Squamata.

The data matrix, mainly based in previously published data and our own observations of *Tijubina pontei*, is composed by 25 terminal taxa, representing the main Squamata groups, and 187 morphological characters. Rooting was done by outgroup comparison of selected Lepidosauria, such as *Saurosternon*, Youngniformes, Kuehneosauridae and Sphenodontida. Strict parsimony analyses was performed using the PAUP program (version 3.1.1), as well as summary statistics, and analysis of bootstrap and Bremmer's branch support.

This resulted in one most parsimonious tree, completely resolved with 1120 steps, CI = 0.798 and RI = 0.677, and may be described as: (*Huehuecuetzpalli* (*Tijubina pontei* (Iguania (Lacertidae (Teiidae, Gymnophthalmidae)), (Xantusiidae (Cordylidae (Scincidae (*Tepexisaurus*, *Paramacellodus*))))), (Xenosauridae, Anguidae), (Helodermatidae (*Varanus*, *Lanthanotus*)), (Gekkonidae (Pygopodidae (Serpentes (Amphisbaenia, Dibamidae)))))). Many branches are supported by high indexes values, especially Squamata, Scleroglossa,

Varanoidea and Teiioidea, together with new suprageneric taxa. *Tijubina pontei* is the sister-group of the crown-group Squamata (Scleroglossa + Iguania), occuping a more internal position compared to *Heuheucutzpalli*.

PES ANATOMY IN SAUROPOD DINOSAURS: IMPLICATIONS FOR FUNCTIONAL MORPHOLOGY, EVOLUTION, AND PHYLOGENY

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Although Sauropoda is diagnosed primarily on limb and foot characters related to locomotion, the evolutionary functional morphology of these features remains poorly understood. Unlike the digitigrade posture of most saurischians, the pedes of most sauropods assumed a semi-plantigrade configuration. This change in foot posture may be correlated with astragalus reorientation in which the distal articular surface was directed anteroventrally. This angulation of the pes may have facilitated plantarflexion by changing the angle of insertion through which plantarflexors acted on the pes and/or a plantar aponeurosis. A small, ossified calcaneum has been reported for all sauropod clades, including diplodocids, and may have functioned to resist eversion, stabilize and direct peroneus muscles, and distribute compressive stress from the fibula to the metatarsus. Ossified distal tarsals have never been reported for any sauropod; they may have fused to the proximal surfaces of the metatarsals or remained as small cartilaginous elements. Articulation of the metatarsus and astraglus in neosauropods suggests the metatarsals articulated either directly with the distal roller or through small, cartilaginous distal tarsals.

Proximally, eusauropod metatarsals form a broad arch, and the medial portion of the anterior face of metatarsal V probably articulated posteriorly with metatarsal IV. Diplodocids have low, lateral ridges on the anterior faces of metatarsals I-III that suggest their dorsiflexor muscles were expanded; this feature may represent a synapomorphy of that clade. The lateral, outward rotation of the pes observed in known trackways orients the digits such that digit V is the most posterior; in the absence of a prominent calcaneal tuber, digit V may have acted as a "pseudocalcaneum." The broad articular surfaces, offset flexor tubercles, ventrolateral orientation of the pedal claws, and trackway evidence suggest some flexion and rotation of the claws occurred during contact with the substrate. Overall, tarsus and pes morphology remained conservative during sauropod evolution.

DEVELOPMENT OF THE MEDIAN FINS OF THE SEA LAMPREY, *PETROMYZON MARINUS* (PETROMYZONIFORMES).

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We conducted a new study of the early development of median fins in a developmental series of the sea lamprey, *Petromyzon marinus* from hatching through metamorphosis. Our study shows how features in the development of the median fins can be compared with those of elasmobranchs, dipnoans and actinopterygians. For the first time, we can document with scanning electron microscopy and serially cross-sectioned specimens details of the continuous median fin as it subdivides into separate first and second dorsal fins, the epichordal lobe of the caudal fin, the hypochordal lobe of the caudal fin, and the anal fin. We also document the formation of the fin skeleton and rays. This paper is a contribution to a symposium honoring Hans-Peter Schultze and his many contributions to the anatomy and systematics of fossil and living fishes.

PROBABLE LAMBEOSAURINE (ORNITHISCHIA, HADROSAURIDAE) SPECIMEN FROM THE LATE CRETACEOUS HELL CREEK FORMATION OF MONTANA

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A partial hadrosaur skeleton was excavated from the Hell Creek formation of Montana during the summer of 2001. Comparisons with the hadrosaurines known from the Hell Creek Formation, *Anatotitan copei* and *Edmontosaurus annectens*, revealed that the new specimen does not conform to either, but displays characteristics generally attributed to members of the subfamily lambeosaurinae. This identification is supported by the tibia length to femur length ratio, and by direct comparisons to other specimens. Canadian Museum of Nature specimen WL 139 from the Horseshoe Canyon Formation at Scabby Butte, Alberta, proved to be strikingly similar to the Hell Creek specimen. The ischial shaft of WL 139 was nearly complete and displayed a partially broken, yet distinct, foot on the distal end, which is characteristic of lambeosaurines. The Hell Creek specimen and WL 139 both display a completely enclosed, elliptical obturator foramen in the proximal ischium, as opposed to a typical obturator notch. Obturator foramina were observed in these specimens, two *Hypacrosaurus altispinus* skeletons, and a juvenile lambeosaurine skeleton. The presence of an obturator foramen in a juvenile specimen indicates that the foramen is not an indicator of advanced age. The occurrence of WL 139 in the Horseshoe Canyon Formation is consistent with it being *Hypacrosaurus* or *Saurolophus*. The new specimen cannot yet be identified to genus level, but does establish lambeosaurines in the Hell Creek Formation.

STRUCTURAL CORRELATES OF POSITIONAL BEHAVIOR IN VERTEBRAL COLUMNS OF PALEOCENE SMALL MAMMALS

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The vertebral column is a good indicator of habitual postures and locomotor activity in extant mammals. Functional analyses of isolated vertebrae or elements of the appendicular skeleton may lead to seemingly contradictory interpretations and thus, are often not accurate predictors of positional behavior. In contrast, vertebrae, considered in context of the whole column, constrain possible behaviors more precisely and may substantially refine functional hypotheses based on other anatomical regions.

Vertebral columns of Paleocene mammals are often poorly preserved, making functional interpretations of this anatomical region difficult. This is especially true for small mammals, which are usually represented only by isolated teeth and fragmentary jaws. In contrast, freshwater limestones from the Paleocene of the Clarks Fork Basin, Wyoming, have exceptionally well preserved skeletons for many small mammals, permitting detailed investigation of positional behaviors.

We did comparative analyses of serial vertebral morphology and proportions in extant taxa in order to infer positional behavior for small mammals preserved in the limestone. We evaluated degree and power of sagittal and lateral flexibility in the trunk; location and degree of maximal flexibility in the trunk; and degrees to which trunk vertebrae are constructed to resist dorsal or ventral shear, and torsion. Inter-regional proportions of vertebral columns were also used to examine habitual resting and locomotor postures, relative contributions of fore and hind limbs in locomotion and the degree and direction in which flexion of the vertebral column is incorporated into the gait. Finally, we tested our behavioral inferences by quantitatively comparing the overall proportional similarity of fossil taxa to their inferred functional analogues. In particular, we studied individuals representing several families of Paleocene plesiadapiforms. Our results support those from analyses of other anatomical regions, which indicate a diversity of arboreal positional behaviors in these possible primates.

JAW MUSCULATURE OF A NORTH AMERICAN TRICONODONT MAMMAL OF THE LATE JURASSIC PERIOD

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A tricondont mammal for the Upper Jurassic Morrison Formation is represented by nearly complete right and left mandibles; right and left maxillae with some preservation of zygomatic arch; and a few cranial fragments. This holotype specimen has been described and named *Priacodon fruitaensis*. Jaw musculature of *Priacodon fruitaensis* can be discovered by investigating anatomy of modern mammalian representatives. Sites of masticatory musculature can be identified and those muscles can be reconstructed. Functional analysis can include non-quantitative force vectors for individual muscle lines of action. Also, tooth wear facets can relay information about mastication. Finally, comparison of similar anatomical features in *Priacodon fruitaensis* (family Triconodontidae) to that of modern *Ornithorhynchus* (family Ornithorhynchidae) will be discussed.

STATISTICALLY VALID POPULATION ANALYSES OF MIDDLE JURASSIC DINOSAUR ICHNOCOENOSES

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Middle Jurassic dinosaur remains are "prehistoric specters" that haunt the Western Interior of North America. Fortunately, trace fossils record the presence and activities of these animals. Until recently, the complexities of life in Wyoming during the Middle Jurassic were only vaguely understood. However, the existence of dinosaur tracks in the marine Sundance Formation has prompted detailed analyses of the paleontology and paleoecology of northern Wyoming. These studies have facilitated the understanding of a unique Bathonian population of theropods on the tidally influenced shores of the Sundance Sea approximately 165 million years ago.

The Bighorn Basin contains the most extensive dinosaur track localities in Wyoming and the most thoroughly documented dinosaur tracksites in the world. Ichnology research focuses on tridactyl pes impressions preserving the activity patterns of hundreds of small- to medium-sized primitive tetanurans, ranging in hip height from approximately 32-120 cm. Caution is exercised in characterizing these footprints, as detailed comparison and analysis of tracks at various trackways and sites show consistent variations in morphology and orientation. At one of these localities (Red Gulch Dinosaur Tracksite), 1000 footprints provide over 30,000 track attributes for analysis. This unique and statistically valid data set allows us to make accurate assessments of the trackmakers. It also highlights apparent biases in documentation and interpretation in footprint studies. However, interpretations about a monotaxonomic community of gregarious dinosaurs walking and interacting in the water-saturated sediments near the shore of an inland sea are supported by the analysis of the ichnology data. In addition, the possibility of small, mixed-age packs of theropods (perhaps ranging from yearling to adult) traveling together provides evidence for family group behavior, as well as the proximity to a nesting area and the semi-precocial nature of the young dinosaurs. As new chapters are written about this Mesozoic "dark age" in Wyoming, a better understanding is coming to light about the life and times of the Middle Jurassic of North America.

PALEONTOLOGY AND STRATIGRAPHY OF THE DINOSAUR-BEARING CERRO DEL PUEBLO FORMATION, SOUTHERN COAHUILA, MEXICO

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The Cerro del Pueblo Fm. (CdP; Difunta Group) in southern Coahuila, Mexico, has yielded North America's southernmost assemblage of late Campanian to early Maastrichtian dinosaurs. Paleobiogeographically, it represents a critical datum in studies of Late Cretaceous ecosystems along the vast coastal area extending from Alaska to Mexico. To date, however, little is known of the vertebrate diversity, stratigraphy, and paleoenvironments of this formation. In 2002, the CdP Fm. became the focus of a new international project.

Preliminary paleontolgical results include the discovery of partial skeletons of lambeosaurine and hadrosaurine dinosaurs as well as several extensive, hadrosaur-dominated

mass death assemblages. Also present are centrosaurine and chasmosaurine ceratopsids. Mosasaur remains and a pleurodire turtle have been recovered from marine facies within the CdP Fm., whereas an assemblage including turtles, a crocodile, varanid lizard, snake, pterosaur trackways, and dinosaur eggshell is present in the nonmarine facies.

Geologic efforts to date have focussed on stratigraphic ordering of known and new fossil localities and correlation between and among fossil localities in the basin. Due to extensive urban development we were unable to relocate the type section of the CdP in Saltillo, necessitating the designation of a "principle reference section" northwest of the city. A composite section of the CdP was measured at Rincon Colorado, a fossil-rich area 30 km west of Saltillo. The latter is almost 500 m thick and consists of three trangressive-regressive (T-R) cycles. The best known fossil localities in this area—including dinosaur bonebeds, articulated-to-associated dinosaurs and other vertebrates, and vertebrate microfossil assemblages—occur in uppermost (third) T-R cycle (m 350-475). At El Pelillal (70 km n of Saltillo) the CdP exceeds 500 m in thickness. Bonebeds, articulated-to-associated dinosaurs, and vertebrate microfossil assemblages are common between meters 130-200, suggesting that these assemblages are slightly older than those preserved at Rincon Colorado.

THE FOSSIL FISHES FROM THE MARILIA AND ADAMANTINA FORMATIONS, UPPER CRETACEOUS OF BRAZIL

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The fish fauna from the Marilia and Adamantina formations, Upper Cretaceous of Bauru Basin, southeastern Brazil, represents a typical basal neotropical fauna in where primitive clades such as ceratodontids and lepisosteids are found together with osteoglossids, characids and siluriforms. The systematic position of these taxa will be discussed, comparing them with extant South American and African faunas. A discussion about stem-group and crown-group will be present in this work.

THECACHAMPSOIDES MINOR AND EARLY GAVIALOID HISTORY: COASTAL ATLANTIC ORIGINS OF LONGIROSTRINE CROCODYLIANS

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Thecachampsoides minor is a small gavialoid from the Late Paleocene of eastern North America. The holotype is a fragmentary skeleton from New Jersey, but more complete material from New Jersey, Virginia, and Maryland—including material figured by Leidy—allows a more complete description. It can be distinguished from other gavialoids on the basis of an enlarged quadrate foramen aereum and arrangement of dentary alveoli into couplets. *"Crocodylus" marylandicus* is a *nomen dubium*, but may be based on a specimen of *Thecachampsoides*; and some longirostrine crocodylians from the European Eocene may be close relatives. Inclusion of *Thecachampsoides* in phylogenetic analysis confirms the gavialoid affinity of *Thoracosaurus*, a Late Cretaceous-Early Paleocene fossil usually grouped with tomistomines, but the basicranial morphology of *Thecachampsoides* is more derived, with a craniocaudally expanded basioccipital ventral to the occipital condyle. The occurrence of basalmost gavialoid lineages in marginal marine deposits encircling the proto-North Atlantic may explain the possible presence of physiological saltwater adaptations in extant *Gavialis*, which has never been reported from saline environments. A coastal circum-atlantic distribution is also seen in the earliest tomistomines in the Early Eocene.

A NEW PERSPECTIVE ON LAMELLAR BONE AND ITS POTENTIAL FOR LIFE HISTORY RESEARCH IN THE PALEONTOLOGICAL RECORD

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Incremental structures reflect biological and environmentally elicited rhythms in developing organisms. As skeletal incremental structures may persist well after formation, analyses of these structures provides a means of appreciating aspects of organismal growth rate and life history in the recent and paleontological past. Here we report the first calculation of a lamella incremental formation rate for a reptile. The developing bones of 12 female and male laboratory-reared juvenile green iguanas (*Iguana iguana*) were vitally labeled with Calcein, Xylenol Orange, or Tetracycline. Individuals were given 4 injections. Each injection, averaging 25mg/kg of label, was separated by 28 days. One control animal was injected with saline on the same schedule. Animals were sacrificed 30 days after the final injection. Midshaft femur and humerus bone blocks were embedded in poly methyl methacrylate and styrene, sectioned, ground, and polished to provide 100 micrometers thick thin sections. Preliminary observations of thin sections by fluorescence and polarizing microscopy reveal that one lamella forms in one day in the juvenile iguana. This rate is the same as that reported for the growing rat. This result enables us to demonstrate, with 24-hour resolution, growth rate variability of the iguana. This rate is not interpreted by us as a circadian rhythm but, rather, a rate integrated into iguana life history, one that is characterized by a particular growth rate and body size, etc., at this life stage. It remains to be determined whether this rate is characteristic of all lamellar growth by this species at all ages and sizes, or whether it may extend to the genus level or to other organisms with similar life history attributes. The primary significance of this work is that it provides a new perspective on and potential for life history research in the paleontological record that was heretofore impossible.

INEFFECTIVE CONSOLIDATION: POOR PENETRATION OR PERIPATETIC POLYMER?

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Stabilization of friable specimens has always been a fundamental goal of fossil preparation. Various chemical consolidants have been used over the years with varying success, but achieving thorough (deep) consolidation has been an eternal problem for preparators. Traditional wisdom attributes shallow consolidation to a lack of penetration by the polymer/solvent consolidant solution and asserts that solutions should be kept dilute to facilitate maximum penetration. Experimental results, however, show that shallow consolidation is not necessarily the result of shallow penetration of the consolidant solution, but is more often the result of the migration of polymer back towards the surface of a specimen as the solvent carrier evaporates.

Strategies that help mitigate consolidant migration include using multiple applications of increasing polymer concentration, physically or chemically slowing solvent evaporation, and using a mixture of solvents with different solubility/volatility properties.

Some historic and recent remedies that have been suggested have included using various non-solvent-based consolidants, however few if any of those materials are acceptable to conservators. Since conservators are concerned with the long-term preservation of specimens and minimum alterative intervention, goals which should be shared by the vertebrate paleontology community, we would do well to heed their advice. The safe approach is to understand the mechanics and limitations of solvent-based consolidant systems which meet conservation standards and to modify our methods of application to achieve maximum effect. When combined with good storage materials and methods, there is seldom need to resort to more risky treatments. While extreme situations may occasionally require extreme action, routinely relying on quick and easy "fixes" that do not meet (or have not yet met) conservation standards should be avoided.

ONTOGENY OF VERTEBRAL OSTEOLOGY IN LAGENORHYNCHUS ACUTUS (CETACEA)

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Living dolphins exhibit considerable heterogeneity in vertebral osteology associated with diverse habitats and swimming styles. The carangiaform swimming style of oceanic species is associated with osteological traits that have a hierarchical distribution among less derived living and fossil taxa, supporting a hypothesis of stepwise acquisition in evolutionary time.

In this project we asked if similar vertebral heterogeneity and distribution exist among conspecific individuals of different ontogenetic stages. Correlating increased size with age, we sampled individuals of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*, a species with highly derived vertebral anatomy and oceanic habits. We documented a wide range of vertebral parameters, of which centrum length, neural process angle and neural process orientation varied most significantly.

Data was analyzed by comparison of standardized curves of vertebral dimensions and by computation of complexity metrics designed by McShea for serial structures. We conclude that the vertebral columns of small (juvenile) dolphins are neither smaller models of larger (more adult) individuals nor mimics of ancestral species, but unique mosaics with both primitive and derived traits. In comparison with columns of juveniles of the same species, adult *L. acutus* columns have relatively longer and more steeply angled neural processes and longer relative centrum length. Vertebral count, which has changed rapidly in evolutionary time, is fixed throughout ontogeny. Adult columns are also more highly regionalized and more highly polarized than those of juveniles are. We conclude that these variations produce a more rigid torso and allow a faster and more sustained swimming style in adults. Juveniles attain an "adult" pattern of vertebral dimensions long before they reach fully adult body size.

NEW MATERIAL OF *ELMISAURUS* (THEROPODA, ELMISAURIDAE) FROM THE LATE CRETACEOUS HELL CREEK FORMATION OF SOUTHEASTERN MONTANA

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Two new specimens of the rare theropod *Elmisaurus* have been recovered from the Hell Creek Formation of Carter County, Montana. Specimen one consists of the proximal and distal tibia, proximal fibula, distal metatarsal III and partial metatarsal shaft, various phalanges, and two manus unguals. The second specimen is a partial metatarsus, including the distal end and partial shaft of metatarsal III and IV, and various fragments. The two specimens are referable to Elmisauridae based on the medial groove in the dorsal surface of the shaft of metatarsal III. At this time, there are no characteristics that suggest the new specimens are taxonomically distinct from *Elmisaurus elegans*. These specimens are unusual given their size, estimated as three times larger than MOR 752, the only previously described specimen of *Elmisaurus elegans* from the Hell Creek Formation. These specimens indicate *Elmisaurus* attained sizes approaching that of *Struthiomimus*.

CONVERGENT EVOLUTION OF DENTAL ANATOMY FEATURES OF SAUROPTERYGIANS, ICHTHYOSAURS, MOSASAURS AND TOOTHED CETACEANS

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Sauropterygians (Triassic–Late Cretaceous), ichthyosaurs (Triassic–Late Cretaceous), mosasaurs (Late Cretaceous), and toothed cetaceans (Eocene–Recent) are unrelated amniotes that share similar dental morphologies. Sauropterygians, ichthyosaurs and mosasaurs are aquatic diapsids and toothed cetaceans are highly derived mammalian synapsids. Despite being unrelated, all of these groups evolved aquatic adaptations, a large body size and carnivory. Many members of the above groups have robust, relatively conical and moderately recurved teeth with enlarged "roots" attached by a periodontal ligament to the walls of a socket (thecodont attachment). The mode of tooth attachment in these creatures may be due to similar feeding habits. Recurved, conical teeth are usually found in aquatic and terrestrial species that swallow their food whole. The recurvature of the teeth facilitate the posterior passage of prey into the esophagus and the robustness of the teeth resists forces that may cause tooth

breakage. Thecodonty, the plesiomorphic mode of tooth attachment for amniotes, may be adaptive to the whole-prey swallowing feeding method as the ligamentous attachment absorbs the shock of biting on hard prey and facilitates easy tooth loss if the prey gets lodged on a tooth. The dental histology of the above groups will be examined to explore the observed dental morphology similarities.

A NEW NORTH AMERICAN RECORD OF THE GIANT TYLOSAURINE *HAINOSAURUS* (REPTILIA: MOSASAURIA) FROM SASKATCHEWAN

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The tylosaurine *Hainosaurus* was first described in 1885, yet remains one of the more incompletely known mosasaur genera. First collected in Belgium, its geographic range has recently expanded to France, across the Atlantic to Manitoba, Canada, and is now represented by an additional North American record from the Late Cretaceous Bearpaw Shale of Saskatchewan. This new fossil includes a complete, articulated skull, which will allow an unprecedented description of *Hainosaurus* cranial anatomy. The diagnostic morphology of the quadrate, hitherto plagued by incomplete or crushed examples, is perfectly preserved on the right side of the skull. The braincase, largely unknown in *Hainosaurus*, is completely present. Also preserved are a partial vertebral column, a nearly complete appendicular skeleton, and a collection of stomach contents. This exceptionally well-preserved skeleton of *Hainosaurus* offers an excellent opportunity to clarify the anatomy and taxonomy of this poorly understood genus, as well as to evaluate its phylogenetic position within the Mosasauria.

STATE OF THE ART GIS APPLICATIONS AT THE MIOCENE AGE FOSSIL SITE IN GRAY, TENNESSEE

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A Geographic Information System (GIS) provides a powerful tool for the mapping, analysis, and display of spatial data. GIS is unique in that all mapped features are georeferenced as to their real world position and that there is a relational database containing attribute information. Additionally, each map layer exhibits topology, or the mathematical relationship that allows the software to determine where an object is located, what the object is, and how the object is spatially related to the other objects in the layer. As these data are significant with respect to fossil specimens, it is logical to build a GIS database as the fossils are collected.

The recently discovered Miocene-aged fossil site in Gray, Tennessee provides an excellent opportunity to test GIS applications to paleontological data. Furthermore, this site offers the occasion to employ these techniques during the initial stages of systematic excavations at the site. A research grid has already been established and is tied into the Tennessee State Plane Coordinate System. As each fossil is exposed it will be surveyed and the cartesian coordinates recorded. Where appropriate multiple coordinates points will be collected to record the spatial orientation of individual fossil elements. This data will be placed into the GIS database and additional information such as element, taxonomic categories, taphonomic categories, quality of preservation, etc. added. In addition, with the new software currently available a three dimensional matrix will be established. It will then be possible not only to visualize the site in three dimensions but to perform analyses to look for spatial patterns.

WHY SMALL DINOSAURS HAVE BIG BRAINS

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Maniraptoran dinosaurs include the smallest adults, but have relatively the largest brains among the dinosaurs. Why is this so? Evidence drawn from the rest of the skeleton may provide some answers. Allometry may account for part of the discrepancy, but cannot account for all of it. Eyesight seems to have been emphasized while the smaller brained carnosaurs relied more on their sense of smell. More importantly, this improved eyesight was probably used in an open habitat where long distant interactions between individuals was possible. The large neural canal and specializations of the spinal cord may indicate improved manual dexterity. Comparison with modern birds and mammals provide evidence for the relationship of brain size to activity patterns.

DINOSAUR EGGS FROM THE UPPER CRETACEOUS OF CATALONIA, SPAIN: TAPHONOMIC STUDIES

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Descriptive and taxonomic approaches have dominated the study of dinosaur eggs and embryos. Our attempt is a taphonomical characterization of the Faidella nesting site, from the Upper Cretaceous of the Tremp Formation (Catalonia, Spain). Faidella represents a broad nesting site in a fluvial environment where dinosaurs brooded periodically. Six clutches were unearthed. Eggshell studies revealed oospecies of *Megaloolithus siruguei*. One of these clutches was cleaned off, expecting that new data on their macro and micro shape will be provided. Comparative mineralogical studies analysing recent crocodiles, ostrich, and *Megaloolithus* resulted on almost identical diphractograms, with calcite as a predominant mineral phase, plus a small quarzt pike. The geochemical study shows that, with the exception of Sr, the composition of the fossil eggshell experienced little change throughout the diagenetic taphonomic processes that operated in this site.

THE LATE CENOZOIC ANTILOCAPRID RECORD IN CENTRAL MEXICO

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In Mexico, the fossil record of Antilocapridae has been recovered from upper Cenozoic deposits in the northern and central regions of the country. The greatest part of the material proceeds from Plio-Pleistocene deposits in Central Mexico, and represents at least six different genera. Paleontological work carried on the states of Guanajuato, Hidalgo, Puebla and Tlaxcala, provided additional fossil material belonging to antilocaprids. A few specimens of *Hexobelomeryx* have been previously reported from Plio-Pleistocene localities in Guanajuato and Hidalgo. The specimen reported here includes 3 astragali and two isolated molariforms recovered from Hemphillian sediments in the northeastern area of the Hidalgo. Regarding Guanajuato, the additional material includes a large collection of Hemphillian and Blancan age mandibles and upper and lower isolated molariforms. Also from the Hemphillian of Guanajuato, several lower and upper molariforms referable to *Texoceros* and cf. *Subantilocapra* represent the first records of these genres in the country, extending their geographic distribution to central Mexico. The fossil material referable to *Capromeryx*, is known from Pleistocene sediments in Aguascalientes and the Basin of Mexico. The new records of this genus are two skull fragments with the horn cores, four mandibular fragments, and isolated molariforms. These specimens were recovered from Rancholabrean sediments in the south central area of the State of Hidalgo, and the Valsequillo Basin, Puebla. From the same localities were collected three partial skulls with parts of the horn cores, an isolated posterior horn core, and two fragments of horn core bases, referable to *Stockoceros*. New elements of *Tetrameryx* have been collected from the Valsequillo Basin. The specimens are fragments of a skull with the left horn core, an isolated anterior horn core, and a posterior horn core base. These materials represent the second record of the genus from central Mexico. These new records contribute on the taxonomy and history knowledge of this group of artiodactyls during the late Cenozoic of Central Mexico and North America as a whole.

SQUAMATE PHYLOGENY AND THE IMPORTANCE OF FOSSILS: CONSTRUCTING A WEB DATABASE

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Recent species totals for extant squamates list 4770 species of non-snake squamates and 2911 species of snakes (=7681). Living snakes are classified within 18 families (e.g., Colubridae = 1795 species); living non-snake squamates are classified wihtin 30 families (e.g., Scincidae = 1254 species). A brief survey of the literature finds more than 700 species of fossil non-snake squamates and more than 250 species of fossil snakes. Fossil squamates are classified within extant families, but also within a large number of extinct and very ancient families. The earliest fossil squamates are non-snake taxa from the Bathonian (Middle Jurassic) of England; snakes are not known from the fossil record until the upper part of the Lower Cretaceous. Many of these fossil squamate species are known only from fragmentary remains and present little phylogenetically informative data. However, many fossil species are also known from well preserved specimens that do preserve phylogenetically informative characters. Until recently, published analyses of squamate phylogeny did not include fossil taxa as terminals in their data sets. The potential influence of these missing fossil data on tree topologies remains untested and unknown. Collecting, synthesizing, and analyzing these disparate data have historically been very difficult. However, current technologies of image analysis, collection, storage, and transfer make it possible to contruct dynamic and accessible web-based databases. The goal of this project is to create a research coalition that will maintain an active, interactive web database of squamate characters, data, and analyses. Infrastructure already in place is proposed to serve as a framewwork for this project. Current efforts have amassed a number of squamate character matrices; extraction of redundant characters is ongoing. Cladograms produced from analysis of this expanding database will be presented.

ONE “COLLECTOR’S” TRASH IS A PALEONTOLOGIST’S TREASURE: RE-EXCAVATION OF A TRICERATOPS SITE NEAR K/T BOUNDARY IN GARFIELD COUNTY, MONTANA

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Eastern Missouri Society for Paleontology (EMSP) and St. Louis Science Center (SLSC) are developing a paleontology field program in the Hell Creek of Montana. Purpose of the program is to introduce interested public participants to field collecting proceedures and to stimulate their interest in paleontology and geology. As part of the program, specimens are collected as training material for demonstrating and teaching preparation techniques to the public, especially children, at SLSC.

In June 2001 EMSP members located a few weathered *Triceratops* ribs on BLM land north of Jordan, Montana. After securing appropriate permits (BLM Permit M91066), a short recovery program was launched in early September 2001. The specimen was relocated approximately 15 meters below the K/T boundary on top of a small butte consisting of typical Hell Creek overbank deposits. A brief examination of the site revealed that the top of the butte had been cut back perhaps ten to twenty years ago and was an old excavation. A “collector” had removed the “best” material. We had found his “leftovers”. However, his “trash” was our “treasure”.

This “trash” consisted of parts of four ribs, two articulated dorsal vertebrae, one complete left pubis and the blade of the right pubis. These were perfect for our purposes, to teach children in St. Louis about paleontology, dinosaurs and life in the Cretaceous, and perhaps inspire some future paleontologists.

SLSC erected a temporary prep lab in their earth science gallery. EMSP members donated approximately 500 hours preparing specimens while demonstrating and teaching basic preparation techniques. The public was allowed into the prep lab, could hold and touch

dinosaur bones while we showered them with dinosaur factoids. Friday evenings were devoted to teaching interested children basic preparation skills. After a few hours they were accomplished enough to help with the specimens and be part of the team. The program was a success and we plan to expand it in 2002.

On February 12, 2002 the prepared elements werer deposited with the Johnston Geology Museum, Emporia State University, Emporia, Kansas.

THEROPOD VS AVIAN HINDLIMB LOCOMOTION

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It has become common in some circles to refer to birds as living theropod dinosaurs. In support of this hypothesis some authors have suggested that there is no difference between the hindlimb locomotion of birds and that of theropods, whereas others cite postulated transformations in anatomy and osteology from theropods to birds. Although none of these hypotheses withstand rigorous examination, the fact that they have been proposed and the manner in which they have been proposed have led to the application of avian anatomical nomenclature to theropods. This is unfortunate, and if continued it will inevitably lead to confusion comparable to that resulting from the once widespread practice of applying human anatomical terminology to lower vertebrates.

The crux of the problem seems to lie with the fact that hindlimb locomotion in both birds and theropods has been widely misinterpreted and misunderstood. For birds, maintaining balance during bipedal locomotion in the absence of a long, muscular tail was a primary problem that had to be overcome, whereas for the ground dwelling theropods speed in the chase was likely a more critical functional problem. As a consequence of, and in response to, these different selection pressures, and undoubtedly others, these two groups of bipeds evolved two different anatomical systems for terrestrial locomotion. Although they share the same bony elements common to most vertebrates, how their respective systems function is quite different. Primary functional differences occur in the hip, knee, and ankle joints, where features unique to each group are found. To facilitate the understanding of how these two distinct systems differ, it is necessary to avoid confusion resulting from the application of avian anatomical terminology to theropod osteological features that are probably not even analogous in function. Examples drawn from the literature are used to illustrate the inappropriateness of applying avian anatomical nomenclature to theropods.

VULPES VULPES (RED FOX) REMAINS FROM STANTON'S CAVE, ARIZONA: FIRST KNOWN RECORD FROM THE GRAND CANYON

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Stanton's Cave (927 m elevation; 44 m above the Colorado River) is a large solution cavern in the eastern Grand Canyon (GRCA), Arizona. The cave is best known to Quaternary paleontologists for its abundant late Pleistocene and early Holocene fossil remains of mammals and birds, including *Oreamnos harringtoni* (Harrington's mountain goat), *Ovis canadensis* (bighorn sheep), *Teratornis merriami* (Merriam's teratorn), and *Gymnogyps californianus* (California condor).

I recently examined part of the Stanton's Cave fossil vertebrate collection and found some specimens misidentified, and even unidentified. These will be the subjects of a future publication updating the collection. Of interest here are specimens originally published as *Urocyon cinereoargenteus* (gray fox). Three species of foxes live in Arizona today. *Urocyon cinereoargenteus* and *Vulpes macrotis* (kit fox) are relatively common, though of the two, the kit fox has a more restricted range. In contrast, *Vulpes vulpes* (red fox) exists only in the extreme northeastern corner of the state, and appears to have never been abundant in Arizona. In the fossil record, the red fox occurs at more than 25 Wisconsinan age sites in North America, including (but not restricted to) southern and western states such as California, Colorado, New Mexico, and Texas, but apparently not Arizona.

Two broken mandibles (left and right side) found in the Stanton's Cave collection were originally identified and published as *Urocyon cinereoargenteus*. Morphometric and morphological comparisons find the specimens consistent with *Vulpes vulpes*. The bones were originally recovered from 10-20 cm within a consolidated packrat midden inside the cave. While there is no radiometric age for this particular location, consolidated packrat middens in Grand Canyon caves tend to date from late Pleistocene to early Holocene. Material attached to the bones may allow future radiocarbon dating. While the specimens cannot be regarded unquestionably as Pleistocene in age, they do remain the first record of *Vulpes vulpes* from the Grand Canyon.

NEW INFORMATION ON AN OLD FISH: *BUNGARTIUS PERISSUS* (PLACODERMI: ARTHRODIRA)

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New discoveries of arthrodiran (Placodermi) fossils have added greatly to our knowledge of these Devonian fishes. In an attempt to understand the phylogenetic interrelationships among arthrodires these new forms are often compared with taxa from a number of classic localities from North America, Europe, the Russian platform, Asia, and Australia. The detailed anatomy of fossils from localities such as the Gogo, Western Australia, shows that our knowledge of many taxa is limited.

In the case of the North American material, much of it was initially described at the end of the nineteenth century and early twentieth century. In the 1920s to 1940s, Peter A. Bungart collected from the Cleveland shale what is now a significant portion of the Cleveland Museum of Natural History's collections. In 1965-1966, the Cleveland Museum of Natural History conducted the Interstate-71 Paleontological Salvage Project. This project nearly doubled the collections from the Cleveland shale. The Cleveland shale fauna is well known for its size and diversity of Late Devonian fishes; however, many taxa are still only known from incomplete and disarticulated specimens. Remaining work falls within one of three categories: (1) revision of taxa based on undescribed Interstate-71 material, (2) description of new forms, and (3) revision of poorly known taxa in light of current understanding.

The current analysis provides a reinterpretation of *Bungartius perissus* Dunkle. *Bungartius* is an aspinothoracid arthrodire showing similarities with selenosteids, most specifically *Gymnotrachelus*. In contrast, the enlarged orbits of *Bungartius* appear to be unique, distinct from selenosteids in that the snout is shifted forward to accommodate the increased orbit size. A fusion of the anterior superognathals is similar to the condition seen in *Mylostoma* and possibly *Paramylostoma*, although these latter taxa are poorly known. The description of *Bungartius* and the continuing work on other members of the Cleveland shale fauna shows much promise towards a better understanding of arthrodires and their phylogenetic interrelationships.

EVOLUTION OF BASAL TYRANNOSAUROIDEA FROM NORTH AMERICA

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Tyrannosauroids were the dominant terrestrial predators in Laurasia during the Late Cretaceous (K) and are among the few theropod clades with a substantial fossil record. Ghost lineages indicate Tyrannosauroidea diverged from other coelurosaurs by the Late Jurassic but the record of diagnostic fossils currently extends to near the beginning of the Late K. Recent cladistic studies of tyrannosauroids are compromised by a lack of diagnostic basal forms. New specimens from the late Campanian of Alabama and New Mexico represent new species that increase tyrannosauroid diversity in North America and provide the opportunity to reconstruct an inclusive phylogeny and historical biogeography of the clade.

A cladistic analysis of 109 morphological characters among eight ingroup- and seven outgroup taxa indicates that the new specimens are basal forms that are critical for, ultimately, identifying the sister taxon of the clade. A time-calibrated phylogenetic analysis reveals a dichotomy in tyrannosauroid phylogeny and a distribution of the clade throughout North America prior to the Albianian transgression of the Western Interior Seaway. The basal most tyrannosauroid in eastern North America is *Dryptosaurus,*from the late Maastrichtian of New Jersey. The new taxon from the late Campanian of Alabama is more highly derived than *Dryptosaurus.*The eastern forms retain a conservative morphology, such as the large forelimbs of *Dryptosaurus*and shallow maxillae of the Alabama species. The new species from the San Juan Basin of New Mexico is the sister taxon of Tyrannosauridae. These results indicate that basal tyrannosauroids, as well as basal ankylosaurians (e.g., *Nodocephalosaurus*), persisted into the late Campanian in western North America.

CERATOSAURS: A GLOBAL PERSPECTIVE

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Recent discoveries coupled with new studies of theropod anatomy and systematics provide strong support for the hypothesis that ceratosaurs (*Ceratosaurus* + abelisauroids) form a monophyletic clade exclusive of coelophysoids. In addition to resolving several inconsistencies, these studies have enabled the assignment of many incomplete remains to the ceratosaur lineage. The global evolution of this diverse theropod group can now be more clearly documented.

The earliest ceratosaurs are found in the Late Jurassic of North America (cf. *Elaphrosaurus, Ceratosaurus*), Africa (cf. *Ceratosaurus, Elaphrosaurus*) and Europe (*Ceratosaurus*). The group next occurs in Albian of Europe (*Genusaurus*) and persists there through the Maastrichtian (*Tarascosaurus*, ?*Betasuchus*). Ceratosaurs are the most common Late Cretaceous theropods in South America, where they comprise abelisaurids (*Abelisaurus, Aucasaurus, Carnotaurus*) and several poorly known taxa (*Xenotarsosaurus, Ilokelesia, Genyodectes, Noasaurus*, ?*Velocisaurus*). They were also dominant predators in Late Cretaceous Madagascar (*Majungatholus, Masiakasaurus*) and India *Lametasaurus/Indosuchus/Indosaurus, Laevisuchus*). Fragmentary remains suggest their presence in the Cretaceous of Africa (an unnamed Baharîja form, ?*Deltadromeus*), but coeval forms appear to be absent from North America. Currently ceratosaurs are unknown from Antarctica, Australia and mainland Asia.

Although ceratosaurs cannot be documented prior to the Late Jurassic, their global distribution at that time strongly indicates a more ancient origin. The clade likely had a near-Pangaean distribution during the Jurassic that was later largely restricted to Gondwana; descendants survived in Europe only as relatively uncommon faunal elements. However, their Late Cretaceous abundances run the gamut: ceratosaurs are absent from coelurosaur-dominated faunas (North America, Asia), rare where tetanurans are common (Africa, Europe), dominant in faunas with few coelurosaurs (South America), and prevalent where coelurosaurs are lacking (India, Madagascar).

PALEONTOLOGY AND STRATIGRAPHY OF THE TECOLOTLÁN BASIN, JALISCO, MÉXICO

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The Tecolotlán Basin of Jalisco is located in the Transmexican volcanic belt, 112 km southwest of the city of Guadalajara. Paleontological and stratigraphic study in this basin over the past few years has shown that it contains important information relative to the late Cenozoic faunal and geological history of the region. The Basin is a north-south oriented graben ounded by Cretaceous limestones, Oligocene-Miocene andesites and Pleistocene basalts.

Fossiliferous sediments aproximate 80 m in thickness, and range in age from late Hemphillian through Pleistocone. However, positively established Blancan-age sediments are rare. Hemphillian sediments tend to be finer grained and appear to represent lacustrine and floodplain environments. The lower units of coarse to fine grained sands and intercalated clays are tentatively named the Santa María- Los Corrales beds. Overlying these are more uniformly fine grained alluvial deposits of latest Hemphillian age, provisionally named the San José–La Hacienda beds. Datable volcanic ash layers exist in them. One age obtained from these beds is 4.89 ± 0.16 Ma based on Ar/Ar dating. A sandy to mostly conglomeratic sequence unconformably overlies these beds, which represents a marked change in deposition. These are called the Las Gravas beds, and are either latest Blancan or earliest Irvingtonian in age. Fossils show good preservation. Late Hemphillian vertebrates of the Santa María beds include, *Canis, Rhynchotherium, Teleoceras, Neohiparion eurystyle,* and *Dinohippus mexicanus. Nannippus minor* is better known here than elsewhere in Mexico. Latest Hemphillian vertebrates recovered from The San José-La Hacienda beds include *Megalonyx* (found in the dated ash), *Osteoborus* cf. *cyonoides, Machairodus* cf. *coloradensis, Teleoceras, Neohipparion eurystyle, Dinohippus mexicanus, Prosthennops, Alforjas, Hemiauchenia,* and *Hexobelomeryx*. Fossils found in the Las Gravas Beds include *Glyptotherium, Neochoerus* cf. *cordobai, Rhynchotherium, Equus simplicidens, Platygonus,* and *Camelops*. Additional taxa will be needed to establish the age of these beds with certainty.

MAMMALIAN BIOGEOGRAPHIC PATTERNS DURING THE EARLY BARSTOVIAN (MIDDLE MIOCENE) IN THE WESTERN UNITED STATES

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Today, western North America can be divided into distinct biogeographic provinces based on unique assemblages of mammals, which can then be grouped into distinct superprovinces and regions. However, it is unclear if the relationships among these provinces are the result of recent events (Pleistocene to Recent) or are more deeply rooted in Earth's history (Miocene or older). To test these hypotheses, generic occurrences of mammalian taxa during the early Barstovian (15.9 to 14.8 million years ago) were tabulated from the literature and extracted from the MIOMAP database for seven geographic regions: California Coast, Pacific Northwest, Northern Rocky Mountains, Great Basin, Southern Great Basin, Colorado Plateau, Northern Great Plains, and Southern Great Plains. Region boundaries were chosen such that they closely corresponded to recognized extant mammalian biogeographic provinces. The data were analyzed using two methodologies: a parsimony analysis of endemicity (PAE) and a cluster analysis using the coefficients of communities between provinces. The resulting trees suggest that the relationships we see today among mammalian biogeographic provinces were not identical to those of the early Barstovian. Similarities include a Great Basin/Pacific Northwest clade and a Colorado Plateau/Northern Great Plains grouping. On the other hand, during the early Barstovian the Northern Rocky Mountains showed a closer affinity to the Southern Great Basin than to the Colorado Plateau, and the Southern Great Plains was markedly different from all other provinces, perhaps reflecting a coastal adapted fauna. Further study of the Clarendonian and Hemphillian faunas is currently underway in hope of refining when these shifts in biogeographic patterns occurred.

CHANGING PATTERNS OF ONTOGENY FROM OSTEOLEPIFORM FISH THROUGH PERMIAN TETRAPODS AS A GUIDE TO THE EARLY EVOLUTION OF LAND VERTEBRATES

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Larval stages of both recent and fossil amphibians provide an added dimension—ontogenetic change—that can be used for phylogenetic analysis. This is especially important in regard to the origin and early radiation of tetrapods. A continuous growth series in *Eusthenopteron* shows that a close sister-taxon of tetrapods had direct development, without a recognizable larval stage. Gilled larvae of labyrinthodonts are known no earlier than the Upper Carboniferous, although they may have evolved by the Visean. There is little evidence as to whether the larval stage of temnospondyls and seymouriamorphs evolved from a common ancestry, or by convergence. All lepospondyls show direct development, with even the smallest fossils resembling the adults in body proportions and in possessing highly ossified vertebral centra.

The ancestry of the three "lissamphibian" orders can all be traced to separate Paleozoic lineages, based on both adult anatomy and the pattern of larval development. Frogs and primitive salamanders share similarities with temnospondyls in having gilled larvae, and in the rate and sequence of vertebral development. The sequence of ossification of the skull bones of conservative extant salamanders is identical with that of the early larval stages of the branchiosaurid *Apateon*. The adult cranial morphology of extant salamanders could have been achieved by truncation of ossificiation prior to the appearance of additional skull bones that developed at a later stage in Paleozoic temnospondyls. The ancestors of salamanders may have been facultatively neotenic, with long periods of larval development, but the antecedents of frogs may have gone through a period of direct development before evolving the highly specialized tadpole larvae. Caecilians resemble lepospondyls in the rapidity of vertebral ossification. Most caecilians loose the external gills soon after hatching, which might have been the case in lepospondyls.

A NEW SAUROPOD FROM THE APTIAN-ALBIAN OF BRAZIL AND ITS PHYLOGENETIC RELATIONSHIPS

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A new species of a sauropod from Brazil is presented herein. It was found in Aptian-Albian strata from the Itapecuru Formation (Parnaíba Basin, State of Maranhão), North of Brazil. The region is situated in the eastern limits of the Brazilian Legal Amazon. The fossil was found in a lithofacies that was interpreted as proximal fluvial mouthbars deposits in a deltaic environment. The Itapecuru specimen is known from a few, but diagnostic postcranial skeleton comprising several incomplete vertebrae, isolated centra, neural spines, chevrons, both scapulae and a complete ilium.

The phylogenetic relationships of the new taxon were investigated by a cladistic analysis using the ie* option of Hennig86, version 1.5. The analysis yielded one most parcimonious tree with 93 steps and a consistency index of 0.61, and retention index of 0.78: *Camarasaurus* (*Brachiosaurus* (*Andesaurus*, Titanosauridae)(*Haplocanthosaurus delfsi* (*Haplocanthosaurus priscus* (*Rayososaurus tessonei* (*Apatosaurus* (*Diplodocus*, *Barosaurus*)(*Dicraeosaurus* (*Amargasaurus*, new taxon). The new taxon shares five characters to support its inclusion in Dicraeosauridae, and it represents the first occurrence of a Dicraeosauridae in Brazil and the latest record of this taxon in South America.

The dicraeosaurids were previously known from the Upper Jurassic to Neocomian of Gondwana. The presence of the Itapecuru specimen in Aptian-Albian beds of northern South America extends the stratigraphic and geographic distribution of this taxon. The close relationships to *Amargasaurus cazaui* Salgado & Bonaparte, 1991 and a well-developed proportionally neural spine of the axis, lead us to conclude that this new sauropod presented an elevated sailback-like cervical crest. It is proposed that both should be included on a new suprageneric taxon, which is supported by the presence of a very elongated neural spine of the axis.

A NEW BIOGEOGRAPHICAL MODEL FOR DISPERSAL OF LATE CRETACEOUS VERTEBRATES INTO MADAGASCAR AND INDIA

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Overland dispersal from South America to Antarctica, then onto Madagascar and India during the Late Cretaceous must have been present to allow for the strong faunal similarities that existed between Patagonia and Indo-Madagascar, as seen in the late Campanian fauna from Los Alamitos in Patagonia and the Maastrichtian Maevarano fauna from Madagascar. The faunal similarities occur in abelisaurids and noasaurids dinosaurs, gondwanathere mammals and both notosuchid and peirosaurid crocodyliforms, all of which would reflect very different niches. Ratite birds may have used this same dispersal route to develop their current gondwanan distributions.

Previous tectonic models have a complete separation of Madagascar and India from Antarctica by 110 Ma. These reconstructions are at odds with the paleontological data and molecular data, where dispersals between Patagonia and Indo-Madagascar would have to have occurred in the Campanian, based on occurences of abelisaurids and gondwanatheres . Recent models present a possible disperse route from Antarctica to Indo-Madagascar through Kerguelen Plateau in the latest Cretaceous. Neither the geophysical data, nor the phylogenetic data support a reconstruction that relies on a connection between Antarctica and Indo-Madagascar through the Kerguelen Plateau.

The fauna dispersed from Patagonia through the Antarctica along the margin of the Weddell Sea, crossed to Madagascar at the Gunnerus Ridge by 82 Ma. The abelisaurids and gondwanathers then continued into India. Sri Lanka was in Lutzow-Holm Bay (Antarctica) with it's southern coast juxtaposed with the eastern margin of the Gunnerus Ridge, while Madagascar was located along India's southwestern coast and was connected to Antactica through the Gunnerus Ridge and Kainan Maru Seamount. Consequently, India, Madagascar, and Sri Lanka appear to be pivoting counterclockwise at the Gunnares Ridge, with the final connection of Indo-Madagascar to Antarctica being through the northern end of the Gunnerus Ridge at sometime after 82 Ma. This new model is more consistent with the various data sets than the previous models.

A FLORA AND FAUNAL LIST OF SPECIMENS RECOVERED FROM THE BIG PIG DIG, BADLANDS NATIONAL PARK, SOUTH DAKOTA

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In 1993, two visitors at the Badlands National Park in South Dakota discovered the remains of an ancient rhinoceros. They reported a vertebral column weathering out along Conata Road next to the Conata Picnic Area. Park paleontologists were sent out to collect the vertebrae. What started out as a simple salvage operation has now turned into a major quarrying expedition known today as the Big Pig Dig. Every summer since its discovery, with the exception of 1997, students from the South Dakota School of Mines and Technology quarry the site. Over 6,000 bones have been collected from the site.

The majority of specimens collected at the Pig Dig site include two families of artiodactyls (family Entelodontidae represented by *Archaeotherium* and family Leptomerycidae represented by *Leptomeryx*) and two families of perissodactyls (family Rhinocerotidae represented by *Subhyracodon* and family Equidae represented by *Mesohippus*). To date, 20 individual *Archaeotherium*, 6 *Leptomeryx*, 15 *Subhyracodon*, and 5 *Mesohippus* have been recovered from the quarry. The Minimum Number of Individuals (MNI) was calculated by counting right femora. In the last two years, 3(?) *Merycoidodon* from the family Merycoidodontidae (order Artiodactyla), 2 carnivores from the family Nimravidae, and one *Ischyromys* from the Family Ischyromidae (order Rodentia) have been found. Aside from the mammalian fauna, only one seed from the genus *Celtis* has been recovered which may suggest a preservational or collection bias. Although it is puzzling that there are no confirmed finds of turtle bones, very common fossils in the park, each year of continued excavation brings new additions to either the fauna or number of individuals. One can clearly state that interpretation of this unique deposit is far from over.

DIGITAL MODELING OF A VERTEBRATE TAPHONOMIC QUARRY USING GIS SOFTWARE.

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We have applied GIS technology to a vertebrate taphonomic quarry site in eastern Wyoming in an effort to achieve an optimal level of data retention. We have accumulated high-resolution GPS data (± 1 cm) associated with each bone, then attached this data to digital images of excavated bones, rectifying the images to the GPS data in 3-space. Using this technique in the 3-D module of ESRI's Arcview, we have reconstructed the quarry site in the computer, giving accurate representation to the absolute positions of excavated materials. The resultant maps can be viewed from any perspective in 3 dimensions.

Using off-the-shelf software, we are able to display the results of successive seasons' work from each quarry site as a single image. We can view the site from various perspectives, analyze the orientation of long bones, look at the distribution of such things as tendons and teeth and evaluate the spatial relationship between bones suspected of belonging to the same animal. We have also been able to visualize the thickness of the bone layer, the number of bones per unit area, and the vertical profile of the bones in each site. The formidable learning curve for GIS software can be initially sidestepped by focusing only on procedures required for 3-D display.

One of the objectives of taphonomic quarrying is to preserve as much information from the quarry site as possible, not only for the purpose of present investigations, but so that questions can be asked of the data that may not have occurred to investigators at the time of the initial study. Virtual quarry reconstruction requires high standards for data acquisition and retrieval, thereby ensuring the possibility of future queries from different perspectives.

USING ANCIENT DNA TO EXAMINE POPULATION PERSISTENCE AND GENETIC DIVERSITY IN AN ENDEMIC TUCO-TUCO (*CTENOMYS SOCIABILIS*)

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Evolutionary history is often reconstructed based on spatial patterns of genetic variation. However, the use of ancient DNA can enlighten our interpretation of modern variation as well as provide insight into historical changes. We extracted ancient DNA from teeth in order to examine a population of *Ctenomys sociabilis* over 1000 years to assess its genetic response to climatic change and recent human disturbance. *C. sociabilis* is an endemic tuco-tuco found in Argentina. Our study site, Estancia Nahuel Huapi, is a late-Holocene raptor roost in Parque Nacional Nahuel Huapi, Argentina. We compared cytochrome b sequences from ancient specimens to a modern tuco-tuco sequence from the extant local population. Our results show that of the 17 specimens sampled, all but 1 had identical sequences. Further, these sequences are identical to a representative of the modern population. Thus, this population has remained genetically identical for at least 1000 years in the face of climatic change, human disturbance and proximity of other tuco-tuco species (*C. haigi, C. maulinus*) with adjacent geographic distributions. The use of ancient DNA presents unique challenges due to low copy number, environmental damage to template, and high contamination risk. Despite these challenges, ancient DNA provides a unique perspective on evolutionary history.

SIMILARITIES: SYNAPOMORPHIES AND SCENARIOS—MORE CHARACTERS OF *YOUNGOLEPIS* BETRAYING ITS AFFINITY TO DIPNOI

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The close relationship between Porolepiformes and Dipnoi based on the unusual combination of characters in *Youngolepis* and *Diabolepis*, was suggested about 15 years ago, and has since been well corroborated by many workers. The remaining question, however, is whether *Younglolepis* is closer to Dipnoi or to Porolepiformes. Although new morphological features in the related forms tend to further support the relationship, the problem can not be regarded completely settled. There are strong competing alternative views. Some hold that dipnoans (with or without *Diabolepis*), *Youngolepis* and *Powichthys*) occupy either the basal rhipidistian or basal sarcopterygian position. Others, though accepting the Dipnoan affinity of the Porolepiformes (including *Powichthys*, *Youngolepis* and *Diabolepis*) with reservation, reject categorically the close relationship between *Youngolepis*, *Diabolepis* and the dipnoans.

While revising *Youngolepis*, I reexamined the grinding series and the specimens of *Youngolepis praecursor* Chang and Yu 1981. I was able to identify a few more morphological features, most of which were described in my thesis (1982) and yet have been somehow neglected by most of the workers. These features might bear importantly on the issue, i.e. to confirm and even reinforce the point of view that *Youngolepis* and Porolepiformes are stem dipnoans.

THE MEASUREMENT, ANALYSIS, AND UTILITY OF SYMMETRY, ASYMMETRY, AND MORPHOLOGICAL VARIATION IN FOSSIL VERTEBRATES.

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The analysis of asymmetry in organisms can provide many insights into evolution, population and developmental biology, functional morphology, and taphonomy. Biological explanations have included directional asymmetry, antisymmetry, and fluctuating asymmetry, each with its own evolutionary/developmental explanations and implications. With fossil taxa, there are other sources of asymmetry which also must be taken into account, most typically derived from various taphonomic mechanisms. In addition to the well-established methods available for analysis, mostly concentrating on fluctuating asymmetry and using conventional linear measurements, there are many additional techniques, including a number of geometric morphometric approaches, that provide very useful insight into patterns of variation and asymmetry but have been applied little or not at all to this problem. I review these methods and how they can be applied to the morphology of fossil vertebrates, with a concentration on applying landmark, outline, and combined analyses to the study of cranial variation. I develop methods for assessing asymmetry not only for populations of individuals, but also for estimating the overall asymmetry expressed by a single individual. I then relate this information back to possible biological and taphonomic explanations. Most of these new methods make use of the bilateral symmetry present in vertebrates and compare data for equivalent landmarks or outlines on both sides of the organism. However, many of these methods are also useful at evaluating asymmetry within other contexts and of other structures (e.g., the analysis of asymmetry in the shape of individual tridactyl dinosaur footprints) which can have functional and/or phylogenetic implications. Finally, I present general comments on the measurement of morphologic variation and estimating the overall levels of variability seen in organisms.

THE PERFORMANCE OF FOUR INDICES OF CONGRUENCE BETWEEN STRATIGRAPHY AND CLADISTIC TOPOLOGY

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The stratigraphic occurrence of fossils has been used as an independent source of data against which to test the relative performance of chosen cladograms. Several currently available indices do this by quantifying different aspects of congruence between the fossil record and cladistic topology. The stratigraphic consistency index (SCI) measures the fit of stratigraphic and cladistic order of occurrence, both the relative completeness index (RCI) and the gap excess ratio (GER) measure the amount of ghost ranges implied by different topologies, and the Manhattan stratigraphic measure (MSM) minimizes the distances between the ages of all taxa. Studies suggest that these indices may be biased by tree accuracy, tree shape, sampling intensity, dataset size, taxonomic practice, preservation, and/or evolutionary processes.

We investigate the influence of the first four factors on real datasets obtained from 20 published cladistic analyses of mammalian groups. These datasets have stratigraphic ranges from 4.2 my to 110 my and sizes of 9 to 39 taxa. The data were modified to test for the influence of tree accuracy, symmetry, and minimum and maximum ghost ranges. SCI, RCI, and GER were calculated using the Ghosts 2.3 program while the MSM was calculated directly in PAUP 4.0b7. Results show little or no influence of dataset size on any of the indices. The MSM is not significantly biased by tree accuracy, but is influenced by tree shape, while the RCI is not influenced by tree shape but is biased by tree accuracy and the amount of ghost ranges. The SCI and GER are significantly biased by tree accuracy, shape and ghost ranges. In general, indices were lower in increasingly inaccurate cladograms, in more symmetrical cladograms (except the MSM), and in cladograms with very long implied ghost ranges. These results suggest that groups with uncertain cladistic relationships should be characterized by the MSM while those with uncertain fossil records should be characterized by the GER.

ENANTIORNITHINE (AVES) NEONATES FROM THE EARLY CRETACEOUS OF CHINA

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Mesozoic remains of fetal and neonate birds are very rare. Until recently, a handful of neonate enantiornithines from the Early Cretaceous of Spain and enantiornithine embryos from the Late Cretaceous of Mongolia and Argentina comprised the entire record of early ontogenetic stages of Mesozoic birds. We report on the skeletal morphology of three nearly complete neonate avians from the renown Early Cretaceous Yixian Formation of Liaoning (northeastern China). Evidence of the immaturity of these specimens is expressed in the intense grooving and pitting of the periosteal surfaces, the disproportionately small size of the sternum, and the relative size of the skull and orbits. Size notwithstanding, anatomical differences between these three specimens are minimal, leaving no basis for discriminating them into separate taxa. Numerous osteological synapomorphies indicate they are euenantiornithine birds, the most diverse clade of Enantiornithes. However, their identification as members of a particular euenantiornithine taxon remains unclear. The morphology of the new neonates is significant for a better understanding of the homologies of several avian composite bones, whose elements are preserved prior to their coosification. The general morphology of the wrist and ankle of these neonates highlights once again the striking similarity between non-avian maniraptoran theropods and early birds. Distinct feather impressions indicate that enantiornithine hatchlings fledged their distal flight feathers very early, a fact that bears on our understanding of the developmental strategies of basal birds.

MORPHOMETRIC ANALYSIS OF EVOLUTION AND GROWTH IN THE CERATOPSIAN POSTCRANIAL SKELETON

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A variety of morphometric techniques were applied to the study of the ceratopsian girdle and limb elements, in order to document changes within a phylogenetic context through evolution and growth of these elements.

In order to study differences in shape of the ceratopsian postcranial elements and to compare evolutionary and developmental patterns, multivariate (Principal Component Analysis) and bivariate methods were used to analyze linear measurement data, and the shape methods Resistant-Fit Theta-Rho Analysis (RFTRA), Least-Squares Theta-Rho Analysis (LSTRA), and Euclidean Distance Matrix Analysis (EDMA) were applied to biological landmark data.

Results of the analyses show that in this group of dinosaurs, size is the primary change through evolution of the skeleton. Elements increased through evolution with positive allometry, and increasing structural support is evident, especially in the radius and fibula.

Phylogenetically, the ceratopsian postcrania agree with the skull material included in recent cladistic analyses. *Psittacosaurus* elements are in many ways derived relative to those of non-ceratopsid neoceratopsians, and evidence suggests that *Psittacosaurus* was bipedal, while non-ceratopsid neoceratopsians were not, except maybe for *Udanoceratops*. With increasing body size, neoceratopsian limbs bowed laterally.

Results of the growth analyses show that although ontogeny does not recapitulate phylogeny in this clade, growth trends are nearly identical to evolutionary trends in the elements studied. Heterochronic trends are exhibited in the ceratopsian postcranial skeleton, primarily as peramorphosis. *Avaceratops* is determined to be a valid taxon based on differences in the postcranial skeleton, but *Brachyceratops* is most likely a juvenile form of another taxon.

The variety of methods allows for unbiased interpretation of results, provide more information than any one method, and provide controls for each other. However, sample sizes, especially for the growth analyses, are not ideal, and all results should be treated with caution at this time.

LOCOMOTOR PERFORMANCE AND LIMB PROPORTIONS IN RUNNING MAMMALS

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Traditionally, analyses of peak locomotor velocity have been correlated with osteological parameters, most often hind limb length or metatarsus/femur ratio, in order to identify which parameters were good predictors of peak running speed. The rationale is based on a combination of similar morphological traits in fast running animals, physical principles such as lever mechanics, and stride lengths. The physical principles indicate, however, that substantially more long bone ratios than just m/f ratio could correlate with peak locomotor speed, and that more information may be extracted using multivariate techniques, combining several parameters. A sample of 76 running mammals, spanning a wide spectrum of phylogeny and size, were analysed, using both standard regression analyses, and analyses that take phylogenetic relationships into account. Correcting for the influence of phylogeny unanimously resulted in lower correlations, sometimes significantly so.

The best bivariate predictors of peak running speed are radius/humerus ratio, metacarpus/humerus ratio and olecranon length to cube root of body mass in the forelimb, and limb length and calcaneal tuber length, both normalised to cube root of mass, in the hind limb. Bivariate correlations were modest, but significantly higher correlations were obtained with multivariate analyses. Reliable predictions of peak running speed were most easily obtained using only two osteological variables. Addition of further variables most frequently led to variable redundancy, and the correlations increased only insignificantly, if at all. The highest correlation with two variables, using standard regression analyses, was 0.696 (metacarpus/humerus ratio and calcaneal tuber length to cube root of mass). The highest correlation with two variables, using regressions that correct for the influence of phylogeny, was 0.590 (m/f ratio and cnemial crest height to cube root of mass), collapsing two terminal nodes in the otherwise fully resolved phylogenetic tree. Eigen values and condition indices frequently indicated problems of variable intercorrelation, but this is probably unavoidable in a biological sample.

THE MEDIAL PHARYNGEAL PNEUMATIC SYSTEM (MPPS) IN *ALLOSAURUS FRAGILIS* : MORPHOLOGY AND PHYLOGENETIC SIGNIFICANCE.

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In contrast to the craniofacial and tympanic systems, the MPPS in theropods is poorly understood. Sagitally sectioned braincases, natural infillings of the MPPS, and CT data for *Allosaurus fragilis* provide detail on the MPPS unmatched for any other theropod. The external manifestation of the MPPS is the basisphenoidal sinus on the palate. Foramina in the roof of this sinus lead into a medial chamber which is enclosed within the bones forming the floor of the endocranial cavity. This chamber is divided into right and left halves by an ossified septum. Caudal extensions of this chamber invade the occipital condyle. Published data on the MPPS in other theropods is limited, but the condition in *Allosaurus* is very similar to that shown by Osborn in a sagitally sectioned braincase of *Tyrannosaurus rex*.

The basisphenoidal sinus is lacking in primitive forms such as *Herrerasaurus*, as well as ornithischians and sauropodomorphs and its presence is likely a theropod synapomorphy. It has been suggested that the invasion of the bones of the endocranial floor by the MPPS is a possible synapomorphy of the Tetanurae. However, CT data on ceratosaurians complicates the picture. *Coelophysis* does not show any invasion of the endocranial floor by the MPPS. However, in *Ceratosaurus* there is an extensive invasion, as large as in *Allosaurus*, but it does not extend into the occipital condyle. Either the invasive development of the MPPS occurred more than once in theropods or *Ceratosaurus* is, as a growing of body of evidence suggests, more closely related to the Tetanurae than to other “ceratosaurians.”

A NEW STEM TETRAPOD FROM THE EARLY CARBONIFEROUS OF NORTHERN IRELAND

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We report on the first Carboniferous tetrapod specimen discovered in Northern Ireland, and one of the most primitive tetrapods known from the UK. The specimen consists of a partial left jaw ramus showing sufficient features to diagnose it as a new taxon. The specimen was discovered in 1843 by Portlock, described as a rhizodont fish and housed with the British Geological Survey. Recent work on tetrapodomorph lower jaws has shown that this specimen belongs to an undoubted tetrapod that bears resemblances to deep-skulled forms such as the whatcheeriids and *Crassigyrinus*. The precise locality is uncertain, but it derives from near Londonderry, possibly from the Altagowan Formation. Palynological evidence is equivocal, ranging from late Viséan through early Westphalian, but the Altagowan Formation is usually regarded as early Viséan. The specimen is almost certainly older than those from Jarrow in Eire (Westphalian A), and is certainly more primitive than any tetrapod described from there. The specimen extends the geographical range of known Early Carboniferous tetrapods, which have now been found much further westwards in the British Isles than previously reported, and suggests the possibility of further discoveries in this region.

The jaw displays a distinctive character combination, including coronoids with an organised tooth row, lack of postsplenial-prearticular contact, an open mandibular lateral line sulcus, and a stepped rather than straight dentary-angular suture. A preliminary analysis of lower jaw characters places the new taxon in the neighbourhood of “cf. *Tulerpeton*” (late Famennian jaw material from Andreyevka, Russia) and *Whatcheeria*, above all other Devonian tetrapods, and below *Crassigyrinus*, *Greererpeton*, *Megalocephalus* and an anthracosaur-temnospondyl clade. It may belong to an early and wide-ranging post-Devonian tetrapod radiation.

KINEMATIC ANALYSIS OF LUNG VENTILATION IN CROCODYLIANS

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The morphology and function of the crocodylian respiratory system provides important comparative information with which to interpret the respiratory anatomy and function of extinct archosaurs. Detailed kinematic studies of crocodylian lung ventilation, however, have not previously been made. As part of a project investigating the evolution of respiratory mechanisms in the Archosauria, the skeletal and soft tissue kinematics of breathing in *Alligator mississippiensis* were examined by cineradiography.

Lung ventilation in *A. mississippiensis* is diphasic and arrhythmic, and consists of non-ventilatory phases of variable duration coupled with episodes of consecutive expirations and inspirations. Inspiration is the rest phase, rather than expiration. The inspiratory tidal volume is retained through closure of the glottis. Inspiration is achieved through the contraction of the M. diaphragmaticus, which pulls the liver and viscera caudad, and contraction of pelvic muscles which rotate the pubic bones ventrally. Expiration is achieved through elastic recoil of the liver and viscera, and dorsal rotation of the pubic bones, aided by contraction of the abdominal wall musculature. Costal aspiration breathing can occur in concert with pelvovisceral aspiration, but is generally associated with higher levels of activity. Caudomedial rotation of the ribs and dorsal movement of the sternal ribs and sternum during expiration increase the expiratory tidal volume, followed by craniolateral costal and ventral sternal rotation during inspiration. During exclusive pelvovisceral aspiration, the ribs are maintained at the maximum inspiratory position.

The crocodylian pelvovisceral aspiration pump may be highly derived. Costal breathing, probably plesiomorphic for diapsids, may be a primitive and independent module of the crocodylian aspiration pump, with the potential to increase tidal volume in case of elevated demands for gas exchange. The shift to exclusive pelvovisceral aspiration at rest may provide interesting opportunities to examine the physiological attributes of both costal and pelvovisceral aspiration.

NEW SMALL DINOSAURS FROM THE UPPER JURASSIC SHISHUGOU FORMATION AT WUCAIWAN, XINJIANG, CHINA

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In August-September 2001 our expedition to the Wucaiwan area (a.k.a. Pingfengshan) in the western part of the Junggar Basin, Xinjiang, resulted in a large collection of small tetrapods from the Late Jurassic Shishugou Formation. Vertebrates and ostracods from this formation place it in the early Late Jurassic, and our investigations located two horizons at Wucaiwan that might be dated radiometrically. The extensive badlands in this area had been only briefly examined by previous expeditions, and our six-week survey of the entire area collected over 40 articulated or associated specimens. The most common taxon, surprisingly, is Tritylodontia, represented by ample material of two species cf. *Bienotheroides* differing mainly in size. Other taxa include two species of turtles, a crocodyliform cf. *Sunosuchus*, and a pterodactyloid pterosaur.

Dinosaur material includes fragmentary remains of sauropods and at least 11 associated or articulated skeletons of ornithischians and theropods. Two new theropod taxa include what appears to be a basal coelurosaur represented by a disarticulated skeleton including many skull and postcranial elements. It has a well-developed pocket in the ectopterygoid and a postorbital similar to that of troodontids. A second theropod, represented by the posterior half of an articulated skeleton, is tentatively identified as the oldest definitive record of an ornithomimosaur. These two specimens fill gaps in the Late Jurassic record of coelurosaurs and provide further evidence that these gaps are due to poor sampling of smaller dinosaurs in sediments of this age.

Ornithischian specimens include at least two taxa, a thyreophoran and remains of the poorly known ?ornithopod *Gongbusaurus wucaiwanensis*. The dentary teeth of the thyreophoran have a well-developed cingulum with numerous subsidiary ridges but no primary ridge. The *Gongbusaurus* material includes substantial associated remains of at least two specimens.

AN ORNITHURINE FROM THE EARLY CRETACEOUS OF CHINA

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Although an array of well-preserved enantiornithines and more basal avialans have been described from the Early Cretaceous Yixian and Jiufotang formations of Liaoning Province, China, taxa more closely related to crown clade Aves have been represented only by two poorly preserved specimens. Here we describe the anatomy and phylogenetic position of an exquisitely preserved ornithurine specimen from the Jiufotang Formation. The nearly complete holotype of *Yixianornis grabaui* Zhou and Zhang constitutes the best specimen of an ornithurine from the Early Cretaceous to date and provides important insight into the morphology of basal parts of this clade. *Yixianornis grabaui* preserves a combination of pelvic morphologies primitive within Avialae and a flight apparatus that approaches that of crown clade Aves. For example, the pubes contact in a short symphysis, and gastralia are present as in more basal taxa, while a well-developed procoracoid process, globose humeral head, and proximal and distal fusion of the carpometacarpus are also present.

HOW MUCH KELP COULD A SEA COW EAT? ASSESSING THE IMPACT OF STELLER'S SEA COW ON KELP ECOSYSTEMS USING STABLE ISOTOPE ANALYSIS

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The discovery of the Steller's sea cow (*Hydrodamalis gigas*) in the mid 18th century marked the first documentation of a sirenian inhabiting high latitude, kelp-dominated waters, suggesting that the ecology of this species was different from that of all modern tropical sirenians. Unfortunately, the quick extermination of *H. gigas* by human hunting wiped out any chance for thorough scientific study of the role of this species in kelp ecosystems. Observations by Georg Wilhelm Steller and other explorers suggest that kelp did compose a part of the animal's diet, but the descriptions of the plants the animal consumed are open to interpretation, leaving much doubt as to whether sea cows actually were significant kelp consumers. We propose to identify whether sea cows were primary kelp consumers by analyzing the stable carbon isotope composition of fossilized *H. gigas* bones. Within marine ecosystems, vegetation carbon isotope values vary according to differences in primary productivity and environmental conditions, generating distinct values for phytoplankton (low), kelp (medium), and seagrass (high). These differences in carbon isotope values among potential dietary resources are preserved within the animal's tissues after a consistent fractionation and can serve as a proxy for an animal's dietary preferences.

We collected 25 samples of *H. gigas* from 5 sites located on the Aleutian islands that ranged in age from 100 ka to ~200 yr old. Both bone carbonate and collagen values for individuals from 200 yr old and 100 ka deposits exhibit remarkably similar carbon isotope values, which are too low to suggest consumption of significant amounts of seagrass and are more in line with a kelp-based diet. However, populations of *H. gigas* of intermediate age (~5 ka) have much lower values than values reported for older or younger sites, indicating a dietary shift to other marine resources, possibly species of green and red algae, which can have slightly lower values. Therefore, *H. gigas'* dietary preferences appear to have been quite variable and imply that this marine mammal may have had a more complex relationship within kelp ecosystems than originally perceived.

NOT ALL NOSES ARE HOSES: AN APPRAISAL OF PROBOSCIS EVOLUTION IN MAMMALS

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Fossil mammals with modified bony nasal regions (particularly retracted nasal bones) are commonly reconstructed with fleshy probosces, typically a short tapirlike trunks. We studied a diversity of extant mammalian probosces and their osteological correlates to determine the relationships between skeletal and soft-tissue structures. Hooded seals, moose, saiga antelopes, rhinos, and outgroups were examined through computed tomography (CT), gross dissection, sectioning, and skeletonization. Results include the identification of relatively discreet anatomical conformations or morphotypes of probosces. Virtually all of these share retracted nasals, and thus this attribute is not sufficient to warrant reconstruction of a trunk-like proboscis. Hypertrophic narial anatomies are characterized by specialization of osseocartilaginous and muscular tissues. Moose and hooded seals show an enlargement of nasal cartilages accompanying modified musculature. Saiga exhibit a reduction of nasal cartilages and nasolabial musculature. Rhinos possess more basal features, providing data on the anatomical substrates available for proboscis construction in other perissodactyls. All proboscis-bearing species have highly developed intrinsic narial muscles. None of these probosces are tapirlike trunks, affirming that different styles of probosces have evolved in Mammalia. Indeed, retracted nasal bones serve only as a starting point in reconstruction of a proboscis. Osteological correlates for other major soft-tissue structures (e.g., cartilages, muscles) provide rules of construction for proboscis building and for discriminating among functionally divergent conformations. These data permit proboscis inference to more adequately characterize the narial specializations seen in fossil mammals and to clarify their behavioral and ecological roles.

ORIGIN AND EARLY DIVERSIFICATION OF ACTINOPTERYGIANS

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During the past 5 years, new Devonian (e.g., *Cheirolepis* n. sp., *Dialipina, Limnomis, Osorioichthys*) and Carboniferous actinopterygians (e.g., *Discoserra, Guildayichthys, Wendyichthys, Woodichthys*) have been discovered around the world. In addition, new basal osteichthyan taxa, such as *Psarolepis*, have been found, showing puzzling combinations of actinopterygian and sarcopterygian characters. Although the monophyly of the Actinopterygii has never been questioned, the synapomorphies corroborating the monophyly as well as the interrelationships among basal actinopterygians vary among the studies. The Late Silurian *Lophosteus*, the Early Devonian *Dialipina*, the Middle-Late Devonian *Cheirolepis*, the Frasnian *Howqualepis*, and the recent *Polypterus* have all been identified as the basal taxon of the actinopterygians. A combined data matrix is compiled in order to include more than 140 cranial and postcranial characters from recent phylogenetic analyses of basal actinopterygians and basal osteichthyans as well as new characters. More than 20 species of non-teleost actinopterygians have been coded. Although interrelationships among Devonian and Carboniferous taxa are well corroborated, character distribution raised questions concerning the homology of the rostral complex, the posterior cheek region, the opercular series, and pectoral girdle elements.

TESTING THE RELATIONSHIP BETWEEN PALEOSOL MATURITY AND FAUNAL COMPOSITION IN VERTEBRATE COLLECTIONS FROM THE MCCULLOUGH PEAKS, BIGHORN BASIN, WYOMING

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The lower Eocene Willwood Formation is characterized by mudstone deposits that have been subjected to variable amounts of pedogenesis. These changes in paleosol maturity are thought to be controlled by depositional position on the ancient floodplain and/or extrabasinal influences on short-term sediment accumulation rates (e.g. climatic changes). Since these same deposits have diverse and variable vertebrate faunal assemblages, some researchers have hypothesized a paleoecological relationship between paleosol maturity and faunal composition. We have tested this hypothesis in two different ways using fossil collections from a single faunal zone (Wasatchian 3) in the McCullough Peaks area of the Bighorn Basin, Wyoming. First, we measured stratigraphic sections through existing localities and compared faunal compositions between localities that are characterized by different average paleosol maturities. Results of a principal components analysis of generic raw abundances and average paleosol maturities indicate two basic groupings of taxa. These groupings directly correspond to differences in body size even though no morphological measurements were included in the analysis. Loading of average maturity is weak but indicates a potential relationship between high maturity paleosols and collections with small body-sized taxa (and vice-versa). In order to test this more rigorously, we spent parts of two field seasons collecting paleosol-specific samples from the same faunal zone. Results of this experiment indicate that different paleosol maturities are characterized by almost identical faunas. The only taxa that fall outside the 95% confidence limits determined through bootstrapping are *Diacodexis* (significantly less abundant in mature paleosols), and squamates (significantly more abundant in mature paleosols). These results indicate that paleosol maturity exerts very little control on faunal composition at this spatial scale and that size sorting may be a strong taphonomic process in these collections.

JUVENILE PTEROSAURS FROM THE EARLY CRETACEOUS OF ARGENTINA

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We report on two hatchling pterosaurs from the Lower Cretaceous lacustrine deposits of the Lagarcito Formation (Albian) of central Argentina (San Luis Province). One of the specimens lacks the skull but is otherwise nearly complete and articulated; the other is more fragmentary. Both specimens were found at the same quarry that has provided hundreds of remains of the filter-feeder pterodactyloid, *Pterodaustro guinazui*. The small size (~30 cm wingspan), the lack of fusion of various postcranial elements, the low degree of epiphyseal ossification, and the general porous appearance of the periosteal surfaces indicate that the specimens died at a very early stage of postnatal development. The presence of derived characters unique to *Pterodaustro* (e.g., caudal vertebrae exceeding 15 elements, an apparent reversal within Pterodactyloidea) supports the assignation of the specimens to this pterosaur taxon. The new specimens provide anatomical information previously unknown for *Pterodaustro*, such as the presence of a phalanx on the fifth pedal digit, and shed light on the allometric transformations of this taxon. In contrast to the adults, the hatchlings show a predominance of the proximal segment of the wing over its distal portion (e.g., humerus longer than metacarpal IV), a pattern similar to the allometric growth of extant avians. Likewise, the juvenile humerus is slightly longer than the tibia, a condition opposite to that of the adults. The new specimens are the smallest pterosaurs of the Americas and they likely represent the earliest known ontogenetic stages for the pterosaurs of these continental masses.

SINUS CAVITIES IN FOSSIL AND RECENT TAPIRS: CT EVIDENCE FOR EVOLVING CRANIAL ARCHITECTURE.

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High-resolution X-ray computed tomographic (HRXCT) analysis of fossil and Recent tapirs reveals differences in internal cranial anatomy that appear to be associated with their evolution of a prehensile proboscis. Scanned skulls include: a new taxon of Eocene fossil tapiroid, the Oligocene *Colodon* and *Protapirus*, and three of the four Recent species of *Tapirus*. Dramatic architectural reorganization involves the development and modification of sinus cavities and evolutionary changes in their relationship to the cranial cavity. It is hypothesized that these changes are part of a major reorganization of the tapiroid cranium that occurred in concert with their progressive development of a prehensile proboscis. This reorganization includes the posterior 'telescoping' of the facial portion of the skull relative to the braincase. These observations have ramifications to hypotheses of phylogenetic relationship within Tapiroidea.

TAPHONOMY OF THE BASAL ISCHIGUALASTO FORMATION (UPPER TRIASSIC, ARGENTINA)

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The Ischigualasto Formation (228 Ma) consists of a sequence of fluvial sediments that preserves a rich vertebrate paleofauna, especially in the basal portion of the unit. This paleofauna includes a diverse association of therapsids, rhynchosaurs and archosaurs, including the oldest known record of dinosaurs. Despite great significance from an evolutionary perspective, the taphonomic relationships of the paleofauna are still poorly known.

Four main lithofacies are proposed for the basal portion of the Ischigualasto Formation: L1—lenticular medium- to coarse-grained sandstones with massive and stratified structure; L2—tabular medium-grained sandstones with laminar and massive structure; L3—mudstone with vertical accretion; L4—mudstone with evidence lateral accretion. The L1 and L4 lithofacies are interpreted to represent channel deposits with different sedimentary loads. The L2 lithofacies is interpreted to represent levee and crevasse splay deposits. The L3 lithofacies is interpreted to represent deposits of the floodplain.

The majority of the fossils in the Ischigualasto Formation are in lithofacies L2 and L3. States of preservation vary, and are here relegated to three main taphofacies: T1—articulated skeletons associated with isolated bones. Bones display excellent preservation, with no evidence of pre-burial damage. Fossils are preserved in calcic vertisols. These characteristics are interpreted to reflect attritional deaths and mummification of the carcasses on a dry floodplain. T2—disarticulated skeletons with advanced indication of weathering, embedded in sandy carbonate concretions. This taphofacies is interpreted to represent attritional mortality with prolonged weathering on a dry floodplain. Burial presumably occurred in distal overbank deposits. T3—typically isolated bones with hematite crusts, characterized by minimal weathering. These hematite-coated fossils were likely exposed as carcasses on a dry floodplain, rapidly dispersed by necrophagous agents, and then buried in a short period of time.

FIRST FOSSIL RELATIVE OF *SHINISAURUS* (ANGUIMORPHA, SQUAMATA) AND THE PHYLOGENETIC IMPORTANCE OF "SHINISAURIDAE"

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Shinisaurus crocodilurus is an anguimorph lizard of uncertain phylogenetic affinities. Competing views argue placement within Xenosauridae, as an outgroup to Anguidae, or as an outgroup to Xenosauridae + Anguidae. This difficulty stems not only from inaccuracies in the published data concerning the morphology of *Shinisaurus*, but also from the long missing lineage it represents. All major anguimorph clades (Xenosauridae, Anguidae, Monstersauria, Varanidae, and Mosasauroidea) were distinct by the Late Cretaceous and there are currently no known fossils closer to *Shinisaurus* than to any of these clades.

Recent identification of a lizard from the Green River Formation of Wyoming helps to shorten this missing lineage. This unnamed fossil is well preserved with skull and postcranium articulated in dorsal view and with some of the squamation intact. It is similar to *Shinisaurus* in virtually every aspect of its known morphology, including the form of the dermal sculpturing on the skull, presence of a prefrontal rugosity, extension of the prefrontal to the naris, jugal morphology, tooth morphology, vertebral count, and keeled osteoderms on the tail. The nasal process of the premaxilla is more elongate in the fossil than in *Shinisaurus*.

The new fossil and corrected data for *Shinisaurus* are important for accurate inclusion in anguimorph phylogeny. Existing phylogenetic analyses of Anguimorpha include a limited diversity of fossils; either most terrestrial forms or all mosasaurs are excluded. Moreover, published analyses including *Shinisaurus* invariably contain miscodings resultant from paucity of specimens. These factors negatively influence character polarity and resultant topology. A cladistic analysis of 121 morphological characters was performed for 39 taxa, including mosasaur and terrestrial fossil taxa. *Shinisaurus* and the new fossil form a clade, provisionally titled "Shinisauridae." "Shinisauridae" is the sister-group to Anguidae + Platynota in a consensus tree. The results show topological differences between analyses including and excluding "shinisaurids."

A NEW CHARADRIIFORM AVIAN SPECIMEN FROM THE EARLY MAASTRICHTIAN OF CAPE LAMB, VEGA ISLAND, ANTARCTIC PENINSULA

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A new avian partial skeleton (field number: VI 9901), the oldest and most complete avian specimen from Antarctica, was collected from the early Maastrichtian Cape Lamb Member of the Lopez de Bertodano Formation, Cape Lamb, Vega Island, Antarctic Peninsula in 1999. The partial skeleton consists of: two cervical vertebrae, two thoracic vertebrae, sternal keel, articulated right coracoid and scapula, sternal portion of left coracoid, complete right humerus, partial left humerus, proximal right ulna, proximal left ulna and radius, proximal right carpometacarpus, proximal left carpometacarpus, distal left carpometacarpus, synsacrum, right femur, partial left femur, proximal right tibiotarsus, right and left distal tibiotarsus articular ends, and the proximal right tarsometatarsus.

This specimen differs from other known Cretaceous birds in having several plesiomorphic features such as a non-perforated acetabulum, a fibula which is not reduced but is articulated to the shaft of the tibiotarsus, and a non-ossified supratendinal bridge of the tibiotarsi. In addition, this specimen has morphological features which are comparable to Recent charadriiform families such as: pleuroceolus thoracic vertebrae and an expanded lateral edge of the posterior coracoid. Evolutionarily, the plesiomorphic features of this bird specimen place it as a basal member of the neornithine subclass, within the order Charadriiformes, tentatively within the family Burhinidae. The specimen represents a new genus and species.

With regard to other Cretaceous Antarctic birds, this new taxon is the fourth neornithine fossil found from the continent to date. In general, the Late Cretaceous fossil record of Aves from Gondwana consists of mostly enatiornithine and a few neornithine groups; this taxon being an important early member of the latter. This specimen is an important new fossil which, along with additional Antarctic avian fossils, may better establish the timing and origin of Recent bird lineages that are currently in debate.

EFFECTS OF TRANSPORT-INDUCED ABRASION ON AVIAN SKELETAL ELEMENTS

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Because of the delicate nature of the avian skeleton, with thin-walled and hollow bones, the paucity of the avian fossil record is commonly attributed to the postmortem destruction of skeletal elements during transport and burial. Therefore, it was hypothesized that abrasion from sediment-bone interactions during transport would destroy avian bones more readily than non-avian bones, assuming that all other variables are equal. To test this hypothesis, avian, mammalian, and reptilian skeletal elements were subjected to simulated fluvial transport in the laboratory. Tested variables included sediment grain size, bone size, and weathering stage of the bones prior to transport. Preliminary results indicate that, contrary to conventional wisdom, mechanical abrasion causes similar amounts and types of damage to both avian and non-avian elements. Avian skeletal elements may be relatively more susceptible to other taphonomic processes (e.g., crushing), but the data presented here do not support the hypothesis that, under similar conditions, transport-induced abrasion damages avian skeletal elements more than those of non-avian taxa. These results are supported by a mesovertebrate case study of the Sandy Site from the Upper Cretaceous Hell Creek Formation of South Dakota, where all small skeletal elements exhibit a similar degree of abrasion, regardless of taxonomic affinity.

FORELIMB MORHPOLOGY AND LIMB PROPORTIONS OF MIDDLE EOCENE *OXYAENODON* (MAMMALIA, CREODONTA)

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We present the limb proportions and forelimb morphology of *Oxyaenodon dysclerus* and discuss their implications regarding the locomotor adaptations and behavior of this taxon. The partially articulated skeleton was recovered from the middle Eocene Uinta Formation of northwestern Utah. It was found at locality WU-22 South, in fine-grained overbank deposits within the uppermost reduced grayish beds of Uinta B rocks, but above the "*Amynodon* sands"; these uppermost Uinta B beds contain a mammalian fauna that is probably best considered late Uintan in age.

Numerous craniodental and postcranial elements are represented, including a well-preserved humerus, ulna, radius, femur, and tibia, each of which retains the complete shaft length. A body weight estimate of 1.54 kg ($r^2 = 0.69$) has been calculated by comparisons of its lower first molar length to a sample from extant carnivores and dasyurids. The nearly complete fore- and hindlimb permit comparisons to other taxa on the basis of limb proportions. The brachial index of *Oxyaenodon* (about 76.3) is small compared to most cursorial carnivores and is similar to that of the viverrid *Nandinia*, the mustelids *Meles* and *Spilogale*, and the procyonid *Ailurus*. These animals share a fairly robust build for small carnivores and are locomotor generalists. Specific morphological features of the forelimb, such as marked humeral retroflexion, squarish radial head, prominent greater and lesser tubercles, and relatively robust olecranon process suggest scansorial or terrestrial behavior rather than specialized arboreality. The crural index (about 106.6) is large and is similar to that of the viverrids *Ichneumia* and *Genetta*, the mustelid *Mustela*, and the canid *Vulpes*, animals that move quickly across the ground. A comparison of the hindlimb length to body mass suggests that *Oxyaenodon* is outside the range of carnivores that are specialized for burrowing. Together these analyses suggest a robustly built locomotor generalist relying primarily on terrestrial walking and running (rather than leaping, digging, or climbing).

BIOMECHANICAL PROPERTIES OF IGUANIAN ENAMEL AND ITS CORRELATION TO THE DIFFERENTIAL ARRANGEMENT OF APATITE-CRYSTALS

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A comprehensive understanding of tooth function requires a sound understanding of how individual components function and their emergent contribution to the whole. There is no clear understanding of how the diversification of reptilian enamel microstructure facilitated changes in diet, size (both of tooth and animal), and tooth use (mastication, crushing, prey capture). A clear understanding of the diversification of enamel structures and their biomechanical properties will elucidate these changes.

Enamel consists mainly of inorganic apatite-crystallites held together by an organic matrix. Differential crystallite arrangements convey great crack resistance in hyenas, and wear resistance in masticating animals. Reptilian enamel has been viewed as a homogeneous amalgam of apatite-crystals. Recent studies reveal a complexity similar to that present in mammalia. The enamel microstructure in Iguania was characterized using scanning electron microscopy. Specimens selected included: *Bradypodion pumilum*, *Chameleo hoehnelii*, *Chamaeleo namaquensis*, *Chamaeleo melleri*, *Rhampholeon brevicaudata*, *Leiolepis belliana*, and *Uromastyx hardwickii*. These taxa are representative of the phylogenetic, trophic and morphological diversity within the group. Most taxa have aprismatic parallel crystallite enamel and a defined basal unit layer. The amount of longitudinal wrinkling of the enamel varies between species. Uromastyx possesses type I prismatic enamel. There is an unquantified correlation between the arrangement of apatite crystals and tooth use. Mechanical tests using micro- and nano-indenters were used to quantify the biomechanical properties of the enamel. We are finding substantial differences in the biomechanical properties of the enamel that

appears to be correlated with the differences in microstructure and ecological correlates (diet and tooth use). By using this knowledge in conjunction with fossil evidence inferences can be made concerning the diet of extinct species.

VARIATION IN THE SCHMELZMUSTER AND OTHER ENAMEL FEATURES OF *OGMODONTOMYS* (RODENTIA: ARVICOLIDAE) MOLARS FROM THE MEADE BASIN OF SOUTHWESTERN KANSAS

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The purpose of this study was to investigate several aspects of enamel variation, including the schmelzmuster, in molars from adult *Ogmodontomys* collected in the Meade Basin of southwestern Kansas. First upper molars of *O. poaphagus* were examined from three stratigraphically superposed localities (Ripley B, Hornet, Rexroad 2a) spanning a period of approximately 1.70 million years. Measurements were taken of enamel thickness and percent composition of enamel types. Qualitative assessments included the determination of degree of enamel development and approximate location of schmelzmuster layers. Results indicated some individual variation in enamel thickness and percent composition of tangential and radial enamel, but there was no statistically significant difference in these variables. A significant increase in the development of tangential enamel was observed, but it was not accompanied by change in overall enamel width. Enamel differentiation varied consistently among triangles within the same molar, but no edges displayed the well developed negative differentiation of Old World *Mimomys*. Well developed lamellar enamel, a defining feature of the Old World *Mimomys* schmelzmuster, was not observed in *O. poaphagus,* but a few small patches of possible discrete (primitive) lamellar enamel were seen. Molars assigned to *O. sawrockensis* primarily displayed radial enamel on both leading and trailing edges. These results support the assertion that the schmelzmuster is a consistent and genetically controlled character mosaic that can be used effectively for phylogenetic interpretations, and confirm suggestions in the literature that *Ogmodontomys* is distinct from *Mimomys.*

MAMMALIAN PREDATOR-PREY DIVERSITY PATTERNS: WHAT DO THEY TELL US ABOUT "ISLAND" CONTINENTS?

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Owing to their long geographic isolation, the mammal faunas of Australia and pre-interchange South America represent independent experiments in mammal evolution. Despite this, they are remarkably similar in their absence of native placental predators and their relative paucity of marsupial predators. The present study was undertaken in order to investigate the potential effects of this low predator diversity on prey diversity.

Predator and prey diversity were calculated for 70 modern North American, Eurasian, and African faunas. A second-order polynomial regression was used to derive an equation describing the average (expected) ratio of predator to prey diversity for non-isolated continents; this equation was then compared to data from modern and fossil South American and Australian faunas.

Fossil faunas from both South America and Australia demonstrate a much lower diversity of predators than expected based on prey diversity. This suggests that the low predator diversity does not result from a lack of prey items, but rather from a different predator/prey ratio for faunas with marsupial predators.

Modern South American faunas have predator diversities that are only slightly lower than expected based on prey diversities. This suggests that these faunas might not yet have reached the new predator-prey equilibrium necessitated by the shift from marsupial to placental predators after the Great American Biotic Interchange.

Many modern Australian faunas are "depauperate" compared to their fossil counterparts due to the introduction of placental predators and the correlated extinction of endemic taxa. However, predator-prey ratios from these "depauperate" faunas are closer to expected values (based on other continents) than are the ratios from fossil Australian faunas. This implies that the present decline of Australian native fauna may represent an "expected" adjustment of the continent's predator/prey ratio from a marsupial to a placental level, primarily via a reduction in prey diversity.

THE PLEISTOCENE RECORD OF XENARTHRA FROM THE STATES OF HIDALGO, PUEBLA, AND TLAXCALA, CENTRAL MEXICO. THE PLEISTOCENE RECORD OF XENARTHRA FROM THE STATES OF HIDALGO, PUEBLA, AND TLAXCALA, CENTRAL MEXICO.

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The Pleistocene record of the Xenarthra from the Central Mexico, has been previously recovered from fluviolacustrine aluvial deposits, that outcrop extensively in the States of Jalisco, Aguascalientes, and the Mexican Basin.

Paleontological work carried on diverse localities in the south central and eastern regions of the State of Hidalgo, Tlaxcala, and the Valsequillo Basin State of Puebla, allowed to recover a significantly fossil material belonging to xenarthrans. The identified record includes representative specimens of the families Dasypodidae (*Holmesina* sp.), Glyptodontidae (*Glyptotherium floridanum*), and Megalonychidae (*Megalonyx* sp.) The Dasypodidae is represented by numerous isolated osteoderms, an isolated upper molariform, and a few postcraneal elements, referable to *Holmesina* sp. The material belonging to gliptodonts is fairly abundant, and includes isolated and articulated osteoderms of the dorsal and marginal regions of the carapace, whose configuration is the typical of the species *G. floridanum*. The fossil material referable to Megalonychidae is only known from rancholabrean deposits of the State of Hidalgo. The specimen recovered is represented by a right maxilar fragment with the last two upper molariforms, that was assigned to *Megalonyx* sp.

This record evidence the permanence of the xenarthrans and its integration with Holarctic faunal assemblages of Central Mexico, during the greater part of the Pleistocene. As well as, provides additional information concerning to its distribution and evolutionary history in North America,

A NEW WHITEFISH FROM THE EARLY PLEISTOCENE OF BLUEFISH BASIN, YUKON TERRITORY, CANADA

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A nearly complete fossil of a new species of whitefish of the genus *Coregonus* (Salmoniformes, Coregoninae), was recovered from a concretion at Ch'ijee's Bluff, along the Porcupine River, Bluefish Basin, Yukon Territory. The stratigraphic position of the source concretionary layer, at the base of Unit 3, a lacustrine unit, is below a magnetically reversed interval thought to represent the upper part of the Matuyama chron. The fossil is thus older than 0.79 Ma, and is the oldest known record of the genus. Sedimentary and geochemical analyses suggest that fossilization occurred in an environment characterized by fine sedimentation, in a cold, reducing milieu with a pH of about 7.5. Palynomorphs in the concretion suggest an open shrub tundra environment and a climate colder than that of the present, similar to conditions prevailing at or above the tree line. The lake in which the whitefish lived was possibly part of a hydrographic basin which drained toward the Arctic Ocean.

LATE TRIASSIC VERTEBRATES FROM THE PATRICIA SITE NEAR POST, TEXAS

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Field parties from Texas Tech University have been exploiting the Patricia Site in the Cooper Canyon Formation (Norian) of the Dockum Group near Post since 2001. Various locations at the site produced abundant remains of phytosaurs, and much less common, actinopterygian, metoposaur, aetosaur, rauisuchian, and dinosaur material. Here, we present an overview of the finds with comments on their significance and the depositional settings of selected locations.

Three excellently preserved skulls of the phytosaur *Pseudopalatus pristinus* reveal new anatomical details of the narial region, the palate, and the nature of the dentition in this taxon. A sequence of oxbow-lake deposits yielded an assemblage of aquatic and semiaquatic vertebrates, among them the largely articulated and almost complete postcranium of a pseudopalatine phytosaur. This is only the second phytosaur known that provides details of the tail anatomy, including the structure and proportions of the centra, neural spines, and hemal arches. In addition, the specimen shows a pathologically deformed humerus, which apparently resulted in a remodeling of the shoulder girdle.

Other crurotarsan archosaurs are represented by isolated cranial elements of the rauisuchid *Postosuchus*, and scutes and postcrania of the aetosaur *Typothorax*.

An isolated tibia is referred to a large ornithischian dinosaur and represent one of the few records of ornithischians in the Upper Triassic. The bone was recovered from fluvial channel deposits in association with disarticulated phytosaur remains.

DENTAL VARIABILITY IN EARLY EOCENE *MICROSYOPS* (MAMMALIA, ?PRIMATES), WITH A DESCRIPTION OF NEW SPECIMENS FROM THE WASHAKIE BASIN, WYOMING

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Microsyops is a small-bodied mammalian genus belonging to the enigmatic plesiadapiformes, a possibly paraphyletic group often referred to as the archaic primates. *Microsyops* spans a biostratigraphic range from the early through late Eocene of North America, and is well-known from many areas of the interior Rocky Mountain region. Although *Microsyops* has been described in detail previously, these discussions have largely been based on material from the better-known early Tertiary basins of Wyoming (e.g., Bighorn Basin). Here we present data on a stratigraphically controlled *Microsyops* sample from the middle to late Wasatchian (Wa5-Wa6) of the Washakie Basin, WY. Although the sample described here consists primarily of isolated teeth, one specimen collected in 2001 from Wa6 strata in the Bitter Creek area of the basin is a well-preserved, nearly complete right dentary. This specimen (UCM 96289) preserves the mandibular symphysis, alveoli for the incisor and p2, and complete teeth from p3 through m2. Metric data for this specimen (2.50mm, 3.35mm, 3.34mm, 3.85mm, for p3 through m2 length respectively) fall centrally within published size ranges for *Microsyops latidens*. In addition, this specimen also exhibits a morphology (e.g., p4 talonid structure) consistent with that of *Microsyops latidens*. Specimens from the slightly older Wa5 strata of the Bitter Creek and Patrick Draw areas exhibit a morphology consistent with *Microsyops angustidens* (e.g., variable upper molar mesostyles), therefore indicating a patern of taxonomic diversity for the Washakie Basin similar to that of the Bighorn Basin. The transition from *Microsyops angustidens* to *Microsyops latidens*, which corresponds to the Wa5-Wa6 faunal turnover seen in other mammals in the Washakie Basin, is also similar to that seen in other areas, and suggests a general pattern of mammalian biostratigraphic change and taxonomic diversity throughout the Rocky Mountain region.

TITANOSAUR TAILS TELL TWO TALES: A SECOND MALAGASY TITANOSAUR WITH SALTASAURID AFFINITIES

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The Upper Cretaceous Maevarano Formation of Madagascar yields the remains of two distinctive titanosaurian sauropods. The first, *Rapetosaurus krausei*, is known from numerous cranial and postcranial elements. The second titanosaur, Malagasy Taxon B, is currently known from 12 associated distal caudal vertebrae and a coracoid. Extreme dorsoventral compression of the caudal centra imparts a subrectangular morphology in anterior and posterior views. Prezygapophyses are extremely elongate, and neural spines are low and laminar. The coracoid has a sharp, quadrangular outline in lateral view, subequal proximodistal and dorsoventral dimensions, a large rectangular articular facet for the scapula, and a well-defined infraglenoid lip. The coracoid foramen is located on the edge of the element and is not completely enclosed by the coracoid

A phylogenetic analysis of 364 characters (109 cranial, 255 postcranial) in 34 sauropod taxa recognizes Titanosauria monophyly, and distinguishes three major clades within it. Saltasauridae is strongly supported in all analyses and includes traditional members of the group (*Saltasaurus*, *Neuquensaurus*, *Rocasaurus*) and Malagasy Taxon B. Malagasy Taxon B can be confidently placed within Saltasauridae on the basis of two unequivocal synapomorphies: (1) the presence of dorsoventrally compressed procoelous distal caudals with low neural spines and elongate prezygapophyses, and (2) the presence of an infraglenoid lip on the coracoid. Until now, saltasaurids were known only from South America. The inclusion of Malagasy Taxon B within Saltasauridae significantly extends the geographic range of the group and indicates that saltasaurids were distributed through a large part of Gondwana during the Late Cretaceous.

PHYLLOSTOMID BATS FROM THE OLIGOCENE AND EARLY MIOCENE OF FLORIDA

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Several Oligocene and Miocene localities in Florida have produced abundant microvertebrate fossils including rare specimens of Chiroptera, a group with a sparse Tertiary record in North America. At two of the localities, I-75 and Brooksville 2, the bats include several specimens of a large and a small noctilionoid that may be the earliest known representatives of the Phyllostomidae (Mammalia: Microchiroptera). The specimens represent two new species, both belonging to an undescribed new genus. The samples overlap in including an upper molar of each species; except for size, this tooth is identical in the large and small species. The large species is approximately the same size as the extant greater spear-nosed bat (*Phyllostomus hastatus*); the smaller, near the size of the pale-faced bat (*Phylloderma stenops*). Only the large species is present in the Brooksville 2 fauna, where a better sample is available including an upper molar and all lower teeth except the incisors. The Brooksville 2 local fauna is judged by recent authors and us to represent the late early Arikareean (24-28 Ma; late Oligocene). Each of the bat species is represented by a single tooth in the I-75 local fauna, which we interpret as being late Whitneyan LMA (about 30 Ma; late early Oligocene) in age. The age of these specimens more than doubles the known time depth of the noctilionoid lineage, previously known back to about 12-13 Ma in South America. Both of the localities reflect deposition in paleokarstic situations and suggest a probable cave-dwelling habit for the bats. Several other families of bats also occur in various other late Oligocene and early Miocene sites in Florida (Emballonuridae, Mormoopidae, Natalidae, and Molossidae). Biogeographically, the occurrence of the new phyllostomids and these other families in what is now peninsular Florida, where these Neotropical groups no longer exist, bolsters other faunal data suggesting a subtropical to tropical aspect to the Florida paleoenvironment in the middle Tertiary, and a Neotropical influence or possible tropical North American origin for the Phyllostomidae.

RECONSTRUCTING MEAN ANNUAL PRECIPITATION BASED ON MAMMALIAN DENTAL MORPHOLOGY AND LOCAL SPECIES RICHNESS

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Mean annual precipitation is one of the most important climatic variables in determining both the structure and productivity of terrestrial vegetation. Precipitation thus also indirectly influences the composition and ecology of communities of large and medium-sized mammals, which ultimately depend for their existence on the energy yielded to primary consumers by the local vegetation. Here we describe a simple metric that exhibits a log-linear relationship with mean annual precipitation and is applicable to a wide range of Tertiary mammalian paleofaunas.

Precipitation and species-occurrence data for 151 present-day mammal localities were taken from a global dataset compiled by the Working Group on Mammal Communities sponsored by the National Center for Ecological Analysis and Synthesis. Analysis shows that a metric (*Hn*) consisting of mean hypsodonty (tooth crown height) at a locality divided by the number of species > 1kg in body mass is related to mean annual precipitation (*P*) by the formula: log10 *P*= -1.27(log10 *Hn*) + 1.36.

This relationship accounts for over 60% of the variance in precipitation and is highly statistically significant. World maps showing the distribution of rainfall and the metric *Hn* are highly congruent. It is not surprising that the variables making up *Hn* are related to rainfall. Increasing hypsodonty represents adaptation to higher rates of tooth wear experienced in open, drier habitats—both from increased grit in the diet and from the nature of food plants. Mammalian species numbers also tend to increase with increasing rainfall.

Application to the fossil record is subject to several caveats. Predictions for individual localities are not very precise, but the method should be able to detect trends. Taphonomic factors that truncate the species list will result in rainfall estimates that are too low. On the other hand, if species richness for a particular habitat-type is significantly elevated above modern values in some fossil mammal communities, such as is documented for the mid Miocene of the Great Plains, the result will be estimates that are too high.

PREPARATION OF *CITIPATI OSMOLSKAE*

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The holotype of *Citipati osmolskae*, a nearly complete, articulated skeleton from Ukhaa Tolgod, Mongolia is prepared as separate, disarticulated elements. The extreme brittleness of this beautiful specimen requires that each bone be treated repeatedly and in various manners as the external support of the matrix is pulled away. Materials used include the resins Acryloid B72 and Butvar B76 in acetone and ethanol, plaster bandage, epoxy putty, sand, various papers and foils. Because the forces required for preparation change as work progresses, and these forces differ from the stress of handling for research and storage, some treatments are temporary and some are long-term.

The preparation of this specimen is considered in terms of two ideas drawn from conservation literature: bonding forces and intimacy of contact. Shown here are techniques to manipulate the intrinsic bonding forces within the specimen, matrix and preparation materials as well as the bonding forces and intimacy of contact between the three.

EFFECTS OF LATE MIOCENE COOLING WITHIN A NEVADA INTERMONTANE BASIN REVEALED BY PALEOECOLOGICAL ANALYSIS OF THE VIRGIN VALLEY AND THOUSAND CREEK MAMMALIAN FAUNAS

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The Virgin Valley (Barstovian) and Thousand Creek (Hemphillian) local faunas of northwestern Nevada were used to examine the relative effects of late Miocene cooling on the ecology of a single basin. These faunas accumulated before (Virgin Valley) and within (Thousand Creek) the dramatic late Miocene cooling indicated by the global oxygen-isotope curve. Analyzed data included information from all published localities at Virgin Valley and Thousand Creek as well as the unpublished collections in the UCMP. Preliminary results indicate that taxonomic diversity increases between Virgin Valley and Thousand Creek, with species diversity rising from 17 to 25 taxa. Generic diversity increases from 19 to 24, and familial diversity increases from 16 to 19 taxa. Rarefaction analyses based upon number of specimens indicate that species and generic diversities increase but familial diversity remains unchanged, indicating an increase in species with no increase in lineage diversity. Rarefaction analyses based upon number of localities sampled also indicate an increase in species diversity; however, these rarefaction analyses suggest both generic and familial diversity did not change between the two local faunas. Despite potential biases that might influence the diversity analyses (e.g. the better publication record for Thousand Creek), marked changes in the faunal composition between the two localities indicate an ecological shift. Virgin Valley is dominated by the equid *Merychippus* and the palaeomerycid *Dromomeryx*, indicating a moderately open habitat. Thousand Creek is dominated by the antilocaprids *Sphenophalos* and *Ilingoceros*, which indicate more closed habitats. The nature and extent of faunal change are consistent with environmental change influencing ecological patterns.

VERTEBRAL CENTRUM MORPHOLOGY IN FOSSIL AND EXTANT LAMNID SHARKS

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Not only have vertebral centra been largely overlooked in studies of fossil neoselachian sharks (an historical by-product of relying on fossil shark teeth), but centrum morphology has not been well-documented in extant sharks. We hypothesize that shark centra (1) carry a phylogenetic signal that can be used to supplement, and in many cases improve upon, systematic analyses that are wholly tooth-based, and (2) that they can be used to infer certain functional aspects of fossil sharks (e.g., swimming performance) based on carefully constrained comparisons with the centra of extant taxa. We tested these hypotheses using the Family Lamnidae (Porbeagle, Salmon, Mako, and White sharks). Lamnid sharks present as an ideal study group because their monophyly is strongly supported by both morphological and molecular data, there is a consensus on the family's in-group interrelationships, and these sharks are well-represented in the fossil record by both teeth and morphologically distinctive centra. Important morphological features of lamnid centra considered for this study include: degree of development and surface texture of the centrum wall, proportional variations (both between taxa and in different body regions), development (or closure) of the notochordal canal, spacing and size of foramina for the basiventral and basidorsal arch components, and internal calcification patterns—this last feature is particularly useful because centrum calcification patterns in these sharks consist of a complicated and character-rich combination of concentric rings and radiating lamellae. While the generic assignment of fossil "megatooth" lamnids has been controversial using the results of tooth-based studies, new data on vertebral morphology and internal calcification patterns presented in this analysis provide evidence that they are properly assigned to the genus *Carcharodon* (which also includes the extant Great White Shark, *C. Carcharias*).

A NEW MIOCENE MAMMAL FAUNA FROM THE SEVIER RIVER FORMATION ON THE WESTERN MARGIN OF THE COLORADO PLATEAU OF CENTRAL UTAH

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The uplift of the Colorado Plateau over the past 15 million years has resulted in the exposure

of sedimentary rocks that have provided one of the world's greatest records of Mesozoic and early Cenozoic vertebrate life. Because of this uplift, however, rocks of late Tertiary age are poorly represented and therefore our knowledge of vertebrate faunas on the Colorado Plateau during this time period is quite limited. Recently, mammalian fossils from the Sevier River Formation of central Utah have been discovered. Preliminary work has led to the recovery of cranial, dental, and postcranial remains of proboscidians, carnivorans, rhinocerotids, lagomorphs, and camelids. Previous geological investigations have estimated that these rocks range in age from 14 to 7 million years before present. These fossils provide us a unique opportunity to characterize the late Tertiary mammalian fauna of the western Colorado Plateau during this poorly known time interval. Comparisons of the new fauna with other Miocene faunas of western North America will constrain the age of these rocks and help refine estimates of the timing of uplift and volcanism in this region.

MAKING LEMONADE OUT OF LEMONS: INCORPORATING A CAFÉ INTO AN EXHIBIT HALL

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Offering additional, for-profit amenities to the visiting public has become an increasingly popular method for museums to earn more discretionary income. For these new enterprises to have the greatest success they must go into critical, high-traffic areas often within the long-established museum floor plan. The new Fossil Café located within the Conquest of Land exhibit at the National Museum of Natural History provides a case study of what can happen and how to make the best out of this disruptive situation. Of particular note is that this is no general, nondescript "corner café," or worse, a restaurant themed with pseudo-scientific accouterments. It presents a restatement of the content that would have been lost, the history of flowering plants. I will discuss and illustrate the genesis of the plan, the process the curator and I used to assess the content that would be removed and plan updated presentations, how we presented our ideas to the administration, the strategy we used to secure approval, and stages in the planning, design, and fabrication of this space.

We developed these presentations to fit into the tops of the café tables, designed as high-security, spill-proof shadow boxes. Visitors will sit at these displays for extended periods of time, virtually assuring the visitor's attention to our messages. The table tops contain fossils and other specimens, along with graphics incorporating photos, drawings, and brief text explanations. Special conditions for specimen security were required, and I will illustrate the methods used to protect the fossils against extreme shock forces. The resulting café incorporates paleontological content into the tables, on the walls, in design elements, and even in the menu items. I will conclude by discussing strategies for using this method on vertebrate paleontology content. This originally difficult situation has worked to our advantage; we upgraded an old exhibit, worked cooperatively with the museum administration, and created a place to satisfy the visitors' appetites yet whet their curiosity for more museum exploration.

EARLY DINOSAUROMORPHA EXEMPLIFIED BY ANISIAN-LADINIAN FOOTPRINTS

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In the southeastern region of the Massif Central (France), reptile ichnites have been known since 1858, found in the rocks of the Middle Triassic. More frequently they lie in siliceous gray and brown-red fine grained sandstones. In these levels, convex epirelief imprints are attributed to thecodont reptiles which possessed erect limbs and an easy locomotion. The recognised known ichnogenera are: *Synaptichnium* Nopcsa 1923, *Chirotherium* Kaup 1835, *Brachychirotherium* Beurlen 1950, *Isochirotherium* Haubold 1971, and *Sphingopus* Demathieu 1966. The second and the last indicate the prominence of the three median toes which is exclusively characteristic of dinosaur footprints.They are rather rare in Anisian strata but become more and more frequent in the Ladinian and upper Triassic, and finally dominant in the lower Hettangian, which confirms the given stratigraphic attribution. These footprints were made by bipedal animals with functionally tridactyl feet and long posterior limbs.

Some of the Triassic prints show, to the front of the pes, the irregularly laid down manus imprint, smaller than the hind foot. A long trackway of a large tetradactyl and quadrupedal dinosaur is likely the work of a prosauropod dinosaur, an order of large sized reptiles whose duration was brief, not after the middle Jurassic. The determined ichnogenera are: *Otozoum* Hitchcock 1847, *Coelurosaurichnus* Huene 1941, *Grallator* Hitchcock 1858, *Anchisauripus* Lull 1904. These two last were synonymised as *Grallator*
by Olsen. To these tracks,: *Rhynchosauroides* Maidwell 1911 must be added.

The ichnofauna of this region, through its diversity and its volume, is principally characterised by the first appearence in the Triassic of dinosaur footprints.

NEW DATA ON THE LATE TRIASSIC AETOSAUR *NEOAETOSAUROIDES* BONAPARTE, 1969 FROM THE LOS COLORADOS FORMATION, WEST-CENTRAL ARGENTINA

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The middle-sized aetosaur *Neoateosauroides engaeus* was originally described by Bonaparte based on fragmentary skull remains, incomplete postcranial material, and dorsal, ventral and caudal armors. These specimens were collected in the uppermost section of the Triassic sequence, from levels that yielded abundant prosauropod remains. This taxon is presently diagnosed by the presence of a postglenoid process on the coracoid, reduction of the fifth metatarsal, and faint ornamentation of the dorsal paramedial scutes consisting of radiating ridges and pits. Except for most of the lower jaw and partial maxilla, the skull was unknown as were the cervical vertebrae and associated scutes, and distal forelimbs.

Preparation of undescribed specimens collected several years ago in the same section revealed features that suggest that this material is referable to *Neoateosauroides engaeus*. These additional specimens consist mainly of articulated skull remains, cervical vertebrae, and dermal plates with the same ornamentation pattern as the holotype. This new material provides meaningful information on many characters, such as the extent of the maxillary tooth row with respect to the posterior margin of the external nares, position of the maxilla relative to the external nares, anterior extent of the premaxillary tooth row, shape of the infratemporal fenestra, and presence of ventral keel on cervical centra.

As a result of recent phylogenetic analyses, *Neoaetosauroides* is considered the sister taxon of a clade that includes *Typothorax*, *Desmatosuchus*, *Longosuchus* and *Paratypothorax*, although this placement is weakly supported. The new evidence on *Neoaetosauroides* permits to score, as well as change, the state of several characters for this taxon used in those studies and hence helps to ascertain the phylogenetic relationships of *Neoaetosauroides* within Aetosauria. These relationships are currently being reevaluated.

MEGATRACKSITES IN MIDDLE TRIASSIC CARBONATE TIDAL FLATS IN CENTRAL EUROPE—THE SENSATION—TRACKMAKERS IN BETWEEN TRACKBEDS

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More than 35 new track sites in the carbonates of the Muschelkalk Formation (middle Triassic) of Central Europe were discovered. All track beds consists of mudcracked carbonate biolaminates. They are deposits of the carbonate tidal flats (intertidal) and the sabkha (supratidal) surrounding the Germanic Basin at the old massifs in Central Europe. The occurrence of 21 track beds, which correlate to eustatic sequences, allow a high resolution track bed stratigraphy in a 160-220 m thick section of the Upper Bunter (upper Lower Triassic) to Upper Muschelkalk (upper Middle Triassic) carbonats showing a flat basin, surrounded by large carbonate tidal flat belts. Many track beds are widely distributed showing megatracksites spanning up to 400 km. The Middle Triassic megatracksites partly span over distances of about 400 km and are the result of a carbonate tidal flat surrounding the Rhenish (30 track sites) and Vindelizic Massif (6 track sites), and specialized reptiles living in this environment permanently. They left thousands of the very common tracks *Rhynchosauroides tirolicus* (ABEL), and *Procolophonichnium haarmuehlensis* (HOLST, SMIT & VEENSTRA) which show different speed and age of the trackmakers. Extremely rare are the tracks *Brachychirotherium* isp. and *Coelurosaurichnus* isp. After a siliciclastic intramontane sedimentation of red beds during Lower and Middle Bunter with the presence of *Chirotherium*, *Synaptichnium* and *Rotodactylus* dominated ichnofacies types, the ichnofauna changed consequently with the ingression of the Germanic Basin to *Rhynchosaurides* and *Procolophonichnium* dominated ichnofacies types. The first time in the world in between the Muschelkalk track beds skeletal remains occur. One trackmaker of the *Procolophonichnium* isp. trackways is *Cymatosaurus* sp., a medium sized terrestrial sauropterygian especially found at the boundary Upper Bunter/Lower Muschelkalk. The producer of *Rhynchosauroides* seems to be a prolacertilian, but it is hypothetically *Macrocnemus*.

EARLY PERMIAN (LEONARDIAN) VEGETATION OF THE CLEAR FORK AND PEASE RIVER GROUPS, NORTH-CENTRAL TEXAS

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The Early Permian of North-Central Texas includes the Clear Fork Group, widely known for its vertebrate-bearing continental redbeds, and the overlying Pease River Group, a markedly less fossiliferous unit that contains laterally persistent, bedded evaporites. Significant plant remains within these groups span a stratigraphic interval of approximately 550 m and are preserved in finely laminated claystones to ripple-bedded siltstones and sandstones within several types of channel-form deposits. Whereas the most prolific Clear Fork plant assemblages occur in clay-rich fills of abandoned fluvial channels, mud-filled tidal channels host the most productive Pease River occurrences. The Clear Fork flora represents a continuum of the region's Early Permian plant records and is dominated heavily by seed plants, particularly peltasperms, cycadophytes, conifers, cordaites, and gigantopterids. Marattialean tree-fern foliage is abundant locally, and remnants of the Carboniferous wetland flora occur rarely. Overall, the flora indicates woody, streamside vegetation of shrubs to small trees, with ferns and rare wetland elements in poorly drained floodplain environments. Broad, large leaves of many species suggest a humid, seasonally dry climate. In sharp contrast, the Pease River flora is sparse, completely distinct from that of the Clear Fork, and composed entirely of seed plants, some with Late Permian and Mesozoic affinities; at least two different Pease River floras are present. The dramatic contrasts between the Clear Fork and Pease River floras indicate the existence of distinct biomes in the equatorial regions.

MAGNETIC STRATIGRAPHY OF THE MIDDLE MIOCENE (EARLY BARSTOVIAN) MASCALL FORMATION, CENTRAL OREGON

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The Mascall Formation in the John Day region of central Oregon consists of about 200 m of fluvial-lacustrine siltstones and sandstones, lying below an angular unconformity with the Rattlesnake Formation. It has been famous for over a century for its early Barstovian (early middle Miocene) land mammals, including some of the first Proboscidea in North America. We collected paleomagnetic samples from published sections covering the entire fossiliferous portion of the Mascall Formation in the Rattlesnake Creek area. Samples were demagnetized with both AF (alternating field) and thermal methods. Most samples showed a single component of remanence held in a mixture of magnetite and hematite. The entire lower half of the Mascall Formation is reversed in polarity, but the Mascall tuff bed is normal in polarity, and the upper Mascall has three short zones of reversed-normal-reversed polarity. Based on the Ar/Ar date of 15.8 Ma on a tuff just below the Mascall tuff bed, we correlate the lower reversed magnetozone with Chron C5B4 (15.1-16.0 Ma). The normally magnetized Mascall

tuff bed correlates with Chron C5Bn2n, and the upper reversed-normal-reversed sequence with Chrons C5ADr to C5Bn1r. Thus, the total age span of the sampled section is 14.7-16.0 Ma. This is also consistent with the K-Ar date of 16.6 ± 1.4 Ma on the basal Mascall tuff, and the date of 16.0 Ma on the interbedded Columbia River basalts. These correlations are consistent with earlier observations that the "Proboscidean datum" is diachronous within North America, occurring earlier in Oregon, Nevada, and Florida, than it is in California or the High Plains.

DEPOSITIONAL ENVIRONMENTS OF AN EARLY CRETACEOUS PLESIOSAUR AND ICHTHYOSAUR ASSEMBLAGE FROM THE CLEARWATER FORMATION, WESTERN INTERIOR BASIN

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Heavy oil mining by Syncrude Canada, Ltd. near Fort McMurray, northeastern Alberta, has resulted in the serendipitous discovery of several exceptionally well-preserved specimens of plesiosaurs and ichthyosaurs from the lower Albian Wabiskaw Member of the Clearwater Formation. Nine specimens have been recovered to date, including two ichthyosaurs referable to *Platypterygius*, and seven plesiosaurs, represented by both long and short-necked morphotypes. Initial observations indicate the probable existence of one or more new plesiosaur taxa. The specimens represent the oldest Cretaceous marine reptiles from both North America and the Western Interior basin, and are a significant addition to the global picture of plesiosaur and ichthyosaur diversity and distribution in the Early Cretaceous.

The occurrence of the specimens in the mine has provided precise stratigraphic and sedimentologic control and these data have allowed the succession to be placed within a detailed depositional framework. Identification of sedimentary facies within the Wabiskaw Member was based on an examination of core and large blocks of matrix collected with the specimens. The majority of specimens are restricted to a thin unit (less than 3 meters) of muddy, very fine to fine-grained glauconitic sandstone situated within and overall fining upwards succession. A diverse and well-preserved trace fossil assemblage also revealed the presence of a mixed *Skolithos-Cruziana* ichnofacies. Deposition of the fossil-bearing unit is interpreted to have occurred under fully marine conditions in the shoreface-offshore transition zone, between apparent fair-weather and storm wave base. This deposition occurred during a southward transgression of the Boreal Sea, prior to the establishment of the Western Interior Seaway.

THE CRANIAL MORPHOLOGY OF *SHUVUUIA DESERTI* (THEROPODA: ALVAREZSAURIDAE).

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Recent phylogenetic studies have not reached a consensus on the placement of the rather derived group Alvarezsauridae. This may be a result of the paucity of alvarezsaurid material. To date, only one of five known alvarezsaurid taxa is known to preserve a complete skull. The addition of cranial material to current hypotheses of phylogeny could lend resolution to the question of the phylogenetic position of alvarezsaurids.

The skulls of two specimens of the alvarezsaurid *Shuvuuia deserti* are known from the Djadokhta Formation, Ukhaa Tolgod, Mongolia. These skulls are remarkably well preserved and virtually complete. These specimens were collected by a joint expedition of the American Museum of Natural History and the Mongolian Academy of Sciences, and made available for this study by Dr. Mark Norell.

The smaller of the two skulls represents a juvenile as indicated by the incomplete ossification of the chondrocranium. The larger more completely ossified specimen likely represents the adult ontogenetic stage. I present here some of the morphological novelties and other pertinent cranial characteristics as seen in the skulls of *Shuvuuia deserti* with the aid of computed x-ray tomography. In addition to providing ontogenetic markers for alvarezsaurids, these two specimens add data to test current hypotheses of the phylogenetic position of alvarezsaurids among coelurosaurs.

A NEW EEL-SHAPED ACTINOPTERYGIAN FROM FRESHWATER CRETACEOUS OF MOROCCO

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In the Kem Kem beds, continental Cenomanian of South-eastern Morocco, peculiar clay-rich levels yield well preserved, almost complete plants and articulated molluscs, insects, crustaceans, elasmobranchs, and actinopterygians. Beside hybodonts, the first articulated polypterid (*Serenoichthys kemkemensis*), osteoglossiforms, clupeomorphs, and a peculiar acanthomorph (*Spinocaudichtys oumtkoutensis*), we found a new interesting eel-shape actinopterygian. This bony fish, known by a single and complete specimen, is preserved in part and counterpart. Its body is very elongated and its size is about 119 mm long. The posterior end of the body is slightly curved. Epigenetic muscles mask some parts of the skeleton. This actinopterygian displays particular characters like the presence of a huge hyomandibular, a peculiar skull-bone in opercular position forming by a triangular plate and four curved spines orientated towards the posterior, the complete diplospondyly throughout the vertebral column, rows of spine-bearing scutes, ventrally and dorsally, on the both sides of the posterior part of the body, and unpaired elements articulating with neural and haemal spines.

The phylogenetical relationships of this bony fish are not really easy to understand. This combination of features does not exist, to our knowledge, in fossil and Recent actinopterygians. Diplospondyly might be the best feature to estimate these actinopterygian relationships.

A NEW ORNITHURINE BIRD FROM THE MAASTRICHT FORMATION OF BELGIUM: WAS THERE A BOTTLENECK IN AVIAN DIVERSITY AT THE END OF THE CRETACEOUS?

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A new ornithurine bird from the latest Cretaceous Maastricht Formation of Belgium (type section of the Maastrichtian) is similar to the well-known *Ichthyornis* from North America, although much larger (twice the size of *I. dispar*). This partial specimen preserves elements of the skull, wing, shoulder and hindlimb as well as vertebrae. Its placement within Ornithurae (*Ichthyornis*, *Hesperornis* and living birds [Neornithes]) is supported by derived characters including a humerus with a globe-shaped and convex head, a cranially deflected deltopectoral crest, and a well-developed brachial depression, although the presence of teeth and the morphology of preserved vertebrae prevents its placement within Neornithes. Excepting a number of problematic taxa, the "Maastricht bird" is the first phylogenetically informative ornithurine known from the Late Cretaceous of Europe and the youngest non-neornithine known from anywhere in the world.

Although the phylogenetic relationships of the Mesozoic lineages of birds are well-resolved, the question of whether there was a 'bottleneck' in diversity across the K-T boundary remains unclear. Those in favor of a 'bottleneck' have argued that diversity across this extinction horizon can be correlated with the differential 'survivorship' of Neornithes relative to basal ornithurines. This scenario, however, receives only superficial support from the fossil record. Although the "Maastricht bird" documents that some non-neornithine lineages survived until the very end of the Cretaceous, the last occurrence of most Mesozoic ornithurine lineages predated the end of this Period by several million years. In addition, the oldest specimens complete enough to be confidently included within Neornithes are Paleocene in age. Range correlations of lineages of Cretaceous birds, combined with gap analysis and the estimation of clade confidence intervals shows that there is little evidence for a 'bottleneck' in diversity at the K-T boundary. More fossil specimens, especially of terminal Maastrichtian age, complete enough to be evaluated within a phylogenetic context are required to further address this question.

NEW DISCOVERIES OF PUERCAN MAMMALS IN THE DENVER BASIN, COLORADO: REVISIONS TO LOCAL PUERCAN MAMMALIAN BIOSTRATIGRAPHY THAT INCORPORATE PALEOMAGNETIC AND PALYNOLOGICAL ZONATIONS

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We report several fossils of earliest Tertiary (i.e., Puercan) mammals, including a multituberculate and 11 ungulate taxa, from the Denver Formation in the Denver Basin, Colorado, and provide revisions to local Puercan mammalian biostratigraphy. Discovery of the ungulate *Protungulatum donnae* in Pu1 strata of the Denver Formation represents the southernmost occurrence of the species, while *Oxyclaenus simplex*, also in Pu1 strata of the Denver Formation, represents a temporal and geographic range extension from Pu2 strata of the San Juan Basin, New Mexico. We report first occurrences in the Denver Basin of the mioclaenid *Promioclaenus* and the arctocyonid *Loxolophus faulkneri*.

Refined biostratigraphic interpretations, resulting from new discoveries and incorporating in-progress paleomagnetic and palynological analyses, suggest that Puercan interval zones Pu1 and Pu2 are represented by mammalian faunas in the Denver Formation. South Table Mountain, the Denver *Oxyclaenodon* Site (DMNH 299), and Nicole's Mammal Jaw locality (DMNH 2557) are Pu1 correlatives; they occur in strata of reversed polarity, interpreted as subchron C29R, and in Paleocene pollen Zone P1. Our research corroborates that of others who suggest that the Alexander and South Table Mountain localities (i.e., Littleton Local Fauna) are probably Pu1 in age. When compared to other Puercan faunas, these two localities appear to postdate typical Pu1 assemblages north of the Denver Basin, but predate earliest Pu2 assemblages in the Hanna Basin, Wyoming. The mammalian assemblage at Corral Bluffs is interpreted here as a probable Pu2 correlative, based upon occurrence of *Loxolophus faulkneri*, *Conacodon entoconus*, and *C. delphae*, and absence of Pu3 index taxa. Although more fossils are needed to refine ages, Pu2/Pu3 correlatives near Big Gulch, a tributary of West Bijou Creek, occur in strata of normal polarity, correlated to C29N, and within pollen Zone P2. We demonstrate that the Denver Basin is among the few places wherein correlation among Puercan mammalian biostratigraphy, magnetostratigraphy, and pollen zonation is an attainable goal.

TAPHONOMIC MODES OF LARGE DINOSAURS IN THE HORSESHOE CANYON FORMATION (CAMPANIAN-MAASTRICHTIAN) OF SOUTHERN ALBERTA, CANADA

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Assessing taphonomic modes using a non-marine sequence-stratigraphic framework helps identify biostratigraphic biases. The stratigraphic distribution of large-dinosaur taphonomic modes in Upper Cretaceous Alberta correlates with changes in accommodation, reworking, and shoreline proximity, but poorly with presence/absence of coal and inferred paleoclimate. This presentation examines relationships expressed in the Horseshoe Canyon Fm. at Drumheller.

Five sequence-stratigraphic units are recognized using lithostratigraphy and sedimentology. Unit 1 consists of coal-rich sediments deposited in a vertically-aggrading, high-accommodation system. The dominant taphonomic mode is mudstone-hosted saurolophine bonebeds. However, there are also associated-to-articulated dinosaurs in channel-fill and over-

bank deposits. Unit 2 is coal-poor and includes the Drumheller Marine Tongue – an estuarine unit marking a transgressive event. Paleochannels become thinner upsection, marking a reduction in accommodation. The dominant taphonomic mode is fragmentary elements associated with paleosols and paleochannel lags. Unit 3 is a multistoried paleochannel succession deposited in a low-accommodation setting. The dominant taphonomic mode is vertebrate microfossil assemblages that consist of dinosaur teeth, fish scales, and disarticulated mesoreptiles. Unit 4 is coal-poor and consists of paleochannel and interfluve deposits in sub-equal stratigraphic abundance marking increasing accommodation. Lambeosaurines dominate and occur predominantly as isolated partial-to-complete skeletons; one bonebed is known. Unit 5 is coal-rich with relatively thick paleochannel sheets and lenticles. It marks a return to a wetter paleoclimate and high accommodation. Vertebrate fossils are notably rare but a theropod-dominated bonebed (MNI 13) occurs at the base.

Low-accommodation settings (Unit 3) exhibit taphonomic modes that reflect reworking. Moderate-accommodation settings (Units 2&4) exhibit a broad range of taphonomic modes indicating both in-situ preservation and reworking. High-accommodation settings (Units 1&5) frequently preserve large-dinosaurs in bonebeds or in-situ.

INCREMENTAL GROWTH ASSESSMENT IN OLIGOCENE *GOPHERUS LATICUNEUS* AND *STYLEMYS NEBRASCENSIS*, INCLUDING *GOPHERUS POLYPHEMUS* AS A MODERN ANALOG

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The use of skeletochronology in many reptile groups has become a commonplace method of incremental growth analysis over the last twenty years. With the exception of sea turtles, this method has been largely overlooked as a feasible alternative to scute annuli counts or carapace lengths in turtles and tortoises. Incremental growth layers in sea turtles 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. The discovery of an unusually rich assemblage of fossil tortoises in northwestern Nebraska warranted study of the population dynamics at this site. Incremental growth rings are a viable option in this case for individual age assessment, as carapace lengths are not preserved accurately in the fossil record. The two species in question, *Gopherus laticuneus* and *Stylemys nebrascensis*, were collected within the Orella Member of the Brule Formation. Individual bones were prepared out and thin-sectioned to estimate the tortoises' ages. Before thin sectioning fossil materials, a modern analog (*Gopherus polyphemus*) was tested to determine the validity of methods implemented. This modern example shows enough similarities in size and presumed environmental conditionst to provide a good comparative analog. Data collected from *Gopherus laticuneus* and *Stylemys nebrascensis* will be applied to determine age structure of the populations at this site. Information gathered from *Gopherus polyphemus* will provide the groundwork for other investigators to further explore the technique of skeletochronology and its use with other groups of organisms.

RELATIONSHIPS OF NORTH AMERICAN ARCHAIC UNGULATES USING BASICRANIAL DATA

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Many modern ungulate orders are descended from a diverse group of mammals known collectively as archaic ungulates. Relationships between archaic ungulate taxa are uncertain, and resolution of archaic ungulate relationships is important to understand the relationships within Ungulata as a whole. The mammalian basicranium, specifically the ear region as preserved in the petrosal bone, is useful in the inference of phylogenetic relationships of many placental mammals, including archaic ungulates. By comparing the basicranial structures of various North American archaic ungulates in a phylogenetic context, using Late Cretaceous eutherians as outgroup taxa, ungulate relationships were inferred.

A total of 28 characters were taken from the basicranium and were coded for 25 taxa, including North American archaic ungulates, early members of extant ungulate clades, and Late Cretaceous eutherians. Nine phylogenetic analyses incorporating different numbers of taxa and assumptions were performed. The resulting relationships of these nine analyses include a pairing of Phenacodontidae with Perissodactyla. Characters that unite a phenacodontid-perissodactyl clade include a posterior shift of the anterior opening of the alisphenoid canal and a tympanic opening of the aquaeductus cochleae. A strong relationship between Cetacea and Artiodactyla was also found. Cetacea often nested within Artiodactyla, rendering Artiodactyla paraphyletic, as was concluded by several recent molecular (and some recent morphological) studies. A sister relationship between the artiodactyl *Archaeotherium* and Cetacea includes loss of the stapedial artery and postglenoid foramen, expansion of the squamosal contribution of the external auditory meatus, and an anterior position of the foramen ovale. No strong relationship between Mesonychidae and Cetacea was recovered, nor was Arctocyonidae found to be the sister taxon to Artiodactyla.

BRONTOTHERE (MAMMALIA, PERISSODACTYLA) FOOTPRINTS FROM THE EOCENE OF THE ILY BASIN, KAZAKSTAN

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At Kyzyl Murun near Aktau Mountain in the Ily basin of southeastern Kazakstan (UTM zone 44, 362307E, 4873406N, WGS 84), an extensively trampled surface with at least 100 fossil footprints occurs in fluvio-lacustrine red beds of the upper part of the Eocene (Irdinmanhan) Kyzylbulak Formation. These footprints are in a 0.1-m thick bed of light greenish gray, very fine grained, calcareous silty sandstone that is ~0.5 m above a bonebed dominated by complete, articulated skeletons of the brontothere Protitan. The footprints are preserved in concave epirelief, generally lack clear orientation and are crowded and superimposed to indicate a trampled surface. All footprints are round, ovoid or oblong in shape and have diameters of ~0.2 m and depths of up to ~0.1 m. Some have slightly lobate outlines, but they lack clear indications of digits, pads or hooves and clearly are underprints. A single partial trackway indicates the trackmaker was a quadruped with a gleno-acetabular length of ~1.2 m, and a trackway width of ~0.4 m. The shape and size of the footprints and the estimated dimensions of the trackmaker conform well to the foot structure and size of an Irdinmanhan-age brontothere such as Protitan. Indeed, the footprints closely resemble some other published footprints attributed to brontotheres, and we tentatively identify the trackmaker of the Kazak footprints as a brontothere. This is the first published record of fossil mammal footprints from Kazakstan.

CONSTRAINTS ON CAUSES OF THE END-PERMIAN MASS EXTINCTION

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Severe mass extinctions occurred at the end-Guadalupian (ca. 260 Ma) and at the end-Changhsingian (251.6 Ma). Little is known about the first extinction pulse: the marine extinction was severe although possibly exaggerated by sampling effects and possibly corresponds with a major marine regression. Whether a coincident extinction occurred on land remains unclear. The second triggered an extensive reorganization of marine ecosystems and less pervasive terrestrial changes. Marine extinctions were selective, with suspension feeders heavily affected. In south China the marine extinction occured in <500 ky. Major extinctions occurred on land among vertebrates, plants and insects. This coincides with a drop of $\delta^{13}C$ from +2 to -2 per mil; shifts in sulfur and strontium isotopes; with the eruption of the massive Siberian continental flood basalts; with marine anoxia; and with growing evidence for rapid global warming from the boundary into the earliest Triassic. Possible causes must be consistent with this evidence and include climatic effects, including acid rain and global warming from the Siberian flood basalts; marine anoxia or carbon dioxide poisoning; or an extra-terrestrial impact. Despite the absence of conclusive evidence for impact, much of the data is consistent with this mechanism. The principle inconsistent evidence is the early onset of deep water anoxia, the early onset of the fungal spike (at least 500 k.y. before the marine extinction in S. China) and possibly the duration of the vertebrate extinctions in South Africa. For the Siberian flood basalt the causal connection is unclear. Despite speculation that the Siberian flood basalts may have been impact-induced, Melosh has pointed out that there is no evidence of impact-induced volcanism in the solar system. Further, the Siberian flood basalts include four centers over at least 1000 km. Any impactor sufficient to trigger massive flood basalts would have necessarily produced impact evidence far more extensive than that seen at the KT boundary.

PERMIAN TETRAPOD BIOCHRONOLOGY

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The most extensive Permian tetrapod (amphibian and reptile) records are from the western USA, western Europe, the Russian Urals and South Africa, and only these records are of global biostratigraphic/biochronologic significance at present. Tetrapods support the division of the Permian Period into three epochs, which correspond well but not precisely to a threefold division of Permian time based on marine biostratigraphy. Tetrapod evolution provides the basis for the subdivision of Permian time into 10 land-vertebrate faunachrons (LVFs) with temporal resolution comparable to the eight ages of the standard global chronostratigraphic scale. Nevertheless, the Early Permian tetrapod record is restricted to North America and western Europe, so the biochronological scheme of Early Permian LVFs has no applicability outside of a Euramerican paleoprovince. Furthermore, a problem exists at the Early-Middle Permian boundary, where the basis for the LVFs shifts from North America to South Africa. We recognize a global gap between the youngest North American Permian tetrapods (San Angelo Formation and equivalents) and the oldest, therapsid-bearing faunas, those of Russian Zone I and the Eodicynodon Assemblage Zone of South Africa. A relatively robust Middle-Late Permian tetrapod biochronology can be constructed based on the classic tetrapod assemblage zones of the Karoo basin in South Africa.

A DETAILED DESCRIPTION OF THE LAMBEOSAURINE PRESPHENOID: IMPLICATIONS FOR OLFACTORY SYSTEM ANATOMY AND HADROSAURID PHYLOGENY

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Examination of isolated and articulated presphenoids yields new information about the structure of the presphenoid and the associated olfactory system in lambeosaurines. The presphenoid forms the lateral and ventral margins of the large CN I (olfactory) foramen. A series of deep, longitudinal bony septa radiate from the tapering anterior flange of the presphenoid into the olfactory canal. The ventral surface of the frontal completes the CN I foramen dorsally, but shows no evidence of complementary septa. The olfactory bulbs were likely located between the paired presphenoids, posterior to their septate anteromedial margin. Given the prominent septa, CN I is reconstructed to consist of many afferent branches converging at the CN I foramen. The S-Loop (when present) and the ventral portion of the common chamber occur directly anterior to the braincase. Ramification of the olfactory nerve in this area suggests that these structures may be associated with olfaction.

The interpretation of the olfactory system presented here is consistent with the recent suggestion that the nasal vestibulum was well innervated, and possibly associated with internal turbinate structures. The earlier hypothesis that the olfactory bulbs were located high within the crest is not supported.

Septa on the presphenoid, an abbreviated olfactory tract, and osseous enclosure of the olfactory bulbs are not apparent in the braincases and endocasts of hadrosaurines. Hadrosaurines exhibit a relatively long interorbital region anterior to the brain when compared

to the foreshortened lambeosaurine condition, implying potentially different olfactory organization. Therefore, the presence of septa on the anteromedial surface of the presphenoid may be diagnostic of lambeosaurines.

THE EARLY FOSSIL RECORD OF LIZARDS: ADVANCES AND CONSTRAINTS

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The last major survey of fossil lizards listed only 25 genera for the c. 150 million-year period encompassing the Triassic to the end of the Early Cretaceous (Albian), and of these nine were subsequently reclassified outside Squamata. Furthermore, only Europe, North America, and China were represented. Over the last twenty years, the number of recognised taxa has more than doubled, and more are in the process of being described. The geographical range now includes Europe, North and South Africa, North and South America, Central Asia, Siberia, India, China, and Japan. Nonetheless, there remain significant gaps. Currently the first true squamates date from the Early-Middle Jurassic (India, UK, Central Asia), but several strands of evidence support a much earlier origin, with major lineages (at least Iguania and Scleroglossa) having diverged before the end of the Triassic. As a result, many of the decisive stages in squamate evolution remain unrecorded—e.g. the development of key cranial characters relating to kinesis. This impacts on phylogeny reconstruction. Further problems constrain discussion of paleobiogeography. The Mesozoic terrestrial lizard record of Gondwana is currently limited to a small cluster of specimens, many of which are fragmentary and indeterminate. The Laurasian record is much better but should be read with discretion. It gives the impression that Early Cretaceous squamate assemblages were dominated by surviving representatives of archaic lineages (e.g. basal taxa, paramacellodids, eichstaettisaurs), with more derived groups (e.g. helodermatids, polyglyphanodontine teiids, aquatic varanoids, snakes) appearing later in the Mid-Cretaceous. However, many Jurassic and Early Cretaceous lizard assemblages stem from isolated and/or restricted land areas (e.g. Europe was an archipelago of small islands for much of the Mesozoic) and may not be fully representative of squamate diversity at this time.

REMAINS OF IMMATURE MOSASAURS (SQUAMATA; MOSASAURIDAE) FROM THE NIOBRARA FORMATION (LATE CRETACEOUS) ARGUE AGAINST NEARSHORE NURSERIES

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The Smoky Hill Chalk Member of the Niobrara Formation was deposited from late Coniacian through early Campanian time near the middle of the Western Interior Sea, hundreds of kilometers from the nearest shore. Many well-preserved specimens of marine vertebrates, including 10 species of mosasaurs, have been collected from the chalk since the late 1860s. Like ichthyosaurs and plesiosaurs, it is probable that mosasaurs spent most, if not all, of their lives at sea. Earlier workers reported that the remains of immature mosasaurs were never found in the chalk and proposed that these large (up to 10 m) marine reptiles either laid eggs or gave birth to their young in areas closer to shore where they would be better protected from predation. Despite problems related to the preservation of smaller individuals, a review of more recently collected material shows that immature mosasaurs (estimated body length = 2 m or less) are well represented throughout the chalk. The recent discoveries of fetal material associated with a mosasaur from South Dakota, and with a mosasaurid from Slovenia, provide compelling evidence that these marine reptiles bore live young. The presence of immature mosasaurs in the Smoky Hill Chalk Member of western Kansas strongly suggests that births occurred in mid-ocean and were not limited to sheltered nurseries along the shores of the Western Interior Sea.

A REVIEW OF "*TOROSAURUS*" (DINOSAURIA: CERATOPSIDAE) SPECIMENS FROM TEXAS AND NEW MEXICO

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The late Maastrichtian chasmosaurine ceratopsid dinosaur *Torosaurus* has been reported from as far north as Saskatchewan to as far south as Texas. *Torosaurus* specimens have been used to verify a late Maastrichtian age for some formations, and *Torosaurus* is considered a distinctive part of the late Maastrichtian southwestern North America fauna. However, many of these southwestern occurrences are based on fragmentary or incomplete specimens, making the generic assignment to *Torosaurus* dubious. Reexamination of eight specimens previously assigned to *Torosaurus* held at the Texas Memorial Museum (TMM) and New Mexico Museum of Natural History (NMMNH) showed that four were generically indeterminate.

Of two referred *Torosaurus utahensis* specimens from the Javelina Member of the Tornillo Formation, Texas, only TMM 41480-1, a partial parietal, can confidently be referred to *Torosaurus* sp. An isolated postorbital horncore (TMM 41835-1) is referred to Chasmosaurinae indet. Five specimens from the Naashoibito Member of the Kirtland Formation, New Mexico, were examined. A partial postorbital horncore, NMMNH P.32615, is removed to Chasmosaurine indet. A partial parietal, NMMNH P.25074, is referred to *Torosaurus* sp. NMMNH P.22884, a partial squamosal and parietal, is tentatively retained as *Torosaurus* cf. *T. utahensis*. Squamosal fragments NMMNH P.29006 and NMMNH P.21100 are referred to Chasmosaurinae indet. An unnumbered NMMNH partial skull and skeleton from the McRae Formation of New Mexico is referred to *Torosaurus* sp.

Isolated postorbital horncores do not possess generically diagnostic characters, but both the distinctive squamosal shape and the wide, thin, fenestrated parietal are unique to *Torosaurus*. Determining the validity of *Torosaurus* utahensis requires further study. Because of limited and fragmentary material, *Torosaurus* is not a useful biostratigraphic indicator, and its precise contribution to Late Maastrichtian Southwestern paleoecology cannot be determined.

KEY ADAPTATIONS CREATING ECOLOGICAL GENERALIZATION THROUGH MORPHOLOGICAL SPECIALIZATION: EVIDENCE FROM HYPSODONTY AND STABLE ISOTOPES

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Key adaptations are evolutionary changes in traits that are causally linked to increased diversification rates. Such adaptations may indicate increased specialization (narrowing of ecological niche) or expansion of the suite of lifestyles available to an organism (increasing niche breadth). Hypsodonty is a key adaptation for the Equidae, and may have been a key adaptation for various other ungulate taxa. The evolution of hypsodonty generally has been interpreted as a specialization into a grazing niche from a browsing niche. I tested whether this assumption holds true by analyzing the feeding strategy of a variety of ungulates. If hypsodonty does result in ecological specialization, hypsodont taxa should have a more specialized diet than do brachydont taxa, as reflected by isotopically recognized proportions of C_3 or C_4 forage of ungulates. Because ecological specialists are more prone to extinction, it would also be expected that species of hypsodont taxa have a shorter life span than species of brachydont taxa.

Results from the stable carbon isotope analysis show that individuals of hypsodont taxa, (e.g., *Bison*, *Equus*, *Mammuthus*) generally display a wider range in diet than those individuals of brachydont taxa (e.g., *Odocoileus*, *Mammut*). In additon, there appears to be no correlation between hypsodonty and species life span within the Equidae. Equid species become more long-lived with the advent of hypsodonty. This pattern, similarly observed in the Camelidae, is consistent with expectations if hypsodonty enabled ecological generalization. Overall, hypsodonty does not appear to be strictly associated with obligate grazing and a specialized diet; instead it appears to represent an adaptation that widened niche breadth to allow grazing as well as browsing.

MESOZOIC TETRAPOD FOOTPRINTS IN THE BOTUCATU FORMATION (PARANA BASIN, BRAZIL).

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The Botucatu Formation comprises reddish sandstones from eolian accumulation. It is considered that the environment that deposited this lithostratigraphic unit was a big climatic desert. Actually, its age is presumed between Late Jurassic and Early Cretaceous by geochronological approach, because of the flood basalts of the Serra Geral Formation that capped the Botucatu Sandstones. In a sandstone quarry in Araraquara county, Sao Paulo State, the Botucatu Sandstones present a great variety of footprints of dinosaurs and ancient mammals. Dinosaur trackways are always bipedal with the posterior autopodium tridactyl. The pace angulation is high (170°-180°). Two forms (Theropoda and Ornithopoda) were identificated. There is no evidence of sauropods, maybe related to the arid climate of the paleoenvironment. Mammaloid trackways are bipedal or quadrupedal. *Brasilichnium elusivum* Leonardi 1981, is frequent among mammals and has been considered an endemic form. The foot has an elliptical outline. The transverse axis is bigger than long axis. The toes are short and the claws imprint are only evident in the undertracks. The hands are very small and roundish. Hopping, ricochetal-type gaits and galloping mammals tracks were identificated, and suggest evidences of diversification in this animal group at the end of Jurassic Period. There are evidences from gregarious habits among the ornithopod dinosaurs and mammaloid trackways of *Brasilichnium*. The variation of size and form of theropoda footprints could be explained by different ontogenetic stages. The affirmation that trackways of *Brasilichnium* are more abundant than those of dinosaurs probably isn't true. This is only a coincidence of biozones at the moment of extraction of the slabs in the sandstone quarry.

LATE CRETACEOUS DINOSAUR TRACKS FROM SOUTHWESTERN MEXICO: ITS PALEONTOLOGIC SIGNIFICANCE

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The southern extent, composition and evolution of the North American dinosaur fauna are still poorly understood, because the record in Mexico is quite meager. The finding of numerous dinosaur footprints in Michoacan, southwestern Mexico, is a major contribution to improve this record.

The site lies 410 km WSW of Mexico City, in outcrops of the Aguililla Sandstone located in the Rio El Salto, Municipality of El Aguaje, SW Michoacan. This unit is a fine grained, red volcarenitic arkose that unconformably overlies the Upper Albian-Lower Turonian marine Morelos Formation, and it is intruded by El Tigre Stock of latest Cretaceous age, whose emplacement indurated the sandstone unit by contact metamorphism. The Cenozoic sequence unconformably overlies both the stock and the sandstone body.

The track assemblage here designated El Aguaje Dinosaurichnofauna, consists of hundreds of isolated prints of medium to large sized individuals, referable to these families: Hadrosauridae (isodiametric, rounded, mesaxonic prints; digits highly divergent with subround apices), Tyrannosauridae (rhomboidal, subelongated prints with a well developed heel; narrow digits with pointed apices), Dromaeosauridae (elongated prints with digits III and IV nearly parallel, the digit II impression when present, is shorter and meets that of digit III at an acute angle), and Ornithomimidae (small to medium size elongated prints, with highly divergent digits). All are well known Cretaceous families in North America.

The stratigraphic position of the Aguililla Sandstone, and the hadrosaurids allows one to assign the fauna to the Late Cretaceous (Campanian-Maastrichtian?). The Michoacan site lies some 1200 km south of The Big Bend Cretaceous dinosaur localities; in Mexico, it shares one family with the Late Cretaceous Puebla locality (Mitepec, ~400 km due E), and three with those of Baja California and Coahuila. The Michoacan and the Puebla sites, both placed south

of the Trans-Mexican Volcanic Belt, bear the southernmost records of Cretaceous dinosaurs in North America, thus during the Late Cretaceous, dinosaurs could roam this continent southward at least as far as southern Mexico.

A NEW ELOPOMORPH FISH FROM THE AUSTIN CHALK FORMATION OF FANNIN COUNTY, TEXAS

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The Austin Chalk Formation of the Upper Cretaceous of Texas is known for its diverse assemblage of marine teleost fishes including a number of elopomorph taxa. An elopomorph was found in the Austin Chalk in Fannin County, Texas. This specimen was preserved similar to that of elopomorphs found in the Eagle Ford Shale The preserved skull and anterior portion of the trunk showed little lateral compression. It was originally identified as *Thrissopater* which is a synonym of *Pachyrhizodus.* Like *Pachyrhizodus,* it has a single supramaxilla and lacks both an antorbital and gular plate, but there are several characters that suggest it is not a pachyrhizodontid. These include: 1) apparent lack of the deep depression of the frontals, 2) posterior infraorbitals do not cover the hyomandibula, 3) preopercle lacks a prominent horizontal limb, and 4) teeth absent on upper jaws and mandible. Additionally, it has a deep skull and an oblique mouth. It is unclear as to the specimen's relationship to other elopomorph species, but its presence adds to the diversity of ichthyofauna of the Austin Chalk Formation.

A NEW SPECIES OF XIPHIORHYNCHID BILLFISH (PERCIFORMES: SCOMBROIDEI) FROM THE AUSTRIAN ALPS (EARLY OLIGOCENE)

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The skull and anterior body of a large billfish of the genus *Xiphiorhynchus* was collected in a deep-water, near-shore marine deposit of early Oligocene age (NP 21) at Bad Haering, Austria. It is housed in the Bavarian State Collection for Paleontology and Geology, Munich, Germany. Computer tomography, SEM, and radiography, as well as light microscopy and other standard techniques, were used to study the specimen.

This is the most complete specimen of *Xiphiorhynchus* known. Previous workers identified the genus from isolated fragments of rostra (bills), neurocrania, and vertebrae.

The specimen has the following features diagnostic of *Xiphiorhynchus*: an elongate rounded rostrum composed of paired premaxillae that are fused together distally; the fused portion contains a central canal and two pairs of lateral canals; villiform denticles (or their alveoli) cover the ventral surface of the bill. It has the following features previously unknown in *Xiphiorhynchus*: lower jaw that is as long as the upper, without a predentary, and with a fused symphysis that is superficially similar to the rostrum; large hyoid apparatus; suspensorium; opercular series; pectoral fins and girdles; short dorsal and anal fins; an elongate mesethmoid; minute denticles; eleven articulating precaudal vertebrae. We were unable to locate pelvic fins, maxillae, nasals, or prenasals.

The neurocranium is unlike others identified as *Xiphiorhynchus* with its elongate mesethmoid and apparent lack of nasals. Since all rostra that previously have been identified as *Xiphiorhynchus* were fragmentary and often poorly preserved, it is difficult to make a meaningful comparison with the well-preserved Bad Haering specimen. We suspect some of these "rostra" are actually pieces of the fused lower jaw.

We believe the specimen is a new species and that its features provide strong evidence for an *Xiphiorhynchus*-*Xiphias* clade.

THE FIRST RECORD OF A CRETACEOUS DINOSAUR FROM WESTERN ALASKA: IMPLICATIONS FOR UNDERSTANDING THE PALEOARCTIC

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Cretaceous dinosaurs are recorded for the first time from western Alaska by a series of three tracks found in Aniakchak National Monument. The nearest coeval locality is approximately 1300 km ENE of this site, along the Colville River in northern Alaska. This distance is consistent with a vast Cretaceous paleoarctic terrestrial ecosystem, the extensive homogeneity of which supported significant numbers of large herbivores.

This track site consists of a single large impression and two smaller associated impressions, interpreted as a pes and two manus prints respectively. Three characteristics attribute the prints to an ornithopod: the morphology of the feature is the right shape, the size is appropriate and the preserved bedding is consistent with a load structure.

These tracks are in the Late Cretaceous Chignik Formation, a cyclic sequence of rocks, approximately 500–600 m thick, representing shallow marine to nearshore marine environments in the lower part and continental environments in the upper part of the section. These rocks are part of the Peninsular Terrane and paleomagnetic reconstruction based on the volcanic rocks of this terrane suggest that the Chignik Formation was deposited at approximately the current latitude.

In the modern Arctic biological productivity is controlled by temperature, nutrient availability, and low levels of light. Analysis of the hadrosaurs of northern Alaska suggests that these herbivores were year-round residents of the paleoarctic and the proposed temperatures for the paleoarctic fall within tolerances of some modern reptiles. Therefore, temperature does not seem to be a limiting factor for biological productivity among Cretaceous dinosaurs. In the modern arctic low annual levels of light contribute to controlling biological productivity. Within the terrestrial Cretaceous paleoarctic then, the annual low level of light was likely the dominant parameter of the ecosystem.

WHOLE-TUSK GROWTH RECORDS OF LATE PLEISTOCENE WOOLLY MAMMOTH FROM THE TAIMIR PENINSULA, SIBERIA

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Permafrost deposits of the Taimir Peninsula, northernmost Siberia, have yielded exceptionally well preserved tusks of woolly mammoth (*Mammuthus primigenius*). Radiocarbon dates on these specimens generally fall in the interval 40-11 ka. As part of an international collaborative effort (the "*Mammuthus* Project"), we have sampled complete mammoth tusks by coring at multiple positions along the tusk axis. Dentin increments are more steeply inclined to the tusk axis in females than in males, requiring closer spacing of cores to ensure sufficient overlap of growth records between cores. Overlapping records are correlated by matching patterns of incremental laminae, documented in digital photographs of dentin thin sections. Long-term growth records are compiled along the tusk, yielding multiple decades of data on seasonal and annual rates of tusk growth. Although the last years of high-latitude mammoths typically have fewer than 50 second-order dentin increments per year, earlier years in life frequently show the normal number (ca. 52 ± 2) of second-order increments seen in mammoths from temperate latitudes. We interpret values < 50 as evidence of movement above the Arctic Circle (where seasonally free-running circadian rhythms change the normal relationship between second- and third-order incremental features), and values of ca. 52 as evidence of presence below the Arctic Circle. Intra-tusk variation in these patterns suggests large-scale latitudinal movement of individuals during their lifetimes. We do not yet know how much these patterns vary between individuals, between sexes, within ontogeny, among regions, or through geologic time, but preliminary data suggest that males may have spent much of their lives below the Arctic Circle. Their time in the far north may have been limited to their first year or so of life, shortly after maturation and eviction from the matriarchal family unit, and intervals during their prime reproductive years. Females may have moved north and south on a more frequent basis.

PHYLOGENY OF THE CARNIVORA, 2002

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Comparing multiple lines of phylogenetic evidence (e.g., DNA, morphology, fossil record) generally yields congruent phylogenetic results, and combining them can greatly increase robustness and resolution. Recent molecular or combined analyses of living Carnivora and outgroups have revealed exceptionally strong support for many clades identified in previous morphological phylogenies, including Carnivora, Feliformia (Feloidea), Caniformia, Arctoidea, Musteloidea, and all families (except Viverridae, Mustelidae). Several longstanding controversies or ambiguities appear to be better resolved, but some unexpected results have arisen in integrative analyses. Examples include documenting: Pinnipedia monophyly, Otariidae-Odobenidae pairing, skunks (mephitines) not closely related to other mustelids, the red panda (*Ailurus*) as a basal musteloid, Madagascar carnivoran monophyly, and *Nandinia* is not a viverrid (but rather is basal to all other living Feloidea). The closest relatives of Carnivora among both fossil and living clades remain controversial. Recent fossil-focused studies suggest Creodonta may not be monophyletic and complex relationships of early Cenozoic carnivoramorphs ("miacoids") to living clades. These analyses significantly enhance our understanding of clade divergence ages, ancestral morphotypes, character transformations, biogeography, and ecomorphological and diversity changes through time.

Of particular relevance to integrative phylogenies are recent studies documenting marked rate heterogeneity and violation of molecular clock models in many genes, both among lineages within Carnivora and between carnivorans and other taxa, and using both statistical (likelihood ratio, relative rate) tests and fossil/phylogeny-calibrated "absolute" rate assessments. This may be a general pattern in many groups, but it has been documented for only a few, and may be significant for interpreting molecular clock "inverse calculations" of divergence ages from nucleotide differences among taxa.

A NEW INTERPRETATION OF THE SKULL OF *TANYSTROPHEUS*

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The skull of *Tanystropheus* has traditionally been described with the upper teeth overhanging the those of the dentary. Small or juvenile *Tanystropheus* are believed to have been terrestrial insectivores and had an aquatic lifestyle as an adult (stomach contents have been described with cuttlefish and fish remains). The new interpretation presented here shows the front teeth were more sparsely placed and were interlocking, and the nasals more dorsally placed, similar to mosasaurs. Both small and large partially articulated skulls shows interlocking teeth (as seen in *T. longobardicus* and *T. meridens*). The interlocking teeth and dorsally placed nares in both adult and juvenile specimens indicate that *Tanystropheus* was aquatic throughout its life. The skull resembles those of fish-eating pterosaurs and sauropterygians with interlocking teeth in this aspect rather than terrestrial diapsids. Interlocking teeth would seem to be quite useful for catching insects and a dorsal naris is no difficulty to a land-dwelling form. The distinctive neck of *Tanystropheus* is long and with few vertebrae, which limits the amount of movement of the neck. Elasmosaurid sauropterygians have long necks with an outrageous number of vertebrae. It has been theorized that the neck was extremely flexible. Recent research by Cruickshank et al. (pers. comm., research in progress) strongly disagrees with this interpretation and proposes or posits that the neck had less maneuverability. *Tanystropheus* and elasmosaurids are similar in that they had long necks with limited maneuverability but achieved it by different morphological routes. *Tanystropheus* had a long, thin body and long tail that were more flexible than those of elasmosaurids. The limbs were long but toes were short and the feet didn't evolve into paddles. The feet could have been webbed and would allow the animal to swim slowly and were possibly adopt the strategy of ambush hunters.

OLIGOCENE ORIGINS OF SKIM-FEEDING RIGHT WHALES: A SMALL ARCHAIC BALAENID FROM NEW ZEALAND

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Living right whales (Balaenidae) are slow-swimming filter-feeders which "skim" food using long baleen plates. Baleen originates from the arched rostrum in a skull which is quite disparate from other mysticetes. A partial skull and associated bones (OU 22224) from the Waitaki region of New Zealand provide an early record of right whales and, by implication, indicate the early origin of skim feeding. The fossil is from the lower Kokoamu Greensand (Late Oligocene, provisionally 28 Ma), which was deposited in mid-shelf settings on the margin of the Southern Ocean. The rostrum is fragmentary, and its shape is uncertain. On the disarticulated cranium, the anteroposteriorly narrow frontal descends far ventrally from the vertex. Short rounded parietals form a deep intertemporal region; a short deep cranium is consistent with an arched rostrum. The supraoccipital is rounded in posterior view, and rises steeply from indistinct condyles. The squamosal lies far laterally, with a spacious glenoid cavity. The periotic is archaic, without prominent exostosis, but the bulla is derived in lacking an interprominential notch. All cervical vertebrae are compressed, C3-7 markedly so, but they are unfused. Post-cervical elements include thoracic and lumbar vertebrae, vertebral epiphyses and ribs, mostly indifferently preserved. Patterns of sutures suggest that the individual was not fully mature. A possible conspecific is known from a single periotic, giving 2 putative balaenids known amongst the scores of mysticetes from the New Zealand Oligocene. Elsewhere, the Neogene global record of right whales is similarly patchy, with most specimens represented by isolated bones.

Until now, the oldest described balaenid was the Patagonian Early Miocene *Morenocetus*, also known from a cranium but not the rostrum. The New Zealand specimen extends the range of balaenids by 5+ M years, and offers an early tie point for the cetacean molecular clock. The presence of right whales early in the Late Oligocene further supports the idea of a rapid radiation of Neoceti (crown-group Cetacea) early in the Oligocene.

PHYLOGENY OF THE HORNED DINOSAURS (ORNITHISCHIA, CERATOPSIDAE)

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Ceratopsidae represents a radiation of large-bodied ornithischians restricted to the Campanian and Maastrichtian of western North America (Canada, USA, and Mexico). The nearest outgroup is *Zuniceratops* from the Turonian of New Mexico. The purported ceratopsid *Turanoceratops* from the Coniacian of Asia is too fragmentary, and the associations between its assigned elements too uncertain, to determine its phylogenetic affinity. Thus the biogeographic origin and subsequent evolution of ceratopsids currently appears to be wholly North American.

Our species-level phylogenetic analysis, the first conducted for this clade, shows that Ceratopsidae (currently consisting of thirteen valid genera and 17 species) is a monophyletic group united by at least 30 unambiguous synapomorphies. The clade is here defined as *Centrosaurus, Triceratops,* their most recent common ancestor, and all of its descendents. Ceratopsidae is subdivided into two well-supported clades: Centrosaurinae and Chasmosaurinae. Despite strong support for these three nodes, resolution among ceratopsid taxa is less well constrained. A combination of dental, cranial, and postcranial characters provide support for the node Ceratopsidae. Conversely, the overwhelming majority of characters useful in delineating ceratopsid species are limited to the dermal skull roof. Specifically, these features include various elaborations of narial structures, nasal and postorbital ornamentations, parietosquamosal frills, and associated accessory ossifications (epinasals, epijugals, episquamosals, epiparietals). A central issue in ceratopsid systematics is the differentiation of inter- and intraspecific variation. In particular, ontogenetic and individual variation in the above cranial ornamentations sometimes makes species identification problematic. Nonetheless, current phylogenetic evidence suggests that, following establishment of the ceratopsid "baüplan," anatomical evolution within the group concentrated largely on ornamental skull features likely related to mate competition and perhaps species recognition.

INTEGRATING CURRENT CURATION CONCEPTS INTO THE DESIGN OF A NEW PALEONTOLGICAL CURATION AND RESEARCH FACILITY AT JOHN DAY FOSSIL BEDS NATIONAL MONUMENT, OREGON

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A recent congressional line item budget allocation has granted 8.4 million dollars to construct the Thomas Condon Paleontological Center (TCPC) at the Sheep Rock Unit of John Day Fossil Beds National Monument (JODA). This facility will be one of the largest of its kind in the US National Park Service and the first to be built in over ten years. The JODA paleontology staff was an integral part of the design team at all phases of planning. The result is a facility that will reflect the unique preparation, conservation, accessions, cataloging, storage, and research needs of a large fossil collection.

The TCPC collections management space is partitioned into three separate, but integrated, areas: accessions storage and cataloging, fossil preparation and conservation, and dedicated collections storage. The design of the fossil preparation laboratory required the greatest amount of planning and interdivisional cooperation. Topics such as dust containment, chemical use and storage, specimen safety, worker safety, visitor viewing and education, noise containment, and ADA considerations are some of the major issues that were successfully resolved during the design phase. The laboratory was granted a high priority and few compromises with regard to function and design were accepted. The result will be a highly functional curation and research facility at JODA. The TCPC is scheduled to open in 2004.

PRESERVATION AND ABUNDANCE PATTERNS IN THE VERTEBRATE ICHNOLOGICAL RECORD OF THE MORRISON FORMATION (UPPER JURASSIC; NORTH AMERICA)

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Tracks in the Upper Jurassic Morrison Formation of the western include at least 12 morphotypes and represent more than 250 individual trackways at 50 localities. The track types include representatives of turtles(?), lizards(?), crocodilians, pterosaurs, theropods, sauropods, ornithopods, and stegosaurs. Tracksites most commonly preserve tracks as natural impressions in sandstone bedding surfaces, particularly in the lower half of the formation (SB sites). Sites with tracks made into red and green floodplain muds and preserved as natural sandstone casts below sandstone ledges are next most common (FP sites); limestone bedding surface sites containing natural impressions are the least abundant (LS sites). LS and FP sites are dominated by sauropod and theropod trackways, whereas the SB sites collectively preserve a greater diversity of track types and are dominated by theropod, ornithopod, and indeterminate tridactyl trackways. Sauropods and theropods demonstrate very different patterns of abundance in the various preservation environments: sauropods are more commonly found in FP environments (77% of localities versus 31% for theropods) but theropods are more commonly found in SB environments (50% of localities versus 25% for sauropods). This suggests different track preservational biases (larger tracks occurring mainly at FP sandstone overhangs and not on smaller SB sandstone pieces, which contain a diversity of small theropod and other track types) or a minor environmental separation for sauropods and theropods within the Morrison basin. If the latter possibility has influenced the pattern, theropods may have been found in fewer FP and LS environments simply because of their lower predator population levels but why they would be so much more common than sauropods in SB environments is difficult to assess.

RECONCILING ACADEMIA AND NON ACADEMIA: AN EXAMPLE OF A COLLABORATIVE PALEONTOLOGICAL DATABASE FOR THE WEALDEN OF THE ISLE OF WIGHT, UK

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Conflicts between academic and non-academic paleontologists have been exacerbated in recent years by the escalating prices that vertebrate fossils (particularly dinosaurs) command on the international market. The loss to science of specimens privately sold, or held in otherwise inaccessible collections, and the loss of vital locality data pose serious problems to the study of vertebrate paleontology. Nonetheless, non-academic palaeontologists rightfully assert their continuing role in the discovery of significant specimens. Resolution of this conflict ought to be of interest to all palaeontologists. Here we report a setting in which non-academic paleontologists have successfully interacted with academic paleontologists.

We have created a database for the Lower Cretaceous Wealden of the Isle of Wight, that aims to preserve taxonomic, stratigraphic, taphonomic, and locality data for all specimens, regardless of the collector. Key stratigraphic and taphonomic information is acquired at no cost to the collector. The overall result is beneficial for all parties.

The database is created as a computerized form template. Individual collectors each have copies of the template and fill in the form storing data on their own PCs. This is then easily transferred to the master database using CDs / zipdisks / email. The form template will be compatible with both IBM and Macintosh hardware. We intend to expand the project past the pilot stage and eventually transfer the template onto the internet, allowing direct submission of data by collectors.

Potential academic benefits of such a database are obvious. Equally, the database will benefit local collectors and landowners. Collectors working on the same sites can be put in contact with each other, decreasing fragmentation of specimens and stratigraphic misunderstandings. Landowners can observe exactly what is being collected from their land, and can assess the implications.

In our experience, non-academic paleontologists are as eager to see advancement in the science as are academics. This project provides non-academics a rare opportunity to contribute directly, and meaningfully, to our field.

PERIMORTEM GROWTH HISTORIES OF HISCOCK MASTODONS

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Profiles tracing seasonal and annual variation in the thickness of periodically formed dentin increments in mastodon tusks provide a framework for interpreting variation in tusk stable isotopic composition. Serial microsamples of tusk dentin were analyzed to determine compositional time-series for the last two to three years of life in four female *Mammut americanum* from the late Pleistocene Hiscock Site in western New York, USA. Oxygen isotope variation in the structural carbonate of hydroxyapatite shows a pattern that is compatible with inferences of season determined from spacing of incremental features. Annual ranges of oxygen isotope values are generally low (ca. 2 permil), although two individuals show larger excursions nearly a year prior to death. Carbon isotope variation in structural carbonate and collagen show different, but both non-seasonal, profiles. Both are compatible with dominantly C_3 diets, and both show relatively low ranges of variation. Nitrogen isotope ratios from collagen show the clearest pattern of seasonal variation, with positive excursions in mid-winter, followed by declining values in spring and summer. Annual ranges, however, are generally less than 2 permil, and all values are consistent with low levels of nutritional stress. Compositional profiles offer no indication of either drought stress during summers or severe nutritional stress

during winters. Average oxygen, carbon, and nitrogen isotopic compositions of Hiscock tusks are generally similar to values from other tusks from the Great Lakes region, and annual rates of dentin apposition are only slightly lower than for other Great Lakes specimens we have examined. If environmental change was driving the late Pleistocene megafaunal extinction, the growth histories and isotopic compositions of these animals offer no hints as to its nature.

A DESCRIPTION OF THE ANATOMY OF A DIGITALLY CONSTRUCTED *ACROCANTHOSAURUS ATOKENSIS* (THEROPODA: ALLOSAUROIDEA) ENDOCAST, AND ITS USES

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Acrocanthosaurus atokensis, a large allosauroid theropod, is known from several specimens collected in the 1990s, as well as the two original specimens collected in the 1940s. The holotype, O.M.N.H. 8-O-S9, contains a well-preserved and complete braincase. This braincase was scanned at the High Resolution X-ray Computed Tomography (CT) Facility at The University of Texas at Austin by Richard Ketcham on January 12, 1999.

The resulting images were manipulated using graphics and volume rendering programs to produce a digital endocast of the endocranial cavity. Due to the preservation of the braincase, and the large density difference between the bone and the matrix, a very complete endocast was obtained. Just a cursory glance at the images revealed most of the cranial nerves. Those readily visible include the olfactory bulb and tract (CN I), the optic nerve (CN II), the trigeminal nerve (CN V), the abducens nerve (CN VI), the facial nerve (CN VII), and several branches representing the glossopharyngeal, vagus, accessory, and hypoglossal nerves (CN's IX-XII). Also easily visible are the pituitary fossa, the foramen ovale, the entrance of the internal carotid, and all three semicircular canals. Other structures which may be present but are harder to verify include the oculomotor nerve (CN III), the trochlear nerve (CN IV), and several smaller arteries and veins.

This complete endocast not only allows the description of a previously undescribed endocranial cavity to be done, but it also allows for several different types of comparisons. The volume rendering program used to create the endocast calculates a volume for it once it is constructed, permitting volume comparisons to be made with other digital, natural, and plaster endocasts. The shape of the endocast also permits comparisons with others, and, as might be expected, it is similar to the closely related taxa *Allosaurus* and *Carcharodontosaurus*. It is these types of comparisons that are vital in answering the question of how the modern avian brain evolved.

WHERE HAVE ALL THE TRIASSIC LIZARDS GONE? SPHENODONTIANS AND THE EARLIEST MEMBERS OF THEIR SISTER GROUP, THE SQUAMATA

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Based on numerous shared derived morphological character states, the monophyly of the Lepidosauria (comprising the Sphenodontia and Squamata) is widely acknowledged, despite some contrary molecular evidence. While the Sphenodontia are represented by a variety of taxa in the Late Triassic, and have a widespread distribution, there are currently no definitive records of Triassic squamates. Over the years there have been a number of reports of Triassic squamates, but with re-interpretation these have all since been shown to be false. Given the abundant and rather diverse remains of Triassic sphenodontians, the lack of a Triassic record for their sister taxon is something of a puzzle. This absence of a Triassic squamate record is here considered to be an artifact of sampling and preservation. The majority of Late Triassic sphenodontian records are isolated jaw fragments. The keels and flanges on their acrodont teeth are highly characteristic. Even more important is the posterior process of the dentary that extends back beyond the level of the coronoid. This is a very robust part of the jaw and consequently it is frequently preserved. The lack of similar diagnostic characters in squamate jaws is significant.

As new sphenodontian taxa continue to be described, it is becoming increasingly apparent that they were a very diverse and disparate group, with *Sphenodon* representing just one of many different body plans. The use of the term "Living Fossil" to describe the extant genus, *Sphenodon*, is considered inaccurate.

MEASURING LOCAL GEOGRAPHIC VARIABILITY IN EARLY ARIKAREEAN MAMMALIAN ASSEMBLAGES

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The discontinuous patchwork of modern habitats and ecotones is well-known, and theoretically should also be at least partially retrievable from the fossil record. Most efforts to reconstruct spatially dynamic "paleobiomes" have yielded only coarse descriptions due to limitations resulting from inadequate specimen samples and minimal depositional context studies. It would be worthwhile to document and compare isochronous localities across a broad, environmentally complex geographic region in order to reconstruct the details of paleoecological relationships and the mosaic of terrestrial assemblages at any given interval. Most of the thousands of North American Tertiary vertebrate localities are not suited for such analyses. Of the handful of basins that have model conditions, few have been systematically collected to enable spatial variability analysis. One of these, within central Eastern Oregon, accumulated fossiliferous deposits within a paleoenvironmentally diverse region for which a suitable chronostratigraphic framework has been developed. Both newly developed and existing institutional collections and data sets from the region were studied for this effort. Material retrieved from over 500 discrete Arikareean localities was examined, each containing 100 or more identifiable specimens that could be constrained to a limited temporal-spatial context. All localities with index beds were also correlated in the field. Despite excellent specimen availability, it is unfortunate that most of the available existing data intervals are either too coarse stratigraphically or inconsistently documented to extrapolate statistically meaningful comparisons. Only one richly fossiliferous paleosol interval (Unit "F", between the BBT and PGI) has so far proved suitable for broad geographic variability analysis. This unit illustrates a region that, despite an inferred 200k of time averaging, has significant geographic differences in the vertebrate taphocoenose. Detailed sampling of less than or equal to 50ky time intervals, and consideration of paleosol variability, will be necessary to provide more precise pattern analysis and evidence of depositional cycles.

AN ECOMORPHOLOGICAL ANALYSIS OF THE AFRICAN HERPESTIDAE AND VIVERRIDAE, AND IMPLICATIONS FOR THE PALEOECOLOGY OF EOCENE CARNIVORES

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Paleontologists have succeeded in comparing larger bodied modern carnivorans with their extinct counterparts and inferring their dietary habits. However much less attention has been paid to the smaller carnivorans, many of which are more appropriate analogs for Paleogene carnivores. Analyses of these early forms are important as they document a key time in the evolution of carnivorous mammals, including the decline of the extinct creodonts and the origin of modern families. Modern members of the carnivoran families Herpestidae and Viverridae display a wide range of dental morphologies, and similar diet and size ranges have been inferred for mammalian carnivores of the North American Eocene (including true carnivorans (miacids and viverravids) and creodonts), although no quantitative comparisons have been made. The African members of these modern groups are representative of the families as a whole with diets ranging from a mixture of vertebrates and invertebrates (the mongooses) to those with a higher percentage of vegetable matter (the genets). Some have specialized diets consisting of freshwater prey (*Atilax paludinosus*), termites (*Rhynchogale melleri*), and arboreal prey (*Poiana richardsoni*). They also range in size from <.5 kg (the dwarf mongooses) to 20 kg (the African civet). A multivariate analysis of the feeding structures (cranial and dental measurements) of modern African carnivorans shows that they can be divided according to percentages of vertebrate, invertebrate, and fruit matter as part of their diet. Eocene carnivorans can be classified along similar multivariate axes. The more variable set of carnassials in creodonts poses a problem for direct comparison, although use of ratios of grinding areas and blade lengths allows some inferences to be drawn. Further studies will include a broader range of both modern and fossil taxa.

CLUPEOMORPH FISHES FROM THE LOWER CRETACEOUS OF THE RECÔNCAVO BASIN, NORTHEASTERN BRAZIL

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Since the late 19th century, clupeomorph fishes have been described for several Brazilian basins, especially for the Cretaceous strata. To date all taxa described are endemic to Brazil and are represented by the following species: *Ellimmichthys longicostatus* and *Scutatuspinosus itapagipensis* both from the Lower Cretaceous of the Recôncavo Basin, State of Bahia; *Santanaclupea silvasantosi* from the Lower Cretaceous of the Araripe Basin, State of Ceará; *Codoichthys carnavalii* from the Lower Cretaceous of the Parnaíba Basin, State of Maranhão; *Ellimma branneri* from the Lower Cretaceous of the Sergipe-Alagoas Basin, State of Alagoas; *Elimma cruzi* from the Lower Cretaceous of the Pernambuco-Paraíba Basin, State of Pernambuco. Other undescribed clupeomorphs are registered to the Lower Cretaceous of the Araripe and Sergipe-Alagoas basins, and Upper Cretaceous of the Pelotas Basin.

The specimens from the Recôncavo Basin are preserved in a grayish shales, typical of the Candeias Formation. The sediments were deposited in a probable fluvio-lacustrine paleoenvironment periodically fed by flood-plain and fan deltas, associated to cyclic turbidity events. The material belongs to the Paleozoological Collection of the Departamento de Biologia Animal e Vegetal of the UERJ.

The medium-sized clupeomorphs herein presented are preliminarily assigned to *Ellimma* due to generalized morphological features. They occur in association to remains of semionotid (*Lepidotes*), amiid (*Calamopleurus*), cladocyclid (*Cladocyclus*), clupeocephalan (*Scombroclupeoides*), and mawsoniid (*Mawsonia*).

The state of preservation of the specimens and the diversity of taxa from Candeias Formation indicate that this is one of the most important fossiliferous deposits containing fishes in the Recôncavo Basin.

NEW MATERIAL OF ORNITHISCHIAN (?HETERODONTOSAURID) DINOSAUR *ECHINODON* (EARLY CRETACEOUS, SOUTHERN ENGLAND) FROM THE LATE JURASSIC OF FRUITA NEAR GRAND JUNCTION, COLORADO, USA

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Echinodon becklesii Owen, 1861 is based mostly on 8 small jaws (lectotype Mx+2Pmx; D pair; odd 3D & 2Mx) with teeth from England (Purbeck Limestone Fm., Berriasian). Norman and Barrett this year suggest three potential synapomorphies to support referral of *Echinodon* to the Heterodontosauridae: wedge-shaped predentary, middle cheek teeth with denticles restricted to apical-most third of crown, lack of special foramina.

Four specimens of *Echinodon* sp. from the Morrison Formation (Salt Wash Member, Kimmeridgian) of Fruita, Colorado represent the first associated maxillae and dentaries with postcrania. The Fruita cheek teeth are very similar to those of *Echinodon* but the denticles occupy more of the apical part of the crown with a less acute angle between the ridges that diverge from the base of crown.

Jaws with rostral part preserved: Purbeck: 2 maxillae—canine or large alveolus; 3 dentaries—only small alveoli. Fruita: no maxillae; 2 dentary pairs—canine or large alveolus. So canine is on maxilla in *E. becklesii* and on dentary in Fruita species or, more probably,

Echinodon jaws with canines are males and *becklesii* dentaries without canines are females.

Echinodon autapomorphies: one or possibly two caniniform teeth on rostral end of maxilla; form of symphysis: only dorsal part of dentaries contact each other (subtriangular shaped sutural area with a rounded apex directed caudally), large space ventrally bordered by symphysis and dentaries (for large ventral process of predentary), no contact surface for predentary ventrolaterally; distal part of tibia with craneomedial edge produced into an craneomedially directed sheet.

Derived characters common to *Echinodon* and *Heterodontosaurus* (Lower Jurassic, South Africa): premaxilla with three teeth; one or possibly two caniniform teeth on rostral end of dentary; jaws lack special foramina; head of humerus a thickened boss in middle of proximal end; femur: almost no cleft separating the greater from the lesser trochanter which is a protuberant crest at craneolateral margin of femur, fourth trochanter rod shaped; distal half of fibular shaft very slender; fused astragalus-calcaneum forms a bird-like pulley distally.

AN EARLY LATE CRETACEOUS DINOSAUR TRACK SITE IN CENTRAL YUKON TERRITORY

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Dinosaur tracks and trackways were first reported from the coal-bearing Tantalus Formation near Ross River, Yukon Territory, Canada in May of 1999 by members of a University of Alaska Museum field party. The initial discovery was followed by two subsequent years of field mapping and collection by a joint Alaska and Yukon team. This research has resulted in the documentation of a total of 240 individual tracks at two separate but stratigraphically related sites as well as several trackways at a single site. Six ichnotaxa, at one site, are recognized including *Ornithomimipus*, *Amblydactylus?, Gypsichnites*, and *Hadrosaurichnus*. This ichnoassemblage of 197 individual tracks is compared with those of Alberta, Canada and the North Slope of Alaska that range in age from Albian to Maastrichtian. This poster presents a detailed map of the trackways and associated tracks at one of these sites.

The discovery of unequivocal dinosaur evidence in these rocks resulted in a restudy of the palynology and biostratigraphy of this coal-bearing sequence and the recent assignment of a late Coniacian to early Santonian age to the upper part of the dinosaur-bearing interval.

THE SOUTHERNMOST RECORD OF THE TURTLE *BOTHREMYS* (TESTUDINE: PLEURODIRA) IN THE CERRO DEL PUEBLO FORMATION, NEAR SALTILLO, COAHUILA, MÉXICO.

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Two complete shells and an isolated skull from the Late Cretaceous (Campanian) Cerro del Pueblo Formation in Southeast Coahuila, are the first report of the genus *Bothremys* in Mexico and the southern most report for North America. Both shells resemble those of *B. barberi* having seven neural plates, the contact of the pectoral scute with the mesoplastron and entoplastron plates, and lack of cervical scute; but the large specimen differs in its size, a more enlarged nuchal plate, plastral formula abdominal>femoral>pectoral, equal anterior and posterior lobe width, mesoplastral as wide as long, short xiphiplastron projections, and relatively long epiplastral symphysis, suggesting that it could be a new species.

The previously known distribution of *Bothremys* was restricted to the oriental landmass of the North American seaway called Euramerica with findings in Kansas, Arkansas, Alabama and New Jersey. The discovery of the Cerro del Pueblo *Bothremys* on the west coast of the North American seaway (Asiamerica) have led to interpreted its origin as a vicariant event. As happen with other flora and faunal groups, a more widespread genus *Bothremys* was separated by the Jurassic transgression, splitting its original distribution range, caused by the opening of the North American western interior seaway during the Mesozoic.

The *Bothremys* of Cerro del Pueblo is the only certain record of pleurodiran turtle in the west portion of Asiamerica during the Cretaceous, and could close de biographical gap between North American and South American bothremyids.

AN EOGYRINID FROM THE MISSISSIPPIAN OF HANCOCK COUNTY, KENTUCKY

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Recent finds from the Hancock County, Kentucky, tetrapod site include a partially articulated embolomere, a colosteid, two new tetrapod genera and a diverse fish fauna. The embolomere was recovered from the Palestine Sandstone of the Buffalo Wallow Formation (Mississippian, Chesterian). At the Hanock locality the Palestine Sandstone is a series of laterally accreted and incised channel deposits marked by numerous slump features. The embolomere is preserved on the surface of seven large sandstone blocks from a slightly slumped coset of the incised channel. The seven blocks were recovered as float; four of the blocks can be reassembled, but the relations of the remaining three are unknown.

The embolomere comprises two articulated caudal vertebral series (an anterior caudal series of six vertebrae and a more distal caudal series of four vertebrae), mid-trunk presacral ribs, both ilia, both ischia, a partial pubis, and an articulated pes. In addition to the body fossils, numerous ribs and portions of the pes are represented by casts on the surface of the slump blocks. Neural arches bear a prominent rounded ridge stretching from the level of the transverse processes to approximately midway along the neural spine. These ridges are most pronounced on the more anterior caudal vertebrae. Ridges of similar size have been described for *Eogyrinus* and smaller ones in *Proterogyrinus* and *Archeria*. Haemal arches are short dorsoventrally, but broad anteroposteriorly as in *Eogyrinus*. They are considerably shorter dorsoventrally than in *Proterogyrinus* or *Archeria*.

The limited material available makes generic assignment for this specimen impossible, however the construction of the vertebrae suggests eogyrinid affinities. Eogyrinids are presently restricted to the Pennsylvanian and this would mark the oldest occurrence of an eogyrinid.

THE BIOSTRATIGRAPY AND PALEOECOLOGY OF THE DINOSAUR-BEARING LOWER CRETACEOUS CEDAR MOUNTAIN FORMATION

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Nine new dinosaur taxa, including theropod, ankylosaurid, iguanodontid, nodosaurid, and brachiosaurid taxa, have been recently recovered by the College of Eastern Utah Prehistoric Museum from the Albian-Cenomanian Cedar Mountain Formation. The Cedar Mountain Formation is an alluvial facies association consisting of braided fluvial, alluvial flood plain, and lacustrine facies. Detailed stratigraphic, sedimentological, geochronological, palynological, and paleontological data have been collected along a transect extending from Price River to Mussentuchit Wash, in Carbon and Emery Counties, Utah.

Ar/Ar dates have been obtained from relict sanidine crystals extracted from 3 stratigraphically distinct altered volcanic ash layers. This data has been integrated with all available palynofloral, megafloral, and vertebrate paleontological data and with detailed sedimentological and stratigraphic data to produce a biostratigraphic framework for the Cedar Mountain Formation. This new chronostratigraphic framework provides information about the paleoenvironment and paleoecology of the local areas from which dinosauria have been recovered. This provides insight into the nature of Lower Cretaceous dinosaur niches and evolutionary trends. In addition, the sedimentological framework provides insight into dinosaur biostratinomy.

Sedimentological data suggest that significant climatic changes are recorded in the Cedar Mountain Formation. During the deposition of the lower part of the Cedar Mountain Formation (Ruby Ranch Member), climatic conditions were warm and arid to semi-arid (mid-latitude arid). During the deposition of the upper part of the Cedar Mountain Formation (Mussentuchit Member), conditions became more humid (mid-latitude coastal). The progressive change in climatic conditions may have had significant impact on the diversity, abundance, and evolution of the dinosaurs.

TAPHONOMY AND PALEOECOLOGY OF AN EARLY CARBONIFEROUS FISH LOCALITY, AUSTRALIA

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The earliest tetrapods are known from the Late Devonian, with articulated specimens from the Famennian of East Greenland and fragmentary remains from the Frasnian of Scotland. Devonian tetrapods were present also in Gondwana as indicated by trackways in the Genoa River Beds of Victoria, and a jaw from New South Wales. Besides several fragments from Nova Scotia and an undescribed specimen from Scotland, no tetrapods are known from the first 30 million years of the Early Carboniferous (Romer's Gap). This gap, until recently, was even larger in Australia, spanning 100 millionyears until the end of the Permian.

In 1995 a fossil fauna of fish and tetrapods was located, towards the end of Romer's Gap, in the mid-Viséan Ducabrook Formation of the Drummond Basin, Queensland. These first Carboniferous tetrapods from Gondwana have re-ignited interest in a Tournaisian site near Mansfield, Victoria, first excavated by Sweet during the late 1800s, the fauna being described by Woodward in the early 1900s. Sweet made excavations principally at a locality known as Tannery Paddock. Since this discovery some Mansfield taxa have been redescribed including the only known articulated remains of *Gyracanthides*. Although the fish assemblage is similar to that of Early Carboniferous tetrapod-bearing faunas of Euramerica and Queensland, no tetrapods have yet been found.

The fossil fish locality at Tannery Paddock provides an opportunity to find the earliest Carboniferous tetrapods or, alternatively, to suggest reasons for their absence. This study involves a systematic taphonomic analysis of the fossiliferous strata at Mansfield, and includes re-opening Sweet's original quarries at Tannery Paddock. These sites have been linked to form a continuous stratigraphic sequence from which to reconstruct the contained paleoenvironments and faunas. The project includes the first comprehensive study of microvertebrates from the site.

MURDER IN JURASSIC PARK: THE CLEVELAND-LLOYD DINOSAUR QUARRY AS A DROUGHT-INDUCED ASSEMBLAGE

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A comprehensive analysis of abundant new data has yielded a novel interpretation for one of the most famous dinosaur quarries in the world. The Cleveland-Lloyd Dinosaur Quarry (CLDQ) of central Utah has traditionally been interpreted as an attritional predator trap. This scenario—which postulates that numerous theropods were killed over many years while pursuing mud-trapped herbivorous dinosaurs—is based largely on the remarkable 3:1 predator:prey ratio, dominated by the remains of *Allosaurus fragilis*. The present study addressed the taphonomy of CLDQ from a much broader perspective, combining analyses of both the fossils and the entombing sediments with putative modern analogues and interpretations of Morrison Formation environments. While a variety of taphonomic hypotheses were considered, four in particular—flood, attritional floodplain, predator trap, and drought—were tested against both geological and biological data from the quarry to determine the most parsimonious explanation for this unique deposit.

The bones at CLDQ occur in a fine-grained calcareous mudstone overlain by freshwater limestone, interpreted as a floodplain pond deposit. The bones show minimal carnivore modification and little to no surface weathering. Recently excavated elements exhibit a paucity of high angle dips (>10), and a rose diagram analysis of this sample (n = 168) indicates current alignment in a NW/SE trend. Fluvial alignment is corroborated by the distribution of associated partial skeletons. Approximately 20% of the elements possess greenstick fractures

and 25% show evidence of abrasion. The demographics of the CLDQ sample appear to be highly skewed toward subadult individuals.

Numerous lines of evidence conflict with the predator trap hypothesis. Of the remaining taphonomic alternatives, a catastrophic drought followed by fluvial reworking appears to be most consistent with the entire range of available data. Finally, arid climatic indicators and previous arguments of drought-induced dinosaur assemblages within the Morrison Formation, provide further support for this hypothesis.

UNDERTRACKS AS "TRUE" TRACKS: WHAT LAYER(S) DID A DINOSAUR TOUCH?

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Despite Hitchcock's treatment over 140 years ago, variation in dinosaur tracks with depth is still a confusing issue. "True" tracks are defined as those left on the surface that was exposed during formation. The resultant deformations of sub-surface layers have been called undertracks, ghost prints, transmitted prints, underprints, or subtraces. As Hitchcock and others have noted, however, two different modes of sub-surface deformation can take place: distortion and incision. Sub-surface layers may be distorted indirectly by the foot transmitting forces through overlying sediment. In contrast, on incompetent substrates a foot can pass completely through layers and thereby impact deeper sediment directly. Although these modes represent two ends of a deformation continuum, this distinction is important. Incisions faithfully record the passage of an animal's appendage, whereas distortions do not. By emphasizing the skin-sediment interface rather than depth, it can be argued that incisions are just as "true" as shallower tracks left on an originally exposed surface. Examples from the Late Triassic of Greenland will be used to show how this broader definition facilitates the interpretation of tracks of different depth and the reconstruction of foot motion in early theropod dinosaurs.

THE LATE EOCENE PANGOLIN *PATRIOMANIS* FROM NORTH AMERICA, AND A NEW GENUS OF PANGOLIN FROM THE LATE EOCENE OF NEI MONGOL, CHINA (MAMMALIA, PHOLIDOTA)

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Previous descriptions of the North American, late Eocene pangolin *Patriomanis americanus* were based upon the type material, which included a well preserved braincase and basicranium and fragmentary postcranial remains. The type possessed a sufficient number of diagnostic features to assign it unequivocally to the order Pholidota, but was uninformative regarding many anatomical details. New material of *Patriomanis* comprises two virtually complete skeletons obtained from the same locality as the type, one of which preserves the anterior portion of the skull and much of the mandible. Additionally, a partial skeleton of a fossil pholidotan from upper Eocene sediments in Nei Mongol, China, includes nearly complete hindlimbs, along with portions of the forelimbs and axial skeleton, but no skull material. Although the Chinese specimen is similar to *Patriomanis* in a general sense, it is substantially larger. Moreover, most of the preserved elements are as recognizably different from those of *Patriomanis* as the most divergent extant pangolins are from one another. Thus we believe the Chinese skeleton merits a new generic-level designation.

Both *Patriomanis* and the new Chinese genus display diagnostic pangolin features, including fissured unguals, presence of a prehallux and radial and tibial sesamoids, a fused scapholunar, and an elongate deltopectoral crest on the humerus. In addition, the skull of *Patriomanis* is toothless, with anterior bony prongs on the mandible, a concave palate, a partially ossified tentorium and basisphenoid/basioccipital wings. However, both taxa are decidedly more primitive than the extant pangolins. They possess a convex astragalar head and a large third trochanter located approximately at the femoral midshaft, and *Patriomanis* retains a mandibular coronoid process and globose promontorium. The fossil pangolins differ from modern forms in their more robust limb girdles and long bones, and their less robust manus and pes, suggesting that the fossorially adapted limbs of pangolins have become more modified distally over time.

CONSTRAINT, HOMOPLASY, AND INFORMATIVENESS IN THE EVOLUTION OF THE MEDIAL APERTURE OF THE RECESSUS SCALAE TYMPANI IN LIZARDS

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The recessus scalae tympani (RST) is a distinctive synapomorphy of the ear region of the squamate (lizard) braincase. The anteroventral and posterodorsal parts of the embryonic metotic fissure, the former being the RST and the latter the vagus foramen (VF) in the adult, normally become separated when the posterior ampullary prominence of the otic capsule and the lateral margin of the basal plate grow to abut one another during late prenatal ontogeny. In adult lizards ancestrally, the glossopharyngeal (IXth cranial) nerve passed through the RST while the vagus (Xth cranial) and spinal accessory (XIth cranial) nerves, but not the jugular vein, traversed the VF. There are normally two membrane-covered fenestra in the side walls of the RST, a larger lateral aperture (LARST) facing the pharyngeo-tympanic cavity and a smaller medial aperture (MARST) facing into the cranial vault. The morphology of this extracranial cavity reflects the evolution of a pressure-release system analogous to those that arose independently in mammals, crocodylians, and birds.

We describe phylogenetically informative variation in the position of the MARST and the glossopharyngeal nerve. The braincase is generally regarded as a source of "conservative" characters because it is buffered from the external environment by its core position within the skull, and is thus assumed to be less influenced by adaptive convergence. We nevertheless demonstrate extensive convergence in this system. The braincase may be sheltered from the environment, but the MARST faces a constructional constraint in that there are only three braincase bones through which it could pass. Moreover, one expects few characters to be immune to convergence across an ingroup composed of more than 6,000 species, especially on the vast scope of time—at least 180 million years—over which lizard evolution has taken place. Despite all the convergence, and the decidedly biased pattern to that convergence, there remains a strikingly congruent pattern of variation in the lizard MARST and exit of the IXth cranial nerve, as these braincase apomorphies support a number of otherwise well-corroborated lizard clades.

THE MYTH OF CANNIBALISM IN *COELOPHYSIS BAURI*

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It has been commonly accepted by both the general populace (due to popular books and documentaries) and the vertebrate paleontology community (through several technical publications) that the early theropod dinosaur *Coelophysis* engaged in cannibalism. This has been developed from two extraordinary specimens in which there appears to be a juvenile in the abdominal cavity of an adult. However, a careful review shows that the most likely explanation for the occurrence of juvenile remains within the body cavity of a larger animal is taphonomic, not behavioral.

Several lines of physical evidence indicate that cannibalism has not taken place. In certain places, both the left and right ribs of the adult overlay the juvenile remains, indicating that the smaller animal is actually underneath the adult. Also, volumetric analysis of the elements found within the chest cavity show that the bones would take up the maximum possible stomach size for this animal; not including any flesh that the bones would have on them. Furthermore, many elements of the putative cannibalized animal would be difficult to ingest, due to their size or shape. A partial ilium, a pes, and several articulated vertebrae are obvious examples of oddly shaped elements.

Therefore it is best viewed that the most parsimonious explanation for the apparent occurrence of a juvenile *Coelophysis* within the chest cavity of an adult *Coelophysis* is due to taphonomic features of the Ghost Ranch quarry, and is not reflective of the behavior of these animals.

USING CLIQUES TO INCREASE THE INFORMATIVENESS OF CLASSIFICATIONS: EXAMPLES FROM DINOSAURIA

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Authors of recent dinosaur classifications assert that their classification should be accepted because it is more stable, thus recognizing stability as one of the primary goals of systematics. Unfortunately, the most stable taxa (i.e. the least likely to be rendered redundant or inconsistent with new data) are also the least informative. For example, Sauropodomorpha has been defined as "*Plateosaurus*, *Saltasaurus*, their most recent common ancestor, and all its descendents." Although this taxon is probably stable to future fossil discoveries or analyses, its definition does not specify what other taxa are considered sauropodomorphs. The definition relies either on an assumed consensus or the discretion of the reader for a list of the members of the taxon. Although stability is important, I suggest that informativeness should have a greater role in the naming of taxa. Informative definitions for taxa have several benefits including: effective communication, informative classifications, and testable taxa. Cladistics would be the method for testing taxa, and monophyly would be the criterion used to choose among competing taxonomic names.

Both node and stem-based taxa can be made more informative by redefining them as cliques (i.e. listing multiple taxa that are included in the taxon, and those that are excluded). For example, Sauropodomorpha could be redefined as the clique excluding Theropoda but including Prosauropoda, Diplodocoidea, *Camarasaurus*, Brachiosauridae, Titanosauria, their most recent common ancestor, and all of its descendents. Supraspecific taxa can be used in clique definitions as long as their taxonomic content is enumerated, or an existing classification cited. Making taxon definitions more informative would decrease stability; however, this is not necessarily a negative. Naming a new taxon to replace an existing one would indicate the discovery of contradictory evidence while stable taxa would indicate continued corroboration.

CHEMICAL AND MORPHOLOGICAL ANALYSIS OF SOFT TISSUE PRESERVATION IN A MOSASAUR

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Comparative morphological analysis of a specimen of the mosasaur *Platecarpus* (Squamata; Mosasauridae) from the Niobrara Chalk of Kansas reveals extensive *in situ* preservation of soft tissues, including integument, nearly complete three-dimensional preservation of tracheal rings, and, significantly, two discrete hematitic stains indicative of preservation of visceral organs. The larger of the two putative visceral traces is located anteroventrally in the thoracic cavity, consistent with the position of the liver in extant squamates. The second smaller mass is positioned medial and ventral to the anterior-most lumbar vertebrae; anatomically consistent with the position of the kidney. Preliminary chemical analysis using mass spectrometry and X-ray diffraction techniques reveals the presence of relatively high concentrations of large molecular weight organic compounds and iron in both traces, but not present in control samples of unmodified matrix or preservative. These results are suggestive of catabolism of porphyrin compounds present in hemoglobin and support the original morphological interpretations.

THE VERTEBRATE FAUNA (LATE-IRVINGTONIAN, MID-PLEISTOCENE) OF ASH WASH, COYOTE BADLANDS, ANZA-BORREGO DESERT STATE PARK, CALIFORNIA

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Locally derived Irvingtonian-aged fluvial sediments of the Coyote Badlands, Anza-Borrego Desert State Park, California have produced vertebrate and invertebrate remains. Previously collected vertebrate material from this locality consists almost entirely of larger vertebrates recovered by surface collecting. Screen-washing of sediments (to 0.5 mm) within Ash Wash has produced a number of micro-vertebrate specimens previously unknown from the Coyote Badlands. Nearly all fossil remains occur between the ~750,000 year old Bishop Ash and the ~620,000 year old Thermal Canyon Ash.

Vertebrate remains include: *Sylvilagus* sp. (cottontail), Sciuridae (small squirrel), *Thomomys* cf. *T. gidleyi* (pocket gopher), *Perognathus* sp. (pocket mice), *Baiomys/ Reithrodontomys* (small cricetid rodent), *Neotoma* sp. (woodrat), *Terricola meadensis* (vole), Camelidae (*Camelops* size camel), cf. *Stockoceras* (antilocaprid), Ovibovini (large bovid), *Equus* sp. (large horse), Falconiformes (raptor), Emydidae (pond turtle), Serpentes (snake), *Heloderma* sp. (gila monster), and *Cnemidophorus* sp (whiptail lizard). Of special note, *Thomomys* cf. *T. gidleyi*, a typically Blancan species, are reported here for the first time from an Irvingtonian-aged locality. *Heloderma* sp. and cf. *Stockoceras* are reported for the first time from the Irvingtonian and from California. Fossil *Heloderma* are currently unknown from the Arikareean (Miocene) to late Rancholabrean. *Stockoceras* is typically associated with Rancholabrean faunas.

NEW OSTEOSTRACANS FROM THE MACKENZIE MOUNTAINS, N.W.T., CANADA

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The MOTH locality in the southern Mackenzie Mountains, N.W.T., Canada has yielded many unique specimens of Early Devonian fossil vertebrates. Several new species of acanthodians, thelodonts, heterostracans, and cornuate osteostracans have been described from the Delorme Formation. The described osteostracans include *Superciliaspis gabrielsei*, *Diademaspis mackenziensis*, and *Waengjoeaspis nahanniensis*. Preservation of specimens is generally good, but is limited to dermal bone.

A number of undescribed specimens of osteostracans have been examined and some show quite distinct characteristics. One is unusually large and has distinctive tuberculation on the plates. Unfortunately, that specimen lacks a head shield. Another has tooth-like ornament on the dermal bones of its head and body. The precise number of new species has not yet been determined, but at least three are present, bringing the diversity of MOTH osteostracans to six or more species.

LOGISTICAL AND ENVIRONMENTAL ISSUES SURROUNDING PALEONTOLOGICAL FIELDWORK IN GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, SOUTHERN UTAH

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Over the past two years, the Utah Museum of Natural History has conducted several months of fieldwork in the Late Cretaceous Kaiparowits and Wahweap formations of Grand Staircase-Escalante National Monument (GSENM). These efforts, now formalized in a five-year collaborative agreement with GSENM, have allowed us to gain considerable experience working in the remote backcountry of the Monument.

Conducting paleontological fieldwork in an area as extensive and remote as GSENM presents several logistical challenges. In this largely roadless terrain, fieldwork is constrained by the ability to pack all equipment and supplies in on foot. Excavation equipment is generally limited to easily transported hand tools, thereby limiting excavation techniques and (potentially) access to specimens. Labor-intensive strategies for transporting heavy jackets using ropes and sleds have been utilized for collecting large vertebrate specimens in remote areas. In addition to extremely limited vehicle access, exposures of the Wahweap and Kaiparowits occur largely within regions designated as Wilderness Study Areas, further complicating the potential for mechanized excavation and hindering transport of specimens and equipment. In spite of these difficulties, recent work has yielded abundant, highly significant, well-preserved fossil vertebrate remains, including new dinosaur taxa.

In light of the regulatory and political realities of working in a place like GSNEM, paleontologists must work directly with Monument administrators in developing strategies for conducting surveys and excavations while simultaneously minimizing environmental impact. Highly significant and unique specimens that lie exposed on the surface of these extensive outcrops face serious threats from natural erosion, as well as theft and vandalism. Collaborative efforts by paleontological researchers and monument administration significantly augment our collective ability to locate and preserve globally significant fossil resources before they are lost forever.

A STUDY OF EARLY JURASSIC DINOSAUR FOOTPRINTS IN FOREST PARK, SPRINGFIELD, MASSACHUSETTS

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The dinosaur footprints displayed in Forest Park, Springfield, were discovered in 1932 in the quarry of William Murray in Holyoke, MA, and subsequently sold to the Springfield Park Department. The complete display consists of a slab of Early Jurassic mudstone 15 meters long by 4 meters wide, on which 44 footprints were impressed. Yale Paleontologist R. S. Lull examined them in 1932 and attributed them to 6 ichnospecies: *Eubrontes giganteus*, *E. divaricatus*, *E. tuberatus*, *E. platypus*, *Grallator cuneatus*, and *Anchisauripus exertus*. Newspaper articles covering the acquisition and display of the slab indicate that a resting trace was observed on the track surface, and that one dinosaur increased in speed. Unfortunately, no photographs accompanied the description of these traces, and the identity of these particular traces is not known. Outdoor display of the slab has resulted in considerable weathering of the footprints during intervening years.

I recently completed a study of the footprints in order to identify these traces and to make the information I obtained available for public use. I mapped the site and photographed and measured the footprints. Ichnospecific identification of most footprints was impossible due to weathering, but ichnogeneric identification was possible using 3 criteria: 1) digit III projection ratio, 2) footprint length to width ratio, and 3) total footprint length. A possible resting trace was identified. A small depression was found that might represent the impression of an ischial tuberosity. However, it is impossible to be certain of the origin of this trace because damage caused by weathering has obscured any footprints or tail trace that may have been associated with it. Steadily increasing strides in a trackway referable to *Anchisauripus* indicate that this is the dinosaur that increased in speed. In addition, another trackway referable to *Anchisauripus* has an extremely long stride, suggesting the animal was running. This hypothesis is supported by probable speeds calculated for the trackmaker.

ORIGIN, TIMING, AND RELATIONSHIPS OF PAENUNGULATA

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Paenungulata Simpson 1945 is a controversial supra-ordinal clade of ungulates. Current studies include extant orders Proboscidea, Sirenia and Hyracoidea and extinct Desmostylia, Embrithopoda, "Phenacolophidae" and "Anthracobunidae". It is best supported by molecular studies (e.g., Afrotheria) which state its Late Cretaceous (67-80 Ma) African origin. Morphological data are less explicit: 1) shared paenungulate features such as taxeopody can be interpreted as homoplastic and/or more inclusive, 2) several shared apomorphies of Hyracoidea and Perissodactyla are reported (eustachian sac, cursorial features). However, the debate may relate to considerable fossil gaps. New fossil discoveries such as African condylarth-like species in the Ypresian of Morocco and new material of anthracobunids might shed new light on the origin and relationships of proboscideans and hyracoideans. Tethytheria McKenna 1975 which includes extant Proboscidea and Sirenia is still the best-supported higher clade among paenungulates.

Hyracoideans examplify a native and endemic African adaptive radiation of primitive ungulates. Though diversified, Paleogene hyraxes are poorly known. *Seggeurius* from the early Eocene of North Africa is the oldest and most primitive hyrax. Its teeth display singular features (e.g., no conules) with respect to early perissodactyls.

Proboscideans are recorded since the Ypresian of Morocco with *Phosphatherium*. This taxon supports an African origin of the order and more distant relationships of the Asian "Anthracobunidae".

The earliest sirenians are the middle Eocene "Prorastomidae" *Prorastomus* and *Pezosiren* from Jamaica.The latter, known by the skeleton, has four well developed legs which show the transition between terrestrial and aquatic life. It suggests a digitigrade terrestrial paenungulate or "condylarth" ancestor with long tail and thorax. Early sirenians have a pan-Tethyan distribution—their paleobiogeographic origin is uncertain (eastern Tethyan shores ?).

Desmostylia appeared in the Oligocene (North Pacific), presumably from Asian origins.

DINOSAUR TRACKS IN THE LATE JURASSIC OF POLAND

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Hitherto Polish dinosaur tracks has been well recognized from the Early Jurassic of the Holy Cross Mountains region. Recently, however, in 2001 and 2002, dinosaur tracks have been found in the Upper Jurassic strata of this region, in Ozarów, Baltów and Blaziny sites. The footprints occur in platform carbonates. The specimen from Ozarów resembles ornithopod footprint of *Dinehichnus*. Tracks discovered in Baltów include a small theropod footprint similar to *Jialingpus* and a large blunt-toed ornithischian footprint supposed of stegosaurian origin. A large *Megalosauripus* theropod print and the *Brontopodus* sauropod ichnites were found in Blaziny. The presence of such relatively rich dinosaur ichnofauna in the marine coastal deposits of Poland and in many similar deposits over the world may be related to dinosaur physiology. The sauropsid uricotelic metabolism is much better suited to cope with lack of fresh water than the mammalian physiology. Thus, nearshore, saline environments would be more inviting habitats for dinosaur than they are for their terrestrial heirs, the mammals. Moreover, the occurrence of large theropod, ornithischian and sauropod trackmakers in the Late Jurassic of Poland speaks in favor of the connection of the emerged area with larger land masses.

NEW ORNITHOPOD WITH HADROSAUR-LIKE FEATURES FROM THE LOWER CRETACEOUS OF UTAH

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Traditionally, the origin and early history of hadrosaurs was believed to have been in Asia based on the appearance of derived iguanodontids in the late Early Cretaceous and on the appearance of primitive hadrosaurs in the early Late Cretaceous. Recent discoveries in North America indicate similar advanced iguanodontids, (*Eolambia*) and primitive hadrosaurs, (*Protohadros*), during this same interval, thus challenging this traditional view. The discovery of a new ornithopod with a ilium having some hadrosaur-like features in the Yellow Cat Member (Barremian) of the Cedar Mountain Formation, adds to the hadrosaur origin debate. The ilium has a deep body, a poorly developed ischial peduncle, an elongated and tapering

postacetabular process, and most importantly, a well defined, overhanging antitrochanter on the dorso-lateral border of the ilium above the postacetabular "notch"; this antitrochanter is better developed than in *Bactrosaurus*. However, the ilium also has a preacetabular process that is only slightly deflected ventrally, and well developed pubic peduncle. Other material includes a sacrum of only six vertebrae, a right tibia, metatarsal II, and several ribs. This specimen increases the ornithopod diversity for the Cedar Mountain Formation and indicates the presence of a taxon at the iguanodontid-hadrosaurid split that is significantly older than previous finds.

ORIGIN AND RELATIONSHIPS OF CETACEA: EVIDENCE FROM THE FOSSIL RECORD

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The oldest archaeocete or archaic whale, *Himalayacetus subathuensis*, is a pakicetid of early Eocene age (Ypresian, ca. 53 Ma) that comes from a shallow-marine facies of the middle Subathu Formation in northern India. Formations yielding early middle Eocene (Lutetian) archaeocetes include the fluvial upper Subathu Formation in Kashmir; the fluvial Kuldana, marine shelf Habib Rahi, and shallower marine Kohat and Domanda formations in Pakistan; the marine shelf Mokattam Formation in Egypt; and the shallow marine Kpogamé phosphates in Togo. Most of these are protocetids. Modern Cetacea differ from most other mammals in being fully aquatic, and the order is in some sense defined by its loss of terrestrial characteristics and acquisition of aquatic characteristics. Such loss and acquisition took place simultaneously in mosaic fashion. A multivariate morphometric study of trunk and limb proportions shows the early protocetid *Rodhocetus balochistanensis* to have been an advanced pinniped-like semiaquatic mammal. Early protocetids preserve characteristically artiodactyl astragalus, calcaneum, and cuboid bones of the ankle in direct association with archaeocete skulls and axial skeletons, corroborating the close biochemical relationship of Cetacea and Artiodactyla known for the past half-century. The fossil evidence goes farther in showing: (1) Cetacea were derived directly from Artiodactyla without an intermediate mesonychid stage; (2) the artiodactyl ancestor was generalized and possibly anthracothere-like; and (3) the time of origin of archaeocetes and hence Cetacea is bracketed between the ca. 53 Ma appearance of *Himalayacetus* and the ca. 55 Ma time of origin of Artiodactyla. This is evidently the interval when whales first became (semi)aquatic, which has happened independently in at least eight mammalian orders. The shallow sea is a relatively homogenous environment, and when whales became marine they evidently dispersed rapidly around the margins of Tethys and into the Atlantic.

DIGGING BEHAVIOR AND ECOLOGY OF MIOCENE MYLAGAULIDS (MAMMALIA: RODENTIA) FROM BURROWS IN THE PAWNEE CREEK FORMATION, NORTHEASTERN COLORADO

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Trace fossils represent the petrified behavior of an organisim, providing clues to locomotion, feeding, nesting, and other life activities. Burrow analysis is a new approach to research on mylagaulid rodents, which were highly adapted for life underground. Abundant calcified tunnels of hornless mylagaulid *Mylagaulus laevis* occur in fine silts/sands of the late Barstovian (ca. 13 Ma) Pawnee Creek Formation in Logan County, Colorado. The tunnels average 7.0 x 11.0 cm in diameter, and may be over 17 m long. They are invariably sinuous and lack directionality, unlike the "devil's corkscrew" burrows of colonial Miocene beavers. *M. laevis* tunnel systems resemble those of solitary, root-eating modern pocket gophers (*Geomys bursarius*) and mole-rats (*Myospalax myospalax*), suggesting that mylagaulids shared this lifestyle. *M. laevis* is a good candidate for the excavator of these tunnels, due to its abundance at the site and the long, recurved claws on its manus. Other candidates include gopher tortoises (*Gopherus*), but modern tortoises dig very shallow, wide chambers, unlike the tunnels at the site.

SEM scans of mylagaulid premolars show rows of pits, possibly from sand grains in a diet of soil-covered roots. Structures resembling scarabid beetle (Coleoptera: Scarabaidae) balls occur at the end of one tunnel, which may have been a latrine. Phytoliths from these balls may show specific plants in the diet, and reveal more about mylagaulid habits. Large amounts of grass phytoliths might indicate foraging above ground, whereas scarcity of phytoliths could reflect a diet of phytolith-poor roots, or non-plant foods.

M. laevis tunnels are cross-hatched with claw marks on the sides and floor, indicating that this mylagaulid dug with its forefeet. Tunnel ceilings show pushed-in areas, which may have been made by the head. *M. laevis* nasals show rugose, vascularized bone, which may have been an attachment for a keratin "nasal shield," as in modern head-lift diggers (mole-rat *Spalax*, long-clawed mouse *Geoxus*).

STABLE ISOTOPES AND DINOSAUR ENDOTHERMY: EFFECTS OF THE BURIAL ENVIRONMENT ON HADROSAUR BIOGEOCHEMISTRY

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Reconstruction of dinosaur thermophysiology requires the preservation of isotopically unaltered biogenic phosphate. Phosphates are compositionally complex, and diagenesis in the burial environment may overprint an *in vivo* paleobiological signal. Testable support for the preservation of original isotopic composition is required before $\delta^{18}O$ phosphate oxygen qualifies as direct evidence for dinosaur endothermy.

I attempt to distinguish a paleobiological from a diagenetic signal by analyzing $\delta^{18}O$ and $\delta^{13}C$ of a hadrosaur skeleton, *Brachylophosaurus*, from the Late Cretaceous nonmarine Judith River Fm. (Montana) and co-occurring mosasaur, plesiosaur, and hadrosaur skeletons from the Late Cretaceous marine Bearpaw Fm. (Montana, Alberta) and Moreno Fm. (California). Hadrosaurs found in marine sediments exploited food and water resources significantly different than the marine carnivores they are buried with. Unaltered isotope values should reflect this distinct trophic status and ecology. If the burial environment is not a significant diagenetic factor, $\delta^{18}O$ and $\delta^{13}C$ values from hadrosaurs found in marine and nonmarine sediments should be similar. Conversely, alteration of *in vivo* isotope composition is indicated by statistically different isotope values, absence of a linear correlation between $\delta^{18}O$ cogenetic phosphate and structural carbonate, and failure to yield the same temperature in their relevant isotopic temperature equations. Degree of covariance between $\delta^{18}O$ diagenetic calcite and structural bone carbonate may confirm isotopic alteration of these components, but a corresponding weak covariance with $\delta^{18}O$ bone phosphate is not proof of *in vivo* $\delta^{18}O$ phosphate values because bone carbonate may be susceptible to re-equilibration by succeeding diagenetic events.

I have confirmed that original oxygen isotope values in hadrosaur bone phosphate from the Judith River, Bearpaw, and Moreno Fms. are overprinted. $\delta^{18}O$ values from these dinosaurs reflect burial conditions, not relative body temperature when bone phosphate was precipitated in life. The use of $\delta^{18}O$ values as direct evidence for endothermy in hadrosaurs from these sites is not supported.

PALEOECOLOGY OF CRETACEOUS MAMMALS. I. ESTIMATING BODY SIZE IN CRETACEOUS THERIANS.

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Mesozoic mammals have long been considered ecological generalists, not radiating into various ecological niches until the extinction of the dinosaurs at the end of the Cretaceous. A critical parameter for interpreting mammalian paleoecology is body mass. This study is aimed at estimating body mass for tribosphenic mammals from the Cretaceous. The basis for these estimates involves re-examining predictive equations for body size in some groups of primitive, recent mammals, and generating new predictive equations for others. Body weight data, as well as various cranial and dental measurements, were collected from 45 genera, representing 12 families of Insectivora, Marsupialia and Primates. Least squares regression analyses performed on log transformed data suggest that more refined predictive equations can be obtained, at least at the family level. As predicted, the R^2 values for regression of body mass on various cranial and dental parameters are, in general, higher for individual families than for those of higher taxa. Results indicate that the best predictors of body size not only vary between families, but in some cases, by sex as well, with R^2 values for males and females differing considerably more within families than within higher taxa. Because of the variable nature of these predictive equations, caution must be employed when determining which equation to use in predicting body size in modern or extinct mammals.

A NEW PRIMITIVE DOLPHIN (ODONTOCETI, SQUALODELPHIDAE?) FROM THE BAJA CALIFORNIA SUR LATE OLIGOCENE (EL CIEN FORMATION, SAN JUAN MEMBER), MÉXICO.

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The El Cien Formation of the mid-bay of La Paz at the San Juan de la Costa phosphate mine consists of marine sediments which are late Oligocene in age. The San Juan Member has been known to preserve one interesting cetaceans assemblage. Of the recognized odontocete species from the San Juan Member at San Juan de la Costa outcrops, 2 are from Agorophiidae (one partially described) and one of an undeterminated family, new genus and new species not described yet.

A partial primitive dolphin mandible newly discovered (MHN-UABCS/SJ26/35-3126) from the El Cien Formation (San Juan Member) can not be assigned to any known odontocete species from the San Juan de la Costa fossils collection. This specimen preserves only the left ramus, with at least two teeth in situ. It is 30 cm long, but the sinfisis is not preserved, from the top of the coronoid process to the base of the mandible is 9 cm tall, but decrease in the dentary to 2 cm high, low mandible, relatively thin, almost equal and horizontal in the upper part only in the area of the coronoid process it increases up to 2 cm tall. Behind the last tooth the jaw is sharply compressed, the upper edge elevates and the lower descends rather uniformly.

The teeth could be P3 or P4, they are near homodont teeth, highly triangular, symetrical crowns, compressed laterally, recurved, enamel of lingual surface covered with longitudinal wrinkles. Cutting edge slightly attenuate and without accessory cusps. Root long with a deep median groove throughout its length, bifurcation of root incomplete.

The closest affinity is with *Sulakocetus dagestanicus* Mchedlize 1976, from the late Oligocene of northwest Caspian margin, but this one is bigger, with a 55 cm long jaw. This species probably belongs to Squalodelphidae, formerly referred to the Squalodontidae.

DENTAL MICROWEAR AND BONE HISTOLOGY ANALYSIS OF MID-LATE TRIASSIC AMNIOTES FROM MADAGASCAR: IMPLICATIONS FOR INFERRING DIET AND GROWTH

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Dental microwear studies have proven useful in assessing diet in extant and fossil taxa, particularly in Cenozoic mammals. We have applied these techniques to a Mid-Late Triassic assemblage of traversodontid cynodonts from Madagascar, to determine if systematic differences in microwear patterns indicate dietary diversity not obvious from morphology alone. Dental microwear from several specimens of *Dadadon*, *Menadon*, and an unnamed traver-

sodontid were examined by SEM at 300x magnification and tested for differences in feature density, scratch length and orientation heterogeneity. Pitting is rare to nonexistent in all studied specimens. Both scratch length and orientation heterogeneity, which relate to differences in the material properties of food, differ substantially between taxa. Most microwear on the specimens has been obliterated by postmortem weathering, so scratch density is not considered. While microwear features are not directly attributable to specific diets, they do suggest more ecological complexity among the taxa than would gross morphology alone. In addition, microscopic wear features and orientation reflect patterns of jaw movement. Complementary studies of the masticatory biomechanics in the traversodontids are in progress.

Microstructural analyses of bone histology can elucidate patterns of growth. Preliminary histological analyses of limb elements tentatively referred to the prosauropod taxa recognized previously from the same quarry (from craniodental material) show considerable variability in growth patterns. While some specimens (especially ulnae) display fibrolamellar structure, related to fast growth, as observed in other prosauropods, others display lamellar structure with varying degrees of vascularization and stratification of the cortex. Analyses of additional prosauropod limb elements, as well as those of cynodonts and rhynchosaurs from this fauna, are in progress.

COELACANTH AND AMIID FISHES PRESENT IN THE LATE CRETACEOUS OF MADAGASCAR

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Field work over the last decade in the Mahajanga Basin of northwestern Madagascar has led to a dramatically expanded faunal list of Late Cretcaeous vertebrates from the island, which have provided important new data relevant to Gondwanan paleobiogeography. The majority of these discoveries have come from the Campanian-Maastrichtian Maevarano Formation, but another, less well-explored unit, the Ankazomihaboka sandstone, previously known for ceratodontid lungfish remains, has provided some intriguing recent additions to the Late Cretaceous Madagascan fauna. A Coniacian age has been suggested for the Ankazomihaboka, based on purported intercalations with dated basalts.

Among the interesting new records from the Ankazomihaboka are isloated bones assignable to two noteworthy fish clades: Actinistia (coelacanths), and Halecomorphi (amiids and related forms). Amiids are best-represented in the Ankazomihaboka by a distinctive vertebral centrum that is morphologically very similar to the vidalamiine amiid *Melvius*, which is known from a variety of Upper Cretaceous deposits in North America. The Ankazomihaboka material is the first record, fossil or Recent, of an amiid from Madagascar.

The coelacanth material is the first post-Triassic evidence of the group on Madagascar, and may well represent the youngest Gondwanan fossil coelacanth occurrence. The most distinctive specimen is a median extrascapular—-this element is diagnostic for *Axelrodichthys*, a genus previously known from the Aptian/Albian of Brazil, and the Aptian of Niger. Other pieces of dermal bone (lower jaw?) from the Ankazomihaboka have an ornamentation closely resembling that of *Axelrodichthys*, and/or *Mawsonia* which is also known from the Cretaceous of both Brazil and Africa. Both of these are relatively derived coelacanths, phylogenetically close to the extant genus *Latimeria*, which today survives in the southwestern Indian Ocean around Madagascar, as well as in Indonesian waters.

PLACODERM ANATOMY AND PHYLOGENY, NEW INSIGHTS

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Placoderm fishes are now considered as the sister-group of all other gnathostomata (Chondrichthyes + Osteichthyes). Their phylogeny has been investigated and a cladogram of all the major groups has been proposed. Given their basal position in the gnathostome phylogenetic scheme, a number of supposed diagnostic characters had to be reevaluated.

Some of these characters were unique to the placoderms as a whole, for example, the presence of an optic fissure. In view of the new scheme, this feature which could initially be interpreted as an apomorphy has been reevaluated as a "primitive" gnathostome feature. A similar suggestion has been proposed to interpret the monobasal articulation of the pectoral fin present in early representatives of every placoderm groups.

Taking into account a series of endocranial features and new observations on the anatomy of the body armour of basal placoderms, a reevaluation of some "classic" characters has been performed and a revised scheme of character distribution on the cladogramme is proposed.

GIGANTISM, DWARFISM, AND COPE'S RULE: "NOTHING IN EVOLUTION MAKES SENSE WITHOUT A PHYLOGENY"

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Body size is of fundamental importance in understanding macroevolutionary patterns. Herein, we describe four different kinds of body size evolution, i.e., autapomorphic giantism, autapomorphic nanism, phyletic giantism, and phyletic nanism. The terms *giantism* and *nanism* are preferred rather than the frequently used equivalents, gigantism and dwarfism, respectively. We assert that without a known phylogeny, it is difficult to differentiate these four different modes of body size evolution. Case examples are presented for two groups, i.e., varanid lizards (Family Varanidae) and horses (Family Equidae).

Previous hypotheses of body size evolution within the Varanidae suggest that there were several cladogentic events in which some taxa became large. Mapping known lengths onto a recent phylogeny based on mtDNA indicates that varanids were large early on in their evolutionary history, with the crown group, *Odatria*, becoming secondarily small, on the mainland. Although hypothesized as an island giant island, Komodo Dragon is nested in a clade in which the basal-most taxon reaches body lengths similar to *V. komodoensis* and which lives on mainland Australia, not a small island as predicted by the model.

Fossil horses (Family Equidae) are frequently cited in the literature and portrayed as prime examples of "Cope's rule," i.e., a gradual trend towards body size increase. Recently posited phylogenies of fossil horses from North America have clarified the interrelationships within problematic groups and challenge the belief that fossil horses demonstrate Cope's rule, and suggest that large size was attained independently within multiple groups in horse evolution.

For the two case examples presented herein, we found that island gigantism is difficult to define, and Cope's rule is not as clear-cut as the literature would suggest. The results of our analysis calls into question the most frequently cited modes of body size evolution and recommends that phylogenies be carefully considered before making statements about patterns in body size evolution.

NEW SPECIMENS OF *MAWSONIA* (ACTINISTIA: COELACANTHIFORMES) FROM THE CENOMANIAN (LATE CRETACEOUS) OF BAHARIYA OASIS, WESTERN DESERT, EGYPT

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Two new specimens of the giant coelacanth *Mawsonia* were recovered from the Bahariya Formation during the 2000 field season by members of the Bahariya Dinosaur Project expedition. One of the two specimens is very well preserved, and consists of 11 associated bones, mainly from the caudal part of the skull. Elements from both sides of the head are represented. Three large scales were recovered from the same site, and probably belong to the same individual. The bones were found in close association, but except for the fused right pterygoid and metapterygoid and the articulated right postorbital and squamosal the bones were not in articulation. The remaining bones were slightly scattered. None of the bones show wear from postmortem transport. Several of the bones, including the pterygoid / metapterygoid complex, opercular, quadrate, parietal, and parasphenoid, duplicate elements which were present in the type material of *Mawsonia libyca* destroyed by allied bombing during World War II.

The second specimen comes from a different locality and is poorly preserved. It includes the angular, another of the bones described in the type material of *M. libyca*. Other portions of the skull are closely associated with the angular, but the skull is badly crushed. This specimen is badly weathered and permineralized with gypsum.

PALEONTOLOGICAL MUSEUM EXIBITS: HOW EFFECTIVELY ARE PRINCIPLES OF EVOLUTION COMMUNICATED TO THE PUBLIC?

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Museums continue to draw large numbers of individuals who attend primarily for social-recreational, educational, and reverential reasons. The educational benefits museum exhibits provide children is the number one reason families visit museums. Dinosaurs and prehistoric beasts fascinate children and adults of all ages. Paleontological exhibits are often the most visited, and therefore permanent, facets of a museum's displays. Unfortunately, the enormous potential to educate visitors about evolutionary concepts and conservation is often unrealized. Updating and redesigning museum exhibits can occur at small and large scales. In many cases simple cost effective changes yield significant educational benefits. Display changes must be assessed though public surveys and interviews in order to ascertain the effectiveness in communicating desired concepts and themes.

Case studies of museum exhibits examine how effectively principles of evolution are communicated to the public through paleontological exhibitry. Public surveys and comprehensive critiques reveal exhibit features to be replicated and those requiring improvement. Small and large scale changes yield improvements of communication effectiveness and therefore educational capacity. Through the expanded use of complementary educational brochures and exhibit guides the ability to educate evolutionary principles to the public may significantly improve. Assessing the effectiveness of communicating principles of evolution to children and adults is necessary if exhibits are to improve their educational potential.

A MODEL THAT USES FOUR POINTS TO REPRESENT THE JAW MECHANISM

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Three obvious landmarks on a generalized mammalian skull are the glenoid of the jaw joint, the posterior edge of the third molar, and the anterior end of the upper jaw. These three features, represented as points G, M, and A respectively, are used to construct a fourth point (T) located in the temporal fossa. Point T, in this model, represents the average site of jaw muscle attachment. Assuming that the skull will be constructed with a minimum amount of bone tissue suggests that functionally important distances will be as short as possible. Therefore, point T is found by minimizing two compound distances (MGT and GAT) by setting MG = GT and GA = AT. The straight line connecting M and T defines the line of action, but not the length of the vector, of the resultant muscle force. Two constraints limit the number of ways these 4 points can be arranged in a lateral view. First, to maximize the average bite force, the distances from the action line to G and to A are in the ratio of 3:7, respectively. Second, the angle between the action line, and a line along the tooth row, is greater than 90 degrees so as to limit the model to posteriorly inclined muscle vectors. A graphical analysis based on this model predicts that the inclination of the resultant vector of jaw muscle force varies by approximately 5 degrees to either side of a line that forms an angle of 42 degrees with the line from G to M (angle GMT).

Angle GMA is easily measured on any skull and can be as large as about 178 degrees, but not much larger, because the glenoid in mammals is rarely below the level of the tooth row. The minimum value of angle GMA depends upon the minimum value of angle GMT. Angle GMT can be no smaller than about 37 degrees when the vector is almost perpendicular to the tooth row. Thus, angle GMA can be no smaller than about 128 degrees (37 + ~91 = 128). The actual range of angle GMA in a sample of over 100 primate and suid skulls, representing 44 species, agrees with this prediction of the model, suggesting that the inclinations of posterior vectors have also been correctly predicted.

TOOTH SIZE AND PALEODIET IN PLIO-PLEISTOCENE *MAMMUT AMERICANUM* FROM FLORIDA

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The mastodon *Mammut americanum* is one of the few mammalian species to persist in Florida from the late Pliocene to the end of the Pleistocene. It shows relative morphologic stasis during a period of frequent climatic and vegetational change. Although its fossils are relatively common, this is the first comprehensive quantitative analysis of *M. americanum* from Florida, with the goal of understanding its microevolution in tooth size and adaptability of feeding behavior. Up to four measurements (total tooth length and transverse width across first three lophs) were taken on over 160 molars and deciduous premolars of *M. americanum* from Florida. Specimens ranged in age from late Blancan to late Rancholabrean. Using length and width, mastodon cheekteeth can confidently be assigned to one of the six tooth positions, while morphology is used to distinguish upper from lower teeth. It was found that no significant difference exists in tooth length and width between specimens from Irvingtonian and Rancholabrean, confirming the morphologic stasis of the species in tooth size during the Pleistocene. Microwear scar topography on enamel from the second or middle loph was used to determine variation in paleodiet of *M. americanum* over this interval as well. A large sample from the Aucilla River allowed determination of individual and ontogenetic variation in diet within a population.

LATE EOCENE OTOLITH-BASED FISHES FROM THE MOODYS BRANCH FORMATION IN LOUISIANA AND MISSISSIPPI AND THEIR PALEOECOLOGICAL IMPLICATIONS

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Remains of bony fishes are generally found as isolated and disarticulated skeletal elements in the Tertiary marls, sands, and clays of the US Gulf Coast. This limits the recognition and identification of bony fish. Otoliths or earstones have provided a reliable means of interpreting Tertiary fish faunas of the region. Prior to this study, the otolith-based fishes from the upper Eocene Moodys Branch Formation were virtually unknown and undescribed although the formation and its stratigraphic equivalents outcrop in at least five southern states. Bulk sampling at two localities (northeast Louisiana and north-central Mississippi) yielded nearly 800 otoliths. 646 otoliths representing 22 species were identified from the Heison Landing Locality in northeast Louisiana. The Techeva Creek Locality of the Moodys Branch Formation in north-central Mississippi yielded a significantly smaller number of specimens (133) representing 14 species. The number of otoliths per kilogram of sample at the Heison Landing Locality was much greater (31.4 otoliths/kg) than at the Techeva Creek Locality (6.5 otoliths/kg).

The Moodys Branch Formation fish assemblages from the two localities are similar in many aspects. Sciaenids or drums are the most abundant otolith-based fish at both sites, while haemulids and congrids are also common. *Bregmaceros* is absent or extremely rare at the sites, and neither site has any myctophids or macrourids. Ophidiids or cuskeels comprise a much greater percentage of the assemblage at Heison Landing (22%) than at Techeva Creek (less than 3%). The otolith-based fish assemblage indicates a tropical to subtropical climate with shallow, normal marine waters. The fish are mainly inshore species (found in marine waters less than 200 m). Otolith-based paleobathymetry indicates that the water depths were less than 40 m, and most likely, inner shelf. The substrate was soft and muddy with marine grasses. The significantly larger number of species, the smaller number of sciaenids and haemulids, and the larger percentage of ophidiids may point to somewhat deeper waters with less current at the Heison Landing Locality.

DIVERSITY OF TESSELLATE HETEROSTRACANS FROM THE MOTH LOCALITY, NORTHWEST TERRITORIES, CANADA

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Heterostraci are early jawless vertebrates characterized by a single pair of branchial openings in the dermal exoskeletal shield. This skeleton is composed of large, articulating plates, or small scale-like units that cover the body. The tessellate heterostracans have scale-like, tuberculate armour which may fuse to form plate-like cephalothoracic shields. Hypotheses suggest that tessellate forms are among the most primitive members of the Heterostraci. Thus, they are vital in understanding the evolution of the higher heterostracans and the diversity and origin of early vertebrate life.

The fragmentary nature of most tessellate heterostracan fossils has complicated interpretation of both their morphology and relationships. Branchial openings of many species have not been observed and, therefore, several of these taxa cannot be placed confidently within the Heterostraci. The lack of well-preserved specimens and the difficulty in interpreting the few more complete specimens available has made it nearly impossible to define the relationships of these vertebrates.

The vertebrates found at the MOTH locality, however, are exceptionally preserved. MOTH is located in the Mackenzie Mountains, NWT, Canada. There are over 69 species of vertebrates, at least 20 of these being heterostracans. The most common tessellate form found at the site is *Lepidaspis serrata*.

At least eight other tessellate heterostracan species are present in the MOTH fauna. Three of these are similar to *Lepidaspis serrata*; three are similar to traquairaspidids. Also, there are fragmentary specimens with scales that are similar to those of *Aserotaspis* or *Aporemaspis*.

The description and the morphological and cladistic analysis of these tessellate heterostracans, will aid in our understanding of early vertebrates. This study will test whether the tessellate heterostracans are members of the Heterostraci, and whether they are basal and/or monophyletic within the taxon.

FOUR NEW EUCHONDROCEPHALAN CHONDRICHTHYANS FROM THE BEAR GULCH LIMESTONE (SERPUKHOVIAN, NAMURIAN E2B) OF MONTANA, AND THEIR IMPACT ON THE CLASS CHONDRICHTHYES

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Four chondrichthyan taxa from the Bear Gulch Limestone (Serpukhovian, Upper Chesterian, Namurian E2b) that have been previously referred to as Sup1, Sup2, Sup3, and Sup4 are now defined. These holomorphic euchondrocephalan species share similar dentitions, with teeth conforming to the same tooth species of the putative genus "*Desmiodus*" St. John and Worthen, 1875. *Desmiodus*, therefore, is a *nomen vanum*. They all also exhibit the autodiastylic mode of jaw suspension. Yet, there are notable differences in the details of the suspensorium among these taxa. These functionally related variations are believed to correlate with interspecific variation in orbital to otico-occipital design. Symphysial and postcranial features also differ notably among the species. These taxa have been incorporated into a cladistic analysis of the Chondrichthyes using 97 characters, 33 chondrichthyan species, and theoretical, coelacanth, and actinopterygian outgroups. The analysis provides new insight into the possible pathways of euchondrocephalan diversification. The combination of characters in these four taxa renders these fishes among the most basal members of the Euchondrocephali.

THE NEOPLASM ON THE SKULL ROOF OF AN EARLY TRIASSIC AMPHIBIAN

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The fragment of a skull roof of an amphibian *Parotosuchus* (Temnospondyli: Capitosauridae) from Early Triassic of the Kirov Province, Russia (243-245 Ma) was subjected to research. On a dorsal surface of a specimen (parietale + supratemporale) is present knotty neoplasm the size of 35 x 18 x 5 mm, resembling half of a turned saucer with a deepening at the center. This bony outgrowth was subjected to microscopic, X-ray and CT scanning. We found that the structures characteristic for a functional bone in neoplasm are absent, and the changes found are characteristic for a tumor of the skeletal origin. The neoplasm is represented by atypical bony beams, which very much resemble osteoid. The tumour is densely connected to a usual bone only in the central part of the outgrowth. On periphery of the unit there is a crack. The features of a neoplasm have to exclude this occurrence as result of fibrous dysplasia of a bone, regeneration on a place of a trauma and proliferation of bony fabrics due to defeat by the parasites.

Among the probable diagnoses are osteoma, osteosarcoma, juxtacortical chondrosarcoma, periosteal osteosarcoma and parosteal osteosarcoma. The first two diagnoses are excluded because of infiltrational growth of a tumour and alternation of sites of an afunctional bone and bone fabric of a correct structure with formation of osteons.

Differential diagnoses between last three diagnoses are extremely difficult. In the investigated material completely there are no cells and only mineral structures remain. However, if we assume that atypical structure of bony beams mentioned above represent mineral osteoid, in view of given X-ray, PC scanning data, macroscopic and microscopic picture, the diagnosis from the large share of probability is declined to the parosteal osteosarcoma. It is the earliest known occasion of the development of a malignant tumour at tetrapods.

GALLINULOIDES WYOMINGENSIS: REANALYSIS OF A FOSSIL GALLIFORM BIRD

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A host of work has been produced linking molecular and fossil evidence on the phylogenetic relationships of the avian oorder Galliformes in order to hypothesize a divergence time for the various galliform lineages. The majority of these studies posit *Gallinuloides wyomingensis* as a calibration point for their molecular clock hypotheses. However, the relationship of this fossil taxon to other members of the "landfowl" clade remains controversial, and *G. wyomingensis* has been defined by different authors as a basal galliform, a megapode, and a cracid. A review and cladistic analysis of the osteological features of an as of yet undescribed specimen of this fossil galliform lends new evidence of its phylogenetic affinities within the Order Galliformes and holds great implications for current molecular clock theories.

LATE HOLOCENE ABUNDANCE PATTERNS OF GREBES AND WATERFOWL FROM LAMAR CAVE, YELLOWSTONE NATIONAL PARK, WYOMING

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Although birds are well-studied behaviorally and occupy a wide range of niches, avian paleoecological studies of the Holocene are rare. This millennial timescale provides a critical test of biotic response to predictions made by global change scenarios. Thus far, undertaking an in situ study on organismal sensitivity to climatic changes has been a major challenge for scientists. Such a study requires both precise climatological records and well-defined species histories that can be clearly correlated with one another over time. Although records tracking climatic changes are available for several regions of the world, it has proved largely impossible to concomitantly track species histories in these same regions.

However, recent excavation work in a late-Holocene paleontological site (Lamar Cave)

situated in Yellowstone National Park (Wyoming), has uncovered a remarkably rich faunal assemblage that includes thousands of vertebrate remains (mammals, birds, reptiles, amphibians, and fish) divided over several Holocene time frames. We provide a first overview of the bird remains from Lamar Cave, with particular emphasis on tracking the abundance of podicipedids and anseriforms through the Medieval Warm Period and the Little Ice Age. Avian patterns are compared to those of mammals, which have been well described.

THE HISTORY OF VERTEBRATE PALEONTOLOGICAL FIELDWORK IN FOSSIL BASIN, WYOMING

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The intermountain basins of the west preserve a diverse fossil vertebrate fauna. Fossil Basin, located in the southwest corner of Wyoming, is a north-south trending basin near the town of Kemmerer. Within Fossil Basin three fossil-rich units are well-exposed including: the middle Paleocene Evanston Formation (Tiffanian), the early Eocene Wasatch Formation (Wasatchian), and the early Eocene Green River Formation (Wasatchian). A number of type specimens have been collected and described from these three units in Fossil Basin.

Fossil Basin vertebrate fossils have attracted scientific interest since the 1860s. Field collectors for E. D. Cope and O. C. Marsh were among some of the earliest to collect in Fossil Basin. Since these initial studies, many scientists have contributed to collections and understanding towards vertebrate paleontology of Fossil Basin including: C. L. Gazin, R. L. Craig, P. O. McGrew, D. C. Haddenham, L. Grande, G. F. Gunnell, and others.

The documented significance of the fossil resources in Fossil Basin lead congress to establish Fossil Butte National Monument in 1972. In recent years the Monument has had an increasing roll in facilitating research in Fossil Basin. Recently funded projects have documented newly discovered vertebrate fossil beds in the Green River Formation, plotted fossil occurrences in the Wasatch Formation and mapped the fossiliferous units throughout the basin.

FIRST FOSSIL MOLIDAE (ACTINOPTERYGII: TETRAODONTIFORMES) IN WESTERN NORTH AMERICA

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To date, no Molidae have been documented in the fossil record of the eastern North Pacific. We here announce the presence of molids in five middle to late Miocene marine formations of southern and central California. The northernmost occurrences are on the North American Plate in the middle Miocene Round Mountain Silt of Kern County. The record here consists of upper beaks and caudal ossicles. All other locations are on the Pacific Plate. The Monterey Formation of Santa Barbara County produced a partial vertebral column. The biostratigraphy of this site is the most constrained of the occurrences. The foraminifera indicate the Zone of *Siphogenerina branneri*, approximately 16 to 17 Ma. An operculum comes from an undetermined horizon within the Modelo Formation of Ventura County. The late Miocene La Vida Member of the Puente Formation of eastern Los Angeles County produced a cleithrum. The Topanga Formation (middle Miocene) of Orange County yielded an isolated beak. *Mola mola*, native to the California coastline today, only comes into California waters during periods of relatively warm surface waters. It is probably not coincidental that at least eleven of the thirteen known California molid fossils are from the middle Miocene, which was the climatic optimum for the Neogene. The preserved beaks do not appear to differ significantly from those of *Mola mola*. However, none of the caudal ossicles resemble those of that species. The osteology of *Mola ramsayi*, the other extant species, is not well understood.

FIRST OCCURENCE OF *PTYCHODUS MARTINI* (PTYCHODONTIDAE) FROM THE ROXTON MEMBER OF THE GOBER CHALK (MIDDLE CAMPANIAN) OF TEXAS

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An isolated tooth (SMP-SMU 69031) of the Late Cretaceous shark, *Ptychodus martini* (Williston 1900) (Ptychodontidae) is here reported from the Roxton Member of the Gober Chalk (Middle Campanian) from Fannin County Texas. Until recently, *P. martini* had only been reported in the lower one-third (late Coniacian) of the Smoky Hill Chalk Member of the Niobrara Formation in western Kansas. *P. martini* is a relatively rare and poorly known member of the family Ptychodontidae. SMP-SMU 69031 is a single lower median row tooth and represents the most recent occurrence of the species. The specimen was originally described as a new species, *P. connellyi* by Macleod and Slaughter in 1980. Based on comparisons with the type specimen of *P. martini* (KUVP 55277) and another Kansas specimen (FHSM 2121), *Ptychodus connellyi* is here considered to be a junior synonym of *P. martini*. SMP-SMU 69031 increases the stratigraphic range and temporal distribution of this rare species of *Ptychodus*.

EVIDENCE OF A NEW SPECIES OF *OMALODUS* (ELASMOBRANCHII: OMALODONTIDA) FROM THE MIDDLE DEVONIAN OF THE NORTHERN GONDWANA MARGIN IN MOROCCO

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Teeth of a new species of the elasmobranch *Omalodus* were recovered from the section El Atrous North in the southern part of the Tafilalt, Anti-Atlas, southern Morocco. The El Atrous Syncline is an extended Devonian-Carboniferous fold which ranges roughly in E-W direction from the NW of Taouz for approximately 15 km further to the west. Paleogeographically, the El Atrous area belongs to the southern Tafilalt Platform which was influenced by some terrigenous influx and by the discharge of reefal debris. *Omalodus*, known so far from North America, Poland, Siberia and Mauritania, is a typical representative of the Givetian, primarily found in the *varcus* conodont Zone. Sedimentological and biostratigraphical data suggest that El Atrous North represents a marine environment within the photic zone, between neritic/reefal and pelagic facies. This implies that *Omalodus* of El Atrous probably avoided open pelagic settings and lived preferably near reefal margins, as it is known for a wide range of recent sharks. Besides its diagnostic characteristics such as the labially extended base, the tiny Moroccan *Omalodus* teeth (height less or equal than 1 mm) could be diagnosed by several different characters. Cladistic analyses suggest a close relationship with Givetian *Portalodus, Aztecodus* and *Anareodus* from Antarctica.

NEW TELEOSTOME FISHES AND ACANTHODIAN SYSTEMATICS

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Two new fish species were collected from the Lower Devonian ichthyofauna of the Mackenzie Mountains, Northwest Territories, Canada. These two species are interesting in that they have thelodont-like, or shark-like monodontode scales, lack teeth, and have an unossified axial, visceral, and appendicular endoskeleton. In these respects, the new species match published hypotheses regarding the anatomy of primitive jawed fishes. However, these new taxa have combinations of median and paired fin spines which are nearly identical to those of acanthodian fishes, but lack any other features to suggest relationship within the Class Acanthodii.

Previously, John Maisey noted that prior analyses of acanthodian relationships were limited by a lack of reasonable outgroups. Here, the two new fish species are used as outgroups in a cladistic analysis of acanthodians.

Results show that climatiiform fishes, as previously classified, still are primitive relative to acanthodiform and ischnacanthiform taxa. However, in contrast to previously published analyses, we show that the order Climatiiformes is paraphyletic relative to the other two acanthodian orders. Also, *Lupopsyrus pygmaeus* is placed as the basal-most acanthodian species, *Brochoadmones milesi*, *Euthacanthus macnicoli*, and diplacanthids are relatively derived "climatiiform" fishes, the heavily armored condition in *Climatius reticulatus* and *Brachyacanthus scutiger* is a uniquely derived state and not primitive for all acanthodians, and *Cassidiceps vermiculatus* seems to be related to acanthodiforms, not climatiiforms as suggested in the original description. In addition, *Paucicanthus vanelsti* also seems to be related to acanthodiform fishes based only on striated fin-spine structure. This analysis has allowed us to identify potentially primitive characteristics that are retained in relatively derived fishes, and unfortunately, these plesiomorphic characteristics commonly were used in past classification schemes to diagnose acanthodian higher taxa.

VERTEBRATE FOSSILS, INCLUDING NON-AVIAN DINOSAUR REMAINS AND THE FIRST SHARK-BITTEN BIRD BONE, FROM A LATE CRETACEOUS (TURONIAN) MARINE DEPOSIT OF NORTHEASTERN SOUTH DAKOTA

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Rose Quarry in Grant County, South Dakota, is an inactive Precambrian granite quarry with a massive spoil bank consisting of overlying Upper Cretaceous marine rocks rich in vertebrate remains. Previously reported vertebrate taxa include a chelonian (*Desmatochelys lowii*), a plesiosaur (cf. *Brachauchenius* sp.), various teleosts (*Gillicus arcuatus*, *Ichthyodectes ctenodon*, and *Pachyrhizodus minimus*), and various elasmobranchs (*Ptychodus whipplei*, *Cretodus crassidens*, *Cretolamna appendiculata*, *Cretoxyrhina mantelli*, *Leptostyrax compressidens*, *Scapanorhynchus raphiodon*, *Squalicorax falcatus*, *Ptychotrygon triangularis*, and *Pseudohypolophus mcnultyi*). The faunal composition suggests that the deposit is Middle-Late Turonian in age.

The Science Museum of Minnesota has recently recovered additional vertebrate remains from the site, several of which belong to taxa new to the fauna and include specimens that are paleogeographically and paleoecologically significant. Additional vertebrate taxa include *Ptychodus anonymus*, *Cretomanta canadensis* (Elasmobranchii), *Enchodus* sp. (Teloestei), and at least one species of mosasaurs, non-avian dinosaurs, and birds. The occurrence of non-avian dinosaur remains (e.g., tooth of *Dromaeosaurus* sp.) suggests the deposition at a nearshore environment. The surface of one of the bird bones (possibly the distal 1/3 of a tibiotarsus of a hesperornithiform) has multiple tooth marks (with clear serration grooves) of the Late Cretaceous shark, *Squalicorax* sp. Although it is uncertain whether *Squalicorax* attacked or scavenged the bird, this specimen constitutes the first shark-bitten bird bone in the fossil record and supports the view that *Squalicorax* was a trophic generalist that fed on a variety of animals. Continued collecting efforts at Rose Quarry are expected to help deciphering the Middle-Late Turonian marine paleoecology of this location.

THE EFFECTS OF AIR ABRASION ON VERTEBRATE FOSSILS

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Despite the widespread use of air abrasion for preparing fossils, the potential for damaging specimens using this technique has not previously been investigated. In our study we (1) examined whether air abrasion damaged fossil bone under normal working conditions and (2) evaluated how some of the key factors of the air abrasive technique might contribute to this damage. To reduce variation among samples, we used uniform-sized pieces of bone cut from two ribs of *Pachyrhinosaurus canadensis* from the same quarry. In part one experienced preparators working under normal conditions removed matrix from one sample using a soft brush and distilled water (this was our control sample), from a second sample using a fine needle, and from a third sample using air abrasion. Scanning electron micrographs showed that the needle left shallow, discrete grooves in the bone surface, whereas air abrasion scoured larger areas. In part 2 we air abraded 54 clean bone samples, each with a unique combination

of abrasive powder (sodium bicarbonate, aluminum oxide, or glass beads), working distance (2, 4, or 6 cm), angle of attack (30°, 60°, or 90°), and air pressure (45 or 90 psi). Each sample was air abraded for 5 seconds, using a 0.046-inch nozzle and at the same rate of flow. Scanning electron micrographs revealed differential damage to the fossil bone, ranging from none to severe. In cases of more extreme damage, within only five seconds we produced holes that mimic foramina and pits that resemble the effects of acid etching. Major observations are: (1) sodium bicarbonate is the least destructive of the three abrasives; (2) severity of damage decreases as either the working distance increases, angle of attack increases, or air pressure decreases; and (3) working distance and angle of attack influence the shape and area of the abraded region. While air abrasion is clearly useful for preparing vertebrate fossils, our investigations demonstrate that care must be taken when using this approach.

NEW EVIDENCE FOR DIAPHRAGM BREATHING IN THEROPOD DINOSAURS

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Theropod dinosaurs possessed a number of skeletal and visceral specializations similar to those that facilitate hepatic-piston diaphragm breathing in extant crocodilians. Accordingly, it has previously been hypothesized that theropods themselves were likely to have utilized a crocodile-like, rather than bird-like (i.e., air-sac), pattern of lung ventilation. Recently though, some authors have suggested that the fixed pubis of theropods was unsuitable for hepatic-piston breathing. Rather, they assert that a backwardly mobile, crocodile-like pubis is necessary to reduce intra-abdominal pressure generated during contraction of diaphragmatic muscles in hepatic-piston breathers. However, we present new experimental data that demonstrate that during hepatic-piston breathing in *Alligator*, pubic mobility has no effect on intra-abdominal pressure. These new data also suggest that pubic mobility in crocodilians is far likelier to be an apomorphic attribute associated with the need to supplement lung tidal volume in aquatic crocodilians, all of which are flattened dorso-ventrally. In this context, it is particularly significant that in early, more terrestrial crocodilians (i.e., *Terrestrisuchus*), the pubis was fixed and the body was compressed laterally. Our data also imply that marked opisthopuby in dromaeosaurid theropods was an apomorphic attribute that probably also functioned to supplement lung tidal volume in these forms.

PALEOENVIRONMENTAL AND SEQUENCE STRATIGRAPHIC IMPLICATIONS OF VERTEBRATE TRACES, TRACKWAYS, AND TRAMPLED ZONES TO DELINEATE DISCONTINUITY SURFACES IN CONTINENTAL ENVIRONMENTS

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Ichnofossils play an important role in identifying discontinuity surfaces of varying spatial and temporal scale within alluvial, lacustrine, palustrine, and eolian settings. Such surfaces can be used to develop new approaches in continental sequence stratigraphy, reflecting the complexity of paleoenvironments and the magnitude and frequency of depositional events. Vertebrate traces, trackways, and trampled zones may indicate discontinuity surfaces that reflect degrees of local surface water-logging. In general, many of the discontinuity surfaces dominated by vertebrate bioturbation are restricted to a few closely related paleoenvironments; however, vertebrates can cross environmental boundaries (water table, soil moisture, salinity, Eh/pH) that restrict plant and invertebrate trace-making organisms.

Actualistic studies in extant environments are an appropriate way to assess the relation between discontinuity surfaces and trace-making vertebrates. Several models come from observations of small-to-large herds of cattle in Colorado, Kansas, Nebraska, and Wyoming. The distribution, preservation, and condition of traces, trackways, and trampled zones vary with depositional and climatic setting. The extent and duration of these discontinuity surfaces are analogous to the marine sequence stratigraphic equivalents of bed and bed-set surfaces, flooding surfaces, parasequence boundaries, and sequence boundaries. This comparison allows for a better understanding of how vertebrate-trodden and inhabited surfaces might fit within a continental sequence stratigraphic framework.

Mesozoic and Cenozoic continental deposits afford the best opportunity to examine the spatial and temporal scale of discontinuity surfaces formed by vertebrates. Examples of traces, trackways, and trampled zones are from the Upper Triassic Chinle Formation (UT), the Middle Jurassic Sundance Formation (WY), Upper Jurassic Morrison Formation, the Dakota Formation (UT), and the Oligocene Brule Formation, White River Group (NE). They are used to identify discontinuity surfaces of varying spatial and temporal scale and are placed in a hierarchy of stratigraphically significant surfaces.

PHYLOGENETIC SIGNIFICANCE OF VERTEBRAL MORPHOLOGY IN SNAKES: IMPLICATIONS FOR INTERPRETING THE FOSSIL RECORD

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The fossil record of snakes consists almost exclusively of vertebrae, which have been previously considered to be phylogenetically ambiguous. To test the systematic utility of vertebral morphology in snakes, phylogenetic analysis was performed on a data matrix consisting of 40 characters for 16 higher order snake clades, using amphisbaenids and mosasauroids as outgroups. Results are generally consistent with clade topologies derived from more extensive datasets. Alethinophidia, Macrostomata, and Colubroidea are well supported, as are the more exclusive clades Pythoninae, Erycinae, Natricinae, and Colubrinae. Conversely, vertebral morphology cannot resolve interrelationships within Colubroidea. Boinae and Elapidae, as well as the majority of described fossil alethinophidian genera and species, cannot be diagnosed by discrete vertebral characters. Inclusion of the controversial fossil taxa *Pachyrhachis*, *Haasiophis*, and *Podophis*, results in placement of all within Alethinophidia, even when additional characters including pachyostosis and external hindlimbs are included in analysis only using mosasauroids as an outgroup.

THE BIOSTRATIGRAPHY OF ON YOUR KNEES CAVE, NORTHERN PRINCE OF WALES ISLAND, SOUTHEAST ALASKA

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Five years of excavation at On Your Knees Cave resulted in the recovery of over 5,700 sediment samples (most 30 x 30 x 5 cm) and 35,000 cataloged fossils. Fifteen m of the Seal Passage crawlway were excavated to a maximum depth of 2.4 m. Twelve m of the Bear Passage, including two rooms, were excavated to a maximum depth of 1.2 m to a flat bedrock floor.

Over 18,000 rodent remains have been cataloged, and they comprise four stratigraphic climate zones in the Seal Passage based on dominant species: 1) Early Interstadial cool zone of *Microtus* and *Phenacomys*, 2) Interstadial warm zone of *Microtus* and *Marmota*, 3) Late Interstadial and Last Glacial Maximum (LGM) cold zone of *Lemmus* and *Phenacomys* that ended in the extirpation of all rodents on Prince of Wales Island, and 4) Postglacial warm zone of *Microtus* (the only extant microtine genus on the island). Only zones 2 and 3 are well developed in the Bear Passage, and only the first room of this passage has abundant rodent remains on which to base the zones.

Phoca hispida is a climatic indicator of land-fast sea ice during the LGM, and 26 dated remains range from 24,150 to 13,690 ^{14}C yr B.P. These occur in zones 3 and 4 (the latter apparently from reworking), mostly in the Seal Passage. Reworking seems to be a major problem with bones longer than 2 cm.

Lontra canadensis, Ursus americanus, U. arctos, and *Rangifer tarandus* remains are found in all or most rodent zones, and radiocarbon dates fall before and after (but not during) the LGM. The latter two species were extirpated from the island by early Holocene time. *Odocoileus hemionus* remains fall in zone 4 and all date to the Holocene. Only remains of *Alopex lagopus, Phoca vitulina, Eumatopias jubatus*, and birds date to before, during, and after the LGM.

The only rodent remains dated are six *Marmota caligata* samples ranging from 39,900 to 23,560 ^{14}C yr B.P. Because the larger dated bones are subject to reworking (particularly by denning foxes), they do not always correlate well with the rodent zones or even fall in order of superposition.

THE RISE OF THE RULING REPTILES WAS NO ACCIDENT: THE MICROVERTEBRATE RECORD OF THE UPPER TRIASSIC CHINLE GROUP, SOUTHWESTERN U.S.A.

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Most scenarios postulating opportunistic dinosaurian success by the end of the Triassic are oversimplified. Viewing the Late Triassic as an evolutionary experiment and controlling for time, paleogeography, paleoclimate, and facies reveals that diapsids succeed at all body sizes in niches that favor locomotory advances, adaptation to drying conditions, or both, regardless of real or perceived Triassic extinction events.

Microvertebrate assemblages in the Upper Triassic Chinle Group indicate that both dinosaurs and sphenodontian lepidosaurs were diverse at their first appearance and present, albeit rare, in most sedimentary environs. Dinosaur size and abundance increases gradually through the Chinle stratigraphically. Cynodonts, however, are relatively rare and restricted to 'wet,' non-terrestrial, facies.

Comparison of Triassic dinosaurian synapomorphies to a detailed global biochronology demonstrates that locomotory and/or size-related characters evolved rapidly during the Late Triassic. The majority of these synapomorphies are associated with the hind limb and/or acquisition of an upright posture. Once prosauropods and ornithischians acquired herbivory, cranio-dental characters in both groups evolved relatively slower than those associated with locomotion.

Recasting dinosaurian success in terms of overall diapsid success by the close of the Triassic reveals that dinosaurs succeeded because the overall selective gradient favored dry land locomotors. Apparently the dinosaurian tendency to favor mobility over armor, and the development of at least two independent herbivorous lineages, facilitated their success over contemporaneous crurotarsans (e.g., rauisuchians, sphenosuchians, and aetosaurs). Dinosaurs did not compete with mammals or protomammals, but early lepidosaurs may have, as both groups consisted of small-bodied insectivores and are often found in the same assemblages. During the Late Triassic, the lepidosaurs successfully diversify, whereas mammals are less abundant before the Early Jurassic. Consequently, the rise of the dinosaurs was no 'accident,' but instead a radiation into previously unoccupied ecospace during the Late Triassic.

LATE JURASSIC VERTEBRATES FROM TENDAGURU, TANZANIA

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Tendaguru in southeastern Tanzania is one of the most famous dinosaur localities in Africa. The Tendaguru Beds, Late Jurassic to Early Cretaceous in age, consist of a 140 m thick succession of three, fine-grained limnic to brackish dinosaur-bearing deposits, the Lower, Middle, and Upper Saurian Beds, intercalated between three marine units. The saurian beds have yielded a diverse Late Jurassic dinosaur assemblage, including sauropods (*Brachiosaurus, Barosaurus, Dicraeosaurus, Janenschia, Tendaguria*), theropods (*Elaphrosaurus, 'Ceratosaurus', 'Allosaurus', 'Megalosaurus'*), and ornithischians

(*Kentrosaurus, Dryosaurus*). In contrast to the dinosaurs, fishes (selachians, actinopterygians) and smaller land vertebrates (crocodylians, pterosaurs, and mammals) remain underrepresented. Intensive sampling of the dinosaur-bearing matrix housed in the Museum für Naturkunde, Berlin, produced new remains of actinopterygians (semionotids, teleosts), lissamphibians, crocodylians (*Bernissartia*), lizards (Paramacellodidae), pterosaurs (*Tendaguripterus*), and mammals (*Tendagurodon, Tendagurutherium, Staffia*).

In 2000, a German-Tanzanian expedition returned to Tendaguru with the aim of recovering further small vertebrates, establishing a detailed stratigraphic framework, and collecting detailed sedimentological data. New vertebrate material recovered includes both terrestrial and marine taxa, among them forms (such as a new ray) previously unknown from the Late Jurassic of Africa. Evaluation of all data available gives new insights into the composition and stratigraphic distribution of vertebrate assemblages in the Upper Jurassic of the Tendaguru region. Using this information in combination with sedimentological and floral data, it is possible to reconstruct the depositional environment of the Tendaguru Beds.

WIDE- AND NARROW-GAUGE SAUROPOD TRACKWAYS AS A CONSEQUENCE OF BODY MASS DISTRIBUTION AND THE REQUIREMENTS FOR STABILITY

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Fossil trackways interpreted to have been made by sauropod dinosaurs can be classed as either narrow or wide 'gauge'. Using dynamic, 3D computer models of walking sauropods, and an analysis of preserved footprints, it can be shown that the gauge of a sauropod trackway is a direct result of the relative position of the center of mass of body of the trackmaker.

Computational, 3D 'wire-frame' models of the bodies and axial skeletons of *Diplodocus carnegii* and *Brachiosaurus brancai* were generated to obtain estimates of body mass and centers of mass (CM), and to provide limb geometries for the trackmaking computer models. The diplodocid CM was situated in front of the hips between 10% and 20% of the gleno-acetabular distance, while that of the brachiosaurid was between 40% and 50%.

The key finding was that it was impossible for the diplodocid model, with its more posteriorly placed CM, to produce a wide gauge trackway and remain stable. Similarly, it was impossible for the brachiosaurid model, with its more anterior CM, to produce a narrow gauge trackway and remain stable.

The wide gauge trackway *Brontopodus birdi*, from the Lower Cretaceous of Texas, has a ratio of manus to pes areas of between 40 and 50%. For an unnamed narrow gauge trackway from the Jurassic of Morocco, this ratio was between 10 and 20%. Assuming that the area of the foot was proportional to the load it bore, and that relative fore and hind foot areas are indicators of stress and body mass distribution, the narrow gauge trackway manus/pes area ratio is consistent with the body mass distributions of the *Diplodocus* model. Additionally, occurrence times of diplodocid body fossils and narrow gauge trackways overlap. The poorly known, Early Cretaceous brachiosaurid *Pleurocoelus* has been suggested as the maker of the Lower Cretaceous trackway; congruence between the manus/pes area ratio and the relative position of the CM of *Brachiosaurus* model lends support to this claim.

ON A SAUROPOD DINOSAUR (TITANOSAURIDAE) FROM THE ADAMANTINA FORMATION (LATE CRETACEOUS),

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During the field seasons of 2000 and 2001, a new sauropod dinosaur (MN 5013-V) was collected at the "Prata site," situated at the Serra da Boa Vista mountain ridge along the road Prata-Campina Verde (Minas Gerais). The sedimentary rocks of this area belong to the continental late cretaceous strata of the Bauru Group, more specifically to the Adamantina (at the base) and Marília (at the top) formations, both having furnished dinosaur remains in the past. At the "Prata site," the stratigraphic section consists of fine to coarse grained, reddish, massive sandstones, locally showing cross-stratification, with levels of conglomerates and mudstones of the Adamantina Formation, which have been formed in a fluvial depositional environment. Bioturbation is present in several levels, sometimes in close connection with the dinosaur bones. Several isolated theropod and crocodylomorph teeth, along with turtle elements and some small non-dinosaurian hollow bones were recovered, but the main material belongs to one sauropod dinosaur nicknamed "Rondon". It was found in an area of 3x17m in a coarse sandstone layer, occasionally showing quartz-pebbles, representing the bottom of a river channel. All bones recovered were closely associated, with the cervicals partially articulated. Bones tend to be broken with individual pieces close to their original position, indicating that the carcass was scavenged and partially trampled. Among the recovered elements is an incomplete jaw (the first of a sauropod from Brazil) with up to 3 replacement teeth inside the aveoli. The teeth have an oval cross section, are curved lingually and show well developed lateral enamel edges (carinae), similar to the condition reported for *Nigersaurus* and differing from isolated titanosaurid teeth from other Brazilian deposits. The tail consist of procoelous caudals (a titanosaurid synapomorphy) but include at least one unusual biconvex element; anterior caudal centra are wider than high and lack the "heart-shaped" condition of *Gondwanatitan* and the elongated prezygapophyses of *Aeolosaurus*. Preliminary analyzes indicate that "Rondon" differs from all South American titanosaurid taxa.

EXCAVATIONS IN SHALE—A DAUNTING TASK!

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South Dakota is known for its incredible marine vertebrate fauna such as mosasaurs, plesiosaurs and other creatures that swam the Late Cretaceous inland seas. This fauna is found in extensive shale units that cover the western part of the State to the Missouri River (central South Dakota). Excavating these large vertebrates from shaly matrices is a task dreaded by many field paleontologists. Failure rates during excavation can be high, unless one approaches the task with an understanding of shale and several "tricks of the trade" that have been developed over the years at the Museum of Geology.

Shale deposits containing these specimens must be examined critically prior to any excavation activity. Dry conditions and bentonite stringers exacerbate excavation procedures and can cause problems during transport, storage and preparation if the specimens are not excavated properly. It is crucial that the excavation team trenches deeply around specimens, more so than in other matrices. The use of the "mudding" technique, developed by Dr. Gorden Bell, prevents the drying, exposed shale from parting prematurely, as undercutting takes place. As soon as undercutting begins, damp tissue paper is applied as a separator between the rock and bone layer, and the plaster bandaging that follows. This process is repeated numerous times until the large block sits firmly on one or more shale pedestals. Rope handles may be plastered into the jacket sides to aid in moving the jacket. Support timbers can be added, if necessary, to strengthen the plaster jacket and prevent flexing. Further support can be obtained for the entire block by using steel banding straps, which help maintain structural integrity. Once jacketed, the block is QUICKLY flipped over onto a pad of loose shale by hand or by vehicle. The overturned thick jacket is easily trimmed down to the bone layer, followed by application of a new separator layer and plaster "bottom." The field crew can usually carry the now very thin jacket out of the field.

FIRST RECORD OF *PERSACANTHUS* (ACANTHODII: ISCHNACANTHIFORMES) FROM THE FRASNIAN (LATE DEVONIAN) OF SOUTHERN ALBERTA, CANADA.

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In 1994, Paul Johnston (Royal Tyrrell Museum of Palaeontology) recovered an ischnacanthiform acanthodian from talus below an outcrop of the Upper Devonian (Frasnian) Burnt-Timber Reef (Peechee Member, Southesk Formation). This lower left dentigerous jawbone is the first Devonian acanthodian specimen discovered in Alberta. It belongs to the genus *Persacanthus* Janvier 1977 and may represent a new, third species of that genus.

The jawbone from the Rocky Mountains near Canmore, Alberta, Canada, is similar to *Persacanthus kermanensis* Janvier 1977 and *P. simpsonensis* Reed 1986 based on tooth size and structure and the slender, highly compressed nature of the dentigerous bone. The main teeth are large, sub-pyramidal in shape, joined by slightly crenulate posterolabial crests and separated by deep intertooth pits. A series of sharp, sinuous vertical striations is present on the lingual surface of each main tooth. Each striation is composed of small, smooth denticles and may terminate in a smooth tubercle near the tooth base. New features of this specimen include the denticulate nature of the lingual striations and a lack of ridges on the basal tubercles.

All members of the genus *Persacanthus* and the specimen described herein are preserved in Upper Devonian (Frasnian) rocks. *P. kermanensis* is found in central Iran and *P. simpsonensis* is from Nevada. Together with the new specimen from southern Alberta, it appears that the genus *Persacanthus* had a wide distribution during the Late Devonian and may be useful for stratigraphic correlation.

HISTOLOGICAL AND MICROANATOMICAL CORRELATES OF MUSCLE ATTACHMENT AND IMPLICATIONS FOR MUSCULAR RECONSTRUCTION

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Muscular reconstructions of extinct vertebrates from strictly osteological evidence constitute a sizable portion of published accounts, and this method continues to be used despite findings in actualistic studies that gross osteological features are not reliable indicators of the location and extent of muscle attachment. While tendinous and aponeurotic muscle attachments can be recovered from osteological evidence, direct muscle attachments have almost no gross osteological signature and are extremely difficult to reconstruct. This study examines the use of histological and microanatomical evidence as supplements to create more accurate reconstructions of musculature.

The jaw adductor muscle complexes of 22 specimens representing extant lepidosaurs, crocodilians, and birds were examined by dissection, histological sectioning, and scanning electron microscopy (SEM). Samples of fossilized bone were also examined to determine the efficacy of histological preparations and SEM in identifying the features implicated with muscle attachment. The features found to be of the most utility in muscular reconstruction are extrinsic fibers, also known as Sharpey's fibers. These fibers leave characteristic pits and projections visible by SEM, and are visible in histological sections as fibers roughly perpendicular to the lamellar fibers of periosteal bone, both in recent and in fossilized bone.

Preliminary results indicate a readily identifiable signature of extrinsic fibers for tendinous muscle attachments, whereas direct muscle attachments have an extrinsic fiber profile similar to that of areas entirely without muscle attachment. However, perimysium of muscles with direct attachments does appear to interact with periosteal bone in some cases, leaving a readily definable outline of the extent of that muscle's attachment. By a combination of SEM and histological techniques, muscle attachments on extinct vertebrates may be reconstructed more accurately than is possible from gross osteological data alone.

STRAIGHT FROM THE HORSE'S MOUTH: STABLE ISOTOPES AND INFERENCES ABOUT PLEISTOCENE CLIMATE CHANGE IN THE SOUTHWESTERN UNITED STATES

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Isotopic analyses of tooth enamel carbonate from late Pleistocene grazers are used to interpret ancient climate and vegetation patterns in North America. The current study focuses on two localities in the southwestern that lie within the present Sonoran and Chihuahuan deserts. Both bulk and serial isotopic data were collected from teeth of *Equus* and *Bison* from Murray

Springs (Late Glacial; Arizona, Sonoran Desert) and Dry Cave (Full Glacial through Late Glacial; New Mexico, Chihuahuan Desert). Additionally, published bulk isotopic data from several southwestern localities were compiled for this study. Bulk data from Late Glacial localities suggest regional differences in climate within the southwestern. Sites in the present Sonoran and Chihuahuan deserts apparently experienced warmer mean annual temperatures than those in southern California and Nevada. Whereas bulk data from tooth enamel provide information about variations of mean temperature (and diet), serial data provide detailed records of temperature and diet for slightly more than one complete year of the animals' lives. Serial data from Murray Springs and Dry Cave show a shift from an equable cool environment, with dominantly C3 vegetation, in the Full Glacial, to greater seasonality, warmer mean temperatures, and an increase in C4 vegetation in the Late Glacial. These results corroborate climatic inferences previously made based on studies of paleobotanical and paleofaunal assemblages from the southwest. These serial data also indicate that the Sonoran and Chihuahuan deserts already were distinct climatically during the Late Glacial, which is in contrast to some previous research. Serial sampling of fossil tooth enamel provides an enhanced means of accessing detailed paleoclimate records of environmental change over large spans of time.

RADIOCARBON GEOCHRONOLOGY AND STRATIGRAPHIC/TAPHONOMIC CONTEXTS FOR MAMMUTHUS (MAMMOTH) IN THE UPPER MISSOURI AND YELLOWSTONE RIVER BASINS, NORTH AMERICA

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Mammoth remains in the Upper Missouri and Yellowstone River basins are associated with Middle and Late Wisconsin-age landscapes. Taxonomically, based on metric attributes of molars, they belong to the Columbian mammoth fossil-species group. Fossils have been recovered from intermountain valleys, along the eastern front of the Rockies, and in valleys and upland settings on the Great Plains. Radiocarbon measurements indicate these specimens date to before, during, and after the last full glacial.

The oldest radiocarbon dated remains can be correlated with oxygen isotope stage (OIS) 3. In the Missouri headwaters region, within the Rocky Mountains, mammoths are found in deposits associated with the early Pinedale glaciation and the subsequent interstadial. The youngest remains known from Centennial Valley date to about 19,000 radiocarbon years before present (RCYBP). On the Great Plains, mammoth remains near Box Creek date to about 32,000 RCYBP, while fragments of tusk recovered from high gravels along Beaver Creek date to about 26,000 RCYBP. Mammoth remains from the 12-15 meter terrace gravels at Glendive are associated with the end of interstadial conditions prior to the last full glacial or the beginning of the last full glacial (about 20,500 RCYBP).

Mammoth remains are also associated with late- and post-glacial contexts, generally correlated with the end of OIS 2 and the Pleistocene-Holocene boundary. Post-glacial marsh deposits containing mammoth remains in the Sun River drainage, along the eastern front of the Rockies, date to about 11,500 RCYBP. On the Plains, upland silts in the South Fork of Deer Creek contain mammoth remains dating to about 12,000-11,000 RCYBP.

The mammoth remains have been recovered from a range of stratigraphic and taphonomic contexts. Pre-last full glacial mammoths in the intermountain region were recovered from swamp, paludal, fluvial and debris flow depositional settings while those found in the Great Plains are typically in fluvial gravels. The late- and post-glacial mammoths are found in marsh-swamp deposits in deglaciated landscapes, and within loess deposits in non-glaciated contexts.

NEW DINOSAUR FOSSILS FROM THE LATE CRETACEOUS LA COLONIA FORMATION, CHUBUT PROVINCE, ARGENTINA

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Fieldwork in the marine La Colonia Formation (Late Cretaceous, Maastrichtian) of central Patagonia has resulted in the discovery of numerous lenticular bone beds. These marine deposits are rich in fossils of dipnoans, actinopterygians, and plesiosaurs, as well as terrestrial mammals, crocodyliforms, anurans, and dinosaurs. The fauna indicates the presence of a depositional environment under both marine and terrestrial influences, underscoring the importance of these localities as representative of a Maastrichtian marine transgression. Here we report on dinosaurian remains collected at La Colonia.

Sorting of screen-washed concentrate recovered 26 partial teeth referable to Hadrosauridae indet. Two distinct size classes are present, indicating that some of the material may pertain to juvenile individuals. A dissociated predentary found at the same locality may also be hadrosaurid. In addition, five theropod teeth were recovered. Although surface wear precludes precise taxonomic assignment based on denticle morphology, two distinct tooth morphologies are clearly represented. The larger, more robust form possesses a straight, vertical distal border, whereas the smaller, more gracile form is more strongly recurved.

Although theropods are becoming increasingly well known from Gondwana, ornithischian remains in southern continents are extremely rare. Abundant hadrosaur remains and a faunal assemblage very similar to that of La Colonia have been found in the underlying Los Alamitos Formation. The occurrence of hadrosaurs in the Maastrichtian of South America supports the hypothesis of a land bridge connecting the Americas well into the Late Cretaceous. The high ratio of hadrosaur teeth to theropod teeth might be of paleoecological significance, but further sampling is required to thoroughly test this possibility. Continued collection in the richly fossiliferous beds of La Colonia, as well as close inspection of concentrate already collected, may yield more diagnostic ornithischian material.

FEATHER DIVERSITY: A NEW APPRAISAL

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Avian feathers show many forms. This poses a unique problem in understanding the evolution of "new" structure(s) because no phylogenetic analysis of living species permits identification of a "prototypical feather" and, therefore, of the polarity(-ies) of change(s) involved in its origin and/or subsequent diversification. Three recent models in these contexts, widely quoted as facilitating interpretation of skin characters in theropod dinosaurs, independently resurrect the notion that the prototypical form grossly resembles that of a down feather: rachis, barbules and organized vanes (symmetrical or asymmetrical) are supposedly derived sequentially therefrom via four hypothetical neomorphic developmental events. Our analysis of various data leads us to reject this "down-to-contour" model because it fails to consider either the evolutionary history or tissue distribution of two different types of keratins present in feathers, or the cell-cell relationships necessary to produce barbules and hooklets. Additionally, it perpetuates the misleading notions that developing feathers are cylindrical and mature units are flat, and overemphasizes the role of the so-called "epidermal collar" in histogenesis. Our alternative model accomodates all these issues. It proposes modification of a "contour-like" protoypical appendage along at least four separate radiating developmental trajectories, each involving empirically demonstrable, heterochronic shifts in cell proliferation and differentiation. Only flight feather asymmetry requires invocation of a major mutation affecting development. In contrast to Brush and Prum's ill-defined, antecedent, filamentous "protofeather," which neither author relates to morphological, developmental, or molecular data concerning the skin of non-avian sauropsids, our model is congruent with all data available in these contexts, and accomodates all available data from archosaurian fossils independent of any preconceived notions of hypothesized functional roles for "protofeathers" or systematic disputes concerning the taxa involved.

PHYLOGENY OF FOSSIL AND LIVING OSTEOGLOSSOMORPH FISHES

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Several morphological studies have addressed the interrelationships of Osteoglossomorpha, a group sometimes considered the sister group of all other living teleosts. Many characters used in these studies were found to be poorly defined, to be coded incorrectly or illogically, or to display more variation than was described. The goal of this study is to address these concerns and contribute generally to knowledge of the morphology and systematic relationships of osteoglossomorphs. Analysis of 72 characters scored for 20 genera resulted in 2 most parsimonious cladograms. The only difference in the topologies of these cladograms was in the position of *Lycoptera* (the sister group of either all other osteoglossomorphs sampled or of *Eohiodon* + *Hiodon*). *Ostariostoma* was found to be the sister group of all non-hiodontiform osteoglossomorphs. Mormyridae was found to be the sister group of notopterids + osteoglossids. Mormyrids and notopterids usually are considered sister groups; characters not included here support this relationship and future analysis of these characters must be made. *Palaeonotopterus* was found to be the sister group of mormyrids sampled; however, only 22% of characters could be scored and its resemblance to notopterids is undeniable.

THE CRANIAL ANATOMY OF MASSOSPONDYLUS CARINATUS OWEN, 1854 AND ITS IMPLICATIONS FOR PROSAUROPOD PHYLOGENY

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A revision of the cranial anatomy of *Massospondylus* (Saurischia: Sauropodomorpha) is an essential prerequisite for determining which anatomical features are diagnostic for the species. The description of the skull and mandible emphasizes the importance of several characters: nasal overhanging over the antorbital cavity, the contribution of the maxilla to the palatine in the ventral aspect of the skull, triangular fossa of the lacrimal, the number of surangular foramina, the relative width of the skull, and the relative width of the base of the cultriform process of the parabasisphenoid. Furthermore, a redescription of the cranial anatomy of *Massospondylus* provides new data that can be used to test prosauropod monophyly and independently evaluate previous hypotheses on evolutionary relationships within Prosauropoda and Sauropodomorpha. The data matrix contained 9 prosauropod genera, *Camarasaurus*, *Diplodicus*, and *Brachiosaurus* with *Herrerasaurus* as the outgroup. The characters obtained in this study were combined with the previously published cranial data in order to obtain the most robust hypothesis of phylogenetic relationships among Sauropodomorpha, and determine whether there is significant support for any clades within Prosauropoda. The three most parsimonious cladograms based on 69 cranial characters indicate a monophyletic Prosauropoda and sister-group relationship with Sauropoda. *Massospondylus* can be diagnosed based on three autapomorphies: the skull is at least 10% wider than its height; the anterior base of the cultriform process of the parabasisphenoid process is at least 20% of its length; and, only the anterior surangular foramen is present. *Massospondylus* is the sister taxon to monophyletic Plateosauridae consisting of (*Coloradisaurus* (*Lufengosaurus* (*Plateosaurus*, *Sellosaurus*))). *Massospondylus* and Plateosauridae clade collapses after three additional steps are added to the analysis.

LEMUDONG'O, A LATE MIOCENE MAMMALIAN-DOMINATED LOCALITY IN SOUTHERN KENYA

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Lemudong'o (GvJh15) is a new terminal Miocene fossil locality located in the Narok District of Kenya, on the west margin of the Gregory Rift Valley. Fossils occur within a fining-upward sequence of alluvial gravels, sands, and overbank silts and clays with weakly-developed intercalated paleosols, overlying a lacustrine diatomaceous silt. The site has excellent chronometric control. A fossiliferous volcanic ash in the overbank silty clays dates to 6.04 ± 0.019 Ma by Single Crystal Laser Fusion (SCLF) Ar/Ar. Three stratified tephra immediately below the lacustrine silt have statistically indistinguishable dates of 6.108 ± 0.018, 6.087 ± 0.015 and 6.11 ± 0.04 Ma. Nearly 1,000 identifiable vertebrate fossils were collected during five one-day visits between 1995 and 2000 and from total surface collection and selective dry sieving in July 2001.

The fauna at Lemudong'o includes snakes, birds, and many mammals. The mammals include Hystricidae, Leporidae, Cercopithecidae, Viverridae, Mustelidae, Hyaenidae, Ursidae, Machairodontidae, Hyracoidea, Equidae, Bovidae, Rhinocerotidae, Proboscidea, Suidae, Hippopotamidae, and numerous micromammals (including insectivores and rodents). The birds include Numidinae and a medium-sized accipitrid. The large number of bite marks on bone, apparent bone breakage when fresh, and large number of micromammal fossils suggest that much of the fossil assemblage formed as the result of the action of mammalian carnivores and raptors. Seeds of *Celtis zenkeri*, a widely dispersed African forest and woodland tree, were also recovered.

The fossils indicate a closed habitat, a relatively rare habitat type known from the late Miocene of eastern Africa, but one in which hominid/hominoid fossils have been found elsewhere in Kenya and in Ethiopia. Further work at Lemudong'o and more extensive paleontological survey of the area is in progress.

MAGNETIC STRATIGRAPHY OF THE UPPER MIOCENE (EARLY HEMPHILLIAN) RATTLESNAKE FORMATION, CENTRAL OREGON

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The Rattlesnake Formation in the John Day region of central Oregon has been famous for over a century for its early Hemphillian (late Miocene) fossil mammals, including some of the first immigrant megalonychid ground sloths from South America. The sedimentary portions of the formation consist of about 85 m of fossiliferous conglomerate (from which most of the fossils come) overlain by the rhyolitic Rattlesnake Ash Flow Tuff (RAFT), then about 30 m of additional fossiliferous sandstones and siltstones. Paleomagnetic sampling was conducted in both lower and upper sedimentary sequences at the type section on Rattlesnake Creek, and just to the south of the type section. The samples were analyzed with both thermal and AF (alternating field) demagnetization. Most samples showed a single component of remanence held mainly in magnetite (corroborated by the saturation of the isothermal remanent magnetization) with slight goethite overprints. The basal 25 m of the section is normal in polarity, but the entire upper 100 m of the section (including the RAFT) is reversed in polarity. Based on Streck's Ar/Ar date of 7.05 ± 0.01 Ma on the RAFT, we correlate the type of Rattlesnake section with magnetic Chrons C4n to C3Bn or C3Ar (6.8-7.5 Ma). This confirms the early Hemphillian age of the formation, based on its fossil mammals.

CRANIAL AND POSTCRANIAL EVIDENCE FOR THE AFFINITIES OF *LOPHIODON*

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The genus *Lophiodon* is known from the early to late Eocene of Europe. It is the best known member of the Lophiodontidae, particularly in terms of the anatomy of the skull and the postcranial skeleton. For most of the twentieth century, lophiodontids were classified with tapiroids, largely on the basis of dental similarities. More recently, a number of workers have made arguments for uniting lophiodontids with chalicotherioids, again largely on the basis of dental characters. Although cranial and postcranial remains of *Lophiodon* are known from European faunas, the skull and postcranial skeleton have not been well studied, and few non-dental characters have been employed to investigate the relationships of this genus to other perissodactyls.

As part of an ongoing investigation of cranial and postcranial evolution in perissodactyls, specimens of *Lophiodon* were examined in the collections of the Museum National du Histoire Naturelle in Paris and the Geiseltalmuseum in Halle. *Lophiodon* displays a mosaic of cranial and postcranial features that could be interpreted as possible synapomorphies uniting it with either tapiroids or chalicotherioids. For instance, the absence of nasolacrimal contact, observed in *Lophiodon*, may be a tapiroid synapomorphy. The orientation of the femoral head and the absence of the fovea capitis, on the other hand, are derived features also found in chalicotherioids.

Data collected from these studies were incorporated into a phylogenetic analysis of a variety of perissodactyl taxa scored for characters of the skull, postcranial skeleton, and dentition. Preliminary analysis of these data indicates that lophiodontids, as represented by *Lophiodon*, are the sister-taxon to Ceratomorpha (Tapiroidea plus Rhinocerotoidea). Chalicotherioids are placed as the sister-taxon to this Ceratomorpha-Lophiodontidae clade. Thus, lophiodontids still belong in the Tapiromorpha, but cranial and postcranial evidence does not support a special relationship with either tapiroids or chalicotherioids.

CROTAPHYTUS AND *GAMBELIA* (SQUAMATA; CROTAPHYTIDAE) FROM THE PANACA FORMATION IN THE LOWER BLANCAN, SOUTHEASTERN NEVADA

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Two localities in the Panaca Formation in Meadow Valley, Lincoln County, southeastern Nevada, have produced squamate remains that date to 4.5-4.95 Ma. Everett Lindsay and Yun Mou recovered numerous mammals and incomplete fossil dentaries of *Gambelia* sp. (leopard lizard) and *Crotaphytus* sp. (collared lizard). The recovery of these fossils marks the oldest known record of *Gambelia* and *Crotaphytus*. Although *Crotaphytus oligocenicus* has been described from the early Oligocene, some authors have questioned its validity within the genus *Crotaphytus* and associate the fossil with the tropidurines. All other published records of *Crotaphytus* and *Gambelia* date to the middle Blancan or younger. Additional squamate remains from the Panaca Formation represent *Uta*-sized (snout-vent of 45-50 mm) and medium-sized (snout-vent of 65-70 mm) sceloporines.

FUNCTIONAL ANATOMY OF ARCHOSAURIAN JAW MUSCULATURE: PRELIMINARY FINDINGS

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The skeletomuscular system is a complex and integral component of the cephalic anatomy of vertebrates. Not only is it responsible for complex and powerful movements of the feeding apparatus, but it also contributes biomechanical loadings on the skull, and constrains the size and location of other soft-tissue structures. Although there have been numerous descriptions of jaw muscles and intracranial joints in extant archosaurs and several in non-avian dinosaurs, few studies have been conducted in a phylogenetic context or have incorporated the morphologies of other relevant soft tissues such as arteries, nerves, or air sinuses. Using the EPB approach, we investigate the evolution of cephalic myology and arthrology to identify relevant functional and structural patterns in the feeding system of archosaurs. Objectives of the overall project include a synthesis of relevant hard- and soft-tissue structures in extant archosaurs to establish hypotheses of homology, tests for validity of osteological correlates, congruence testing by surveying fossil taxa, phylogenetic analysis of muscular osteological correlates to map character evolution, soft-tissue reconstruction of the musculature and relevant structures in extinct taxa, and formation of functional and evolutionary hypotheses. The feeding system of representative extant archosaurs was investigated using dissection, histological and whole mount staining, serial sectioning, and imaging techniques. Anatomical correspondences in cephalic musculature and related soft tissues, as well as their osteological correlates, provided a robust similarity test of homology. Congruence testing involves surveying extinct archosaurs for the specified osteological correlates. Preliminary studies of several dinosaur taxa confirm that many of these bony signatures are clearly identifiable. These data on muscle homologies provide the foundation for muscle reconstruction in extinct archosaurs, which in turn will shed light on the functional anatomy, ecology, and evolution of dinosaur feeding.

EVOLUTION OF HYPERCARNIVORY: THE EFFECT OF SPECIALIZATION ON CHARACTER CHANGE.

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In mammalian carnivores, hypercarnivorous specializations are characterized by specific morphological changes including elongation of the carnassial blade and reduction of the post-carnassial molars. The most extreme modifications to the condition are seen in felids and nimravids, but hypercarnivory has also evolved in mustelids, viverrids, hyaenids and canids. In a general context, it has been argued that possession of some character states may reduce the ability to attain certain other states. More specifically, it has been suggested that the extreme specialization in felids and nimravids may have limited the flexibility of the groups, resulting in a reduced ability to take advantage of open niches.

To assess the effect of specialization to hypercarnivory on subsequent evolution, I used two different measures of change, variance and average frequency of change, and compared sister group pairs for six different clades where one sister group was hypercarnivorous and one was not. Individual results were pooled across the categories hypercarnivore and sister. Disparity was calculated as the summed variance of factor scores from principal components analysis. Frequency of change was calculated by mapping characters onto phylogenies and averaging over 25 characters. Tests for differences between the categories were performed using Wilcoxan Rank Sums. Based on these analyses, hypercarnivores as a group do show a reduction in disparity relative to their sister taxa. Hypercarnivores overall are also reduced in average frequency of character change, although nimravids do not follow this general pattern, exhibiting higher frequency of change relative to their sister taxon.

This study provides empirical support for the hypothesis that specialization limits subsequent morphological evolution. It also highlights differences between nimravids and felids, groups whose obvious similarities may have disguised real differences between them in terms of evolutionary flexibility.

ELEPHANT SHREWS: ANAGALIDS, AFROTHERES, TETHYTHERES, OR "CONDYLARTHS"?

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Macroscelidea, or elephant-shrews, are currently known from 14 taxa spanning the early Eocene to the Recent of Africa. The diverse dental morphologies of the extinct forms long vexed paleontologists, leading to misallocations among palaeothentid marsupials, mixodectid insectivorans, "condylarthrans," and hyracoids. Once recognized as a monophyletic group, its position within Eutheria has been difficult to resolve. Initial associations with tupaiids and insectivorans were ultimately rejected, but more recent morphological, paleontological, and molecular analyses have produced conflicting results.

Morphological studies of extant forms have weakly allied the order with Glires and/or the fossil Anagalida, and possibly with Leptictimorpha, based on a number of cranial and postcranial characters. Paleogene macroscelideans, known almost exclusively from dental remains, suggest a very different set of relationships, showing detailed similarities with hyopsodontid condylarths or falling out within Tethytheria in cladistic analyses. Molecular studies have consistently placed the order as a sister taxon of Tubulidentata, as part of Afrotheria, or as a separate branch near the base of Eutheria or Epitheria.

These divergent phylogenetic results are not fundamentally irreconcilable but do highlight problems in taxon sampling. It is readily becoming apparent from recent phylogenetic analyses that early splits in eutherian lineages occurred on southern continents. Unfortunately, African diversity is still poorly-sampled and the determination of character polarities for macroscelidean cranial and postcranial anatomy can only be resolved through analysis of these scant Paleogene remains. However, in the absence of new fossil evidence, it is equally important that our morphological analyses better sample the known diversity of eutherians. "Condylarthrans" and other taxa classed among the archaic ungulates provide important lines of evidence for establishing character distributions and polarities among macroscelideans and other basal eutherians and cannot be overlooked in our attempts to understand the origins of the extant orders.

STRATIGRAPHIC DISTRIBUTION AND PALEOENVIRONMENTAL CONTEXT OF TETRAPOD-BEARING DEPOSITS, LOWER PERMIAN CLEAR FORK GROUP, NORTH-CENTRAL TEXAS

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Continental redbeds in the Clear Fork Group of North-Central Texas are a renowned source of Lower Permian tetrapods. Field-based mapping and sedimentologic studies, combined with regional subsurface investigations, indicate that the Clear Fork Group of this region is an approximately 350 m-thick, overall fining-upward succession of alluvial valley to coastal-plain sediments that accumulated on the landward margin of the Eastern Shelf of the Midland Basin. Although vertebrate paleontologists have recognized three formations—the Arroyo, Vale, and Choza—in discussions of Clear Fork fossils, these units were founded upon poorly exposed, marine-influenced outcrops some 200 km south of North-Central Texas and cannot be applied formally to the continental section. A new, informal stratigraphy based upon mappable beds and members in North-Central Texas provides a higher resolution framework for assessing the distribution of terrestrial fossil assemblages in the Clear Fork. Within the lower 190 to 220 m of the Clear Fork, tetrapods occur most commonly in channel-fill deposits associated with suspended-load, high-sinuosity fluvial channels. A near-total absence of tetrapods in the upper 165 to 180 m of the group corresponds to diminished fluvial sedimentation. This taphonomic pattern is shown also by the distribution of plant assemblages discovered recently in the Clear Fork Group. Tetrapod remains reappear in the overlying Pease River Group, where comparatively few, generally poorly preserved amniotes occur in coarse-grained fluvial deposits of the San Angelo Formation. A direct association between terrestrial fossil occurrences and channel settings conducive to preservation indicates that local depositional environment, not climate change, is the primary control on the distribution of tetrapods in the Clear Fork Group.

THE ORIGIN, TIMING AND RELATIONSHIPS OF PERISSODACTYLA

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Understanding the origins and relationships of a group depends on distinguishing the fundamental characters of that group from those derived within it. Historically in this context, the role judged to have been played by stem horses, as represented by Eocene fossils, has had a strong influence on perceptions of what are the nearest relatives of perissodactyls. It has long been broadly agreed by palaeontologists that perissodactyls emerged with their distinctive dental and pedal characters from a particular extinct group of stem ungulates, the Phenacodontidae. However, other members of a more inclusive group, the Pantomesaxonia (Perissodactyla, Hyracoidea, Proboscidea, Sirenia) may have originated from the same or closely related stem. If so, the Taxeopoda (pantomesaxonian orders plus a paraphyletic Phenacodontidae) would be a more appropriate grouping. A special relationship between perissodactyls and hyracoids, resurrected recently on morphological grounds, is still controversial. Neither this relationship nor integrity of the Pantomesaxonia are supported by molecular studies. There is thus currently no consensus regarding the interrelationships of perissodactyls within placentals. However, a new morphological cladistic analysis of a range of primitive perissodactyls, including taxa described in the last decade, relates this order more precisely to particular derived phenacodontid genera. Further elucidation of relationships within ungulates of 'condylarth' grade would be an important goal towards resolving the Taxeopoda polytomy.

Recent finds of primitive perissodactyls and phenacodontids in Asia reinforce earlier views of the geographical origin for the order in that continent. The oldest known perissodactyls are approximately earliest Eocene in age and the radiation of phenacodontids had begun by the beginning of the late Paleocene. The most likely timing of origin for perissodactyls is thus within the late Paleocene.

DYNAMICS OF MAMMALIAN COMMUNITY STRUCTURE AND TAXONOMIC RICHNESS THROUGH A MAJOR CLIMATIC WARMING EVENT INFERRED FROM THE FAUNA OF THE MIOCENE CABBAGE PATCH FORMATION, MONTANA

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Recent human-induced climate changes have generated interest in the paleoecological consequences of faunal change. Studies of faunal change across periods of past major climate transitions may help us understand the possible outcomes of current global warming. One potentially informative past climate change occurred between 24 and 27 Ma, near the end of the Oligocene, when the global oxygen-isotope signature indicates a dramatic global warming event. An excellent fossil sequence for studying the faunal changes associated with this event is present in the Arikareean fauna of the Cabbage Patch Formation of western Montana, which was studied extensively by Don Rasmussen. The Cabbage Patch strata produce abundant fossil remains of terrestrial vertebrates, invertebrates, and plants, and the stratigraphy is well resolved, providing a temporal context in which to study changes in the fauna. I studied the structure of the mammalian community through time, in order to determine whether the large-scale changes in the physical environment were accompanied by changes in community structure. Patterns of community structure through time were compared with patterns of taxonomic diversity, a measure typically used to determine faunal response to climate change. For each stratigraphic level, taxonomic richness and relative abundance were computed, and body sizes of included taxa were determined. To quantify community structure, taxa were placed in guilds as inferred from morphology and phylogeny. The data were analyzed across strata in order to determine whether significant changes occurred through the several million years spanned by the deposit. Preliminary analyses show significant changes in species composition, particularly among geomyoids and aplodontids, although simple taxonomic richness does not appear to change. Also, the structure and ecological composition of the community appears to undergo substantial change through the period studied. These results suggest that dramatic changes may occur in the structure and composition of communities with changes in the physical environment, even though taxonomic richness may not change much.

POSSIBLE AESTIVATION BURROWS IN A LOWER CARBONIFEROUS LUNGFISH (CF. TRANODIS) FROM HANCOCK COUNTY, KENTUCKY

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A new Late Mississippian (Chesterian) locality has yielded a diversity of vertebrate taxa comprising semi-aquatic tetrapods and various fishes (*Gyracanthus*, rhizodonts, lungfish, paleonisciforms, and chondrichthyans). The Hancock Site is located on the eastern margin of the Illinois Basin in western Kentucky and preserves a wide variety of depositional environments, ranging from marginal marine carbonate banks to fully terrestrial paleosols. Four lithofacies have produced well-preserved vertebrate remains.

Two horizons within a sequence of estuarine to freshwater carbonaceous shales stratighraphically equivalent to the Clore Limestone contain carbonate mudstone nodules or concretions. We estimate that articulated, *in situ* dipnoans are found in at least 30-40% of the lower horizon concretions. The skeletons are preserved in nearly three-dimensional form and we interpret the cores of the concretions as aestivation burrows. A preliminary analysis of faunal composition of the Hancock Site, as well as its age, suggests that the dipnoan assemblage may be comparable to those at Greer, West Virginia, and Goreville, Illinois, thus containing a monospecific assemblage of *Tranodis* (Ctenodontidae). Continued excavation and preparation will test this hypothesis.

The unfossiliferous upper layer of concretions at the site may represent successfully abandoned burrows. As yet, aestivation burrows containing lungfish specimens are known for only one other taxon—*Gnathorhiza* from the Lower Permian of Texas, Oklahoma, and New Mexico. The Hancock site burrows, if substantiated, would constitute the earliest unequivocal record of lungfish aestivation, and support an earlier timeline for the evolution of facultative/obligatory air-breathing in Paleozoic dipnoans.

KERATINOUS COVERED DINOSAUR SKULLS

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The frills, horns and some other areas of ceratopsian skulls are indented with meandering grooves that have been previously interpreted as channels that carried blood vessels. This vasculature is most prominent on the skulls of ceratopsians like *Triceratops* and *Torosaurus*, and indicates a vast supply of blood feeding an epidermal layer. Comparisons with Pleistocene and Recent mammals and birds indicate that such structures are consistent with bony surfaces located beneath keratinous sheaths. Identical vascular grooves are present on the lateral surfaces of the unguals of the giant ground sloth *Megalonyx*, and also on the bony beaks of all living birds, particularly in areas of a thickened rampothaeca. In *Triceratops* and *Torosaurus* a keratinous sheath appears to have covered nearly the entire skull, including the ventral surfaces of the frill. In modern taxa thickness of the keratin correlates with the size of the vasculature, thicker keratin existing above deep and wide vessels. Based on this morphology, other dinosaur taxa, including some thyreophorans may have also had keratinous coverings on regions of the skull and armor, as suggested by Gilmore of the plates of *Stegosaurus*.

THE POSTCRANIUM OF *REPENOMAMUS* AND ITS IMPLICATIONS FOR EVOLUTION OF MAMMALIAN SKELETAL CHARACTERS

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Repenomamus is a robust triconodont mammal from the Lower Cretaceous Yixian Formation, northeastern China. It is one of the largest Mesozoic mammals and has many detailed morphologies preserved three dimensionally, including the ossified Meckel's cartilage. Its postcranium is similar to that of *Gobiconodon* in some aspects, but differs from the latter in others. The atlas has the intercentrum separated from the arches. The cervical vertebrae bear small cervical ribs. There are about 20 thoracic vertebrae and 6 lumbar vertebrae, and the transition between them is not distinct. The orientations of zygapophyses along the vertebral column indicate that the animal is capable of flexing the neck, posterior thoracic, and lumbar regions in vertical direction. The interclavicle is not fused to the sternum and is in articulation with a stout clavicle. The scapula has a large spine and a supraspinous fossa smaller than the infraspinous one. The coracoid participates the glenoid. The humeral head is dorsally reflected. The distal humerus has an incipient ulnar condyle and a small ulnar condyle. The distal radius is much more expanded than the distal ulna. The three bones forming the pelvic girdle are not fused. The femoral head is slightly reflected proximodorsally. Differing from *Gobiconodon*, *Repenomamus* has neither the third trochanter nor the foramen at the base of the lesser trochanter. The astragalus partially overlaps the calcaneus and has no neck. The cuboid contacts Mt IV and Mt V distally. The phalange of *Repenomamus* is robust and

expends at both ends. The postcranial morphology suggests that *Repenomamus* is more similar to therians than to monotremes, which is in keeping with the results of several recent phylogenetic studies. New evidence also indicates that evolution of some mammalian skeletal characters is heterogeneous. Different groups are derived in different skeletal regions or features that evolved at different rates. The skeletal characters also indicate that *Repenomamus* is probably a clumsy terrestrial walker with a posture intermediate between sprawling and parasagittal postures.

FIRST TERTIARY RECORD OF *SERIPHUS* (PERCIFORMES: SCIAENIDAE) BASED ON OTOLITHS FROM THE LATE MIOCENE OF CALIFORNIA

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The family Sciaenidae (croakers) comprise some 230 extant species assigned to 70 genera. An incomplete neurocranium with sagittae (otoliths) *in situ* (LACM 55484) from the Yorba Member of the Puente Formation, Los Angeles County, California is assigned to the genus *Seriphus*. These rocks are of late Miocene age.

Previous to this report the fossil record of *Seriphus* was based solely on isolated otoliths from the Pliestocene of California. This specimen represents a new species of *Seriphus*. The otolith differs from those of all other species of *Seriphus* in having a more blunted posterior rim, a longer more anteriorly tapering ostium, and a low horizontal dorsal rim.

This taxon is from a significant locality that represents the first such diatomite deposit in which diagnostic otoliths are prerserved with associated teleostean skeletal material.

TYNER FARM, A NEW EARLY HEMPHILLIAN LOCAL FAUNA FROM NORTH-CENTRAL FLORIDA

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The Tyner Farm fossil site was discovered in the spring of 2001 in western Alachua County, Florida. Over 2,800 specimens have been recovered from a variety of sediments including clay, sand, and limestone breccia. Vertebrae, ribs, carpals, tarsals, and podial elements are quite common; skulls and mandibles are rare, but increase in occurrence with depth. The macro-vertebrate fauna is dominated by mammalian herbivores, especially a large species of the rhino *Aphelops* and the small equid *Nannippus*; carnivorans and reptiles are rare. The micro-vertebrate fauna, however, includes abundant squamates, as well as anurans, rodents, leporids, and a bat. The Tyner Farm local fauna shares taxa with both very early Hemphillian sites such as McGehee Farm and Mixson's Bone Bed (e.g., *"Hemiauchenia" minima*, *Aepycamelus major*, *Pediomeryx hamiltoni*, *Amebelodon floridanus*, *Calippus hondurensis*) and late early Hemphillian sites such as Moss Acres and Withlacoochee River 4A (e.g., *Aphelops mutilus*, *Nannippus aztecus*, *Thinobadistes* cf. *wetzeli*), suggesting an intermediate age of about 7 to 8 Ma for Tyner Farm. This intermediate age is also supported by the stage of evolution of several taxa. The new site differs from other late Miocene sites in Florida in the rarity of grazing ungulates, lower diversity of equids, and limited samples of birds and freshwater aquatic taxa.

NEW PHYTOSAURS FROM THE UPPER TRIASSIC OF INDIA

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The Maleri Formation of the Pranhita-Godavari Valley in central India has been suggested to comprise two successive tetrapod assemblages. The better-known Lower Maleri fauna includes, among numerous other diapsids, complete skeletons of the basal phytosaur *Parasuchus hislopi*. Here we report two new phytosaur taxa from the hitherto poorly known vertebrate assemblage of the Upper Maleri Formation. The overlying basal parts of the Dharmaram Formation produced only undiagnostic phytosaur remains.

The two new taxa from India show strong affinities with *Rutiodon* (= *Angistorhinus*) and *Leptosuchus*, respectively. Two skulls share numerous derived characters of the nasal and temporal region with members of the clade *Rutiodon*, but are less derived than *R. carolinensis* in retaining a non-depressed supratemporal fenestra. *Rutiodon* n. sp. is characterized by, among other characters, an extremely elongated and slender snout with the by far highest tooth count (74 per side) in any phytosaur. A third skull is referred to *Leptosuchus* on the basis of a similar structure of the temporal region, but poor preservation prevents an identification at species-level.

The features seen in *Rutiodon* n. sp. underline previous observations that this genus is the morphologically most diverse phytosaur clade. This clade shows numerous cranial traits that were acquired convergently in more derived subsets of Phytosauria. *Leptosuchus* sp. represents the first evidence for this genus outside North America. The presence of *Parasuchus* (lower fauna), and *Rutiodon* and *Leptosuchus* (upper fauna) suggests a Carnian age for the entire Maleri Formation. The occurrence of *Rutiodon* and *Leptosuchus* in India significantly extends the geographical range of both taxa, and supports a wide-spread, almost Pangean distribution of Carnian phytosaur taxa, by contrast to more endemic Norian and Rhaetian assemblages.

REASSESSMENT OF LATE PALEOZOIC TETRAPOD TRACKS FROM GRAND CANYON NATIONAL PARK, ARIZONA

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The Grand Canyon provides unparalleled exposures of Late Paleozoic terrestrial strata. The Supai Group and the Coconino Sandstone contain significant superposed ichnofaunas dominated by tetrapod tracks. A large number of these vertebrate tracks were collected and described by Charles Gilmore during the 1920s. We have begun a comprehensive reassessment of the Late Paleozoic vertebrate tracks from Grand Canyon which includes three main foci: (1) reassessment and relocation of Gilmore's localities; (2) locating and evaluating new sites and new specimens; and, (3) reinterpretation of the vertebrate ichnotaxonomy of all the tracks.

Gilmore found and described specimens from several dozen sites in Grand Canyon, but their exact locations were not well documented. Several track localities have been discovered at Grand Canyon since Gilmore's original work, but most of these have never been well documented or studied.

Redbed ichnofaunas of the Supai Group in Grand Canyon occur in relatively soft lithologies and topographic factors preclude large samples sizes from these strata. At the time of Gilmore's research, there were very limited Late Paleozoic ichnofossils available for comparative studies. Since Gilmore's time, significant and abundant new vertebrate traces from the Late Paleozoic have been discovered and have presented new interpretations. In contrast, the eolian ichnofaunas from the Coconino Sandstone of Grand Canyon are very common on exposures of the resistant sandstones of this unit. Although eolian ichnofaunas of Late Paleozoic age are known from Europe, North America, and South America, those from the Coconino Sandstone in Grand Canyon are the most numerous and significant.

A renaissance in the study of Paleozoic tetrapod ichnofaunas has occurred during the last eight years. The study of large sample sizes of tracks, notably from the Robledo Mountains of southern New Mexico, has led to a clearer understanding of extramorphological variation in Paleozoic vertebrate tracks and has subsequently led to a major re-evaluation of Permo-Pennsylvanian ichnotaxonomy. This new methodology is being applied to the tracks from Grand Canyon.

AN EARLY CRETACEOUS THEROPOD FOOT FROM SOUTHWESTERN ARKANSAS AS A POSSIBLE TRACK MAKER IN CENTRAL TEXAS AND SOUTHWESTERN UTAH

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The remains of the right pes of a theropod were found in 1972 by Robert Friday in the Early Cretaceous Trinity Group stratigraphically above the De Queen Limestone in Sevier County, southwest Arkansas. This fossil, collected from fluvial gravels, is the first and only dinosaur remains recovered from the state. Characterized by differentiated pedal unguals and closely appressed metatarsals, the specimen appears to be closely associated with the small late Jurassic theropod *Ornitholestes*. The size and shape of the Arkansas remains resemble smaller tracks in the Glen Rose Formation(Early Cretaceous) near Glen Rose, Texas and larger tacks found in the Moenave Formation (Early Jurassic) near St. George, Utah. Research is in progress to compare the articular cartilage from the ends of the unguals of emus (*Dromaius novaehollandiae*) and alligators (*Alligator mississipiensis*) to better understand the fleshed out morphology of this theropod in life. A small percentage increase in the elongation of the foot due to the presence of this articular cartilage is expected and will provide a better match of the foot to the track occurrences.

LITHOSTRATIGRAPHY AND BIOCHRONOLOGY OF THE UPPER JOHN DAY BEDS IN THE HAYSTACK VALLEY AND KIMBERLY AREAS, JOHN DAY RIVER VALLEY, OREGON

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The John Day Formation of north-central Oregon preserves a succession of speciose superposed Oligocene through early Miocene faunas establishing the sequence of mid-Cenozoic mammalian evolution within the Pacific Northwest. Upper John Day rock units were initially described by Merriam (1900-1901) in the Kimberly and Haystack Valley areas, and later divided into lower (Kimberly) and upper (Haystack Valley) members by Fisher and Rensberger. We focused our study on the Haystack Valley Member and identified two depositional units south of Kimberly: (a) late Arikareean tuffs (~22.6 Ma) with fluvial channels containing intraformational pebble gravels incised by (b) coarse gravels (welded tuff conglomerates), debris flows, and tuffaceous units, yielding early Hemingfordian mammals (~18.0-18.8 Ma), deposited in angular unconformity with lower units of the John Day Formation. This unit is disconformably overlain by Columbia basalts locally dated at ~16.5 Ma.

In Haystack Valley, Balm Creek dissects the southern limb of a syncline which preserves the most complete local section of upper John Day rocks, here comprising five depositional units: (a) late Arikareean bedded tuffs (~23.5-23.8 Ma) with welded tuff conglomerates—the last occurrence of advanced entoptychine rodents occurs in the lower part of this unit; (b) a massive gray airfall tuff serving as a local marker bed; (c) tuffaceous late Arikareean siltstones and fine sandstones with interbedded lacustrine tuffs; (d) stacked fluvial fining-upward sequences and airfall tuffs; (e) coarse welded tuff conglomerates, debris flows, and tuffaceous sandstones, believed to correlate to the fossiliferous Hemingfordian unit south of Kimberly. Thus, this study indicates that rocks previously included in the Haystack Valley Member range from ~24 to 18 Ma and incorporate multiple depositional events and temporal gaps. The complexity of upper John Day rocks suggests greater local variation in depositional settings in the early Miocene relative to the more uniform Oligocene environments documented by lower John Day strata.

ECOLOGICAL POLARITIES OF THE NORTH AMERICAN FAMILY CANIDAE: A NEW APPROACH TO UNDERSTANDING FORTY MILLION YEARS OF CANID EVOLUTION

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Recent systematic research on two of three subfamilies of the canidae has established important evolutionary trends. Several workers outside of the systematic field have attempted

to establish various methods for quantifying these relationships using complex models and graphs. An ecological polarity method refined by G. J. Retallack defines breeder (incisor dominated), competitor (canine dominated) and tolerator (molar dominated). Breeders are characterized by high fecundity, small size and nervous temperament. Competitors select for moderate fecundity, medium size and aggressive behavior. Tolerators have low fecundity, large size and withstand extremely varied conditions. Individual taxa are scored from functional areas of each of the principle dental elements: I = incisor, C = canine and M = molar. The measurements for incisors are converted into percentages using the equation (I/I+C+M)*100. The results are plotted on a triangular diagram as a polygonal error envelope, representing an organism's position in ecological space with poles at 100% incisor, 100% canine and 100% molar. Canidae subfamilies are well separated, evolving away from the competitor pole early in their history, and back towards this space later. The competitor pole is initially occupied by the ancestral hypercarnivorous subfamily Hesperocyonae, the tolerator role in the Borophaginae. The last subfamily Caninae evolve at the late Arikareean followed by the early Miocene disappearance of the nimravid cat-like predators. The Caninae displaced the earlier subfamilies, evolving toward the competitor pole left vacant by nimravids. Further considerations include local ecological effects, apparent at some locations where paleosols have been studied. The recovery of a skull of a hespercyonae (*Mesocyon coryphaeus*) in wooded grassland paleosols and Borophaginae (*Rhizocyon oregonensis* and *Cormocyon copei*) in dry shrubland paleosols in the medial Arikareean John Day Formation of Oregon, provide examples of environmentally induced separation in ecological space.

SPINY NORMAN, NOAH'S ARKS, AND THE "GARDEN OF EDEN" HYPOTHESIS OF MODERN PLACENTAL MAMMAL ORIGINS

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The persistent finding of clades endemic to southern continents, the Afrotheria and Xenarthra, near the base of the placental mammal tree have led molecular phylogeneticists to suggest an origin of Placentalia on the southern continents. The basal splits within the group have then been associated with vicariance due to the breakup of Gondwana. This scenario ignores several facts. First, the place of origin of Placentalia cannot be reconstructed using phylogenetic reasoning without referring to an appropriate outgroup. When such outgroups are considered, a Laurasian origin of Placentalia is most parsimonious. Second, a model of pure vicariance assuming current molecular phylogenies would require that the splits among placental orders occurred not with the breakup of Gondwana, but of Pangea in the Late Triassic–Early Jurassic. This event was long before even the oldest molecular divergence estimates for Placentalia and coeval only with the earliest mammals in the fossil record. Third, there is an emergent problem with the number of dispersal events that would be required under different scenarios of regions of placental origination. In considering the geographic distribution of the major placental clades at their first fossil record appearance (mostly in the early Cenozoic), it becomes clear that a Laurasian center of origin is more parsimonious in requiring fewer dispersal events. Models of origination from any southern continent require at least twice the number of dispersal events to account for this early Cenozoic distribution in comparison with a model of Laurasian origins. These facts, along with earlier findings speaking against a major placental radiation deep in the Cretaceous without leaving fossil evidence, suggest an origin of Placentalia somewhere in Laurasia with few supraordinal splits occurring before the latest Cretaceous (Campano-Maastrichtian).

ENDOCAST VOLUME AND BRAIN MASS IN A SIZE SERIES OF ALLIGATORS (*ALLIGATOR MISSISSIPPIENSIS*).

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Endocasts are molds of the brain cavity of skulls, whose surfaces reflect the endocranial surface. Endocasts of pterosaurs, *Archaeopteryx*, and small theropod dinosaurs show brain contours, indicating the brain filled the cranial cavity, as in birds and mammals. Endocasts of all other non-avian dinosaurs resemble those of crocodilians, in which the brain does not fill the cranial cavity. Ignorance of the quantitative relationship between brain mass (MBr) and endocast volume (EV) hampers brain mass estimation from dinosaur endocasts. The specific gravity of brain tissue approximates one (1), so that brain mass (g) and volume (ml) are interchangeable. The commonly used MBr:EV ration of 0.5 for (non-avian) reptiles has scanty supporting evidence, and none from crocodilians. Brain mass and endocast volume were measured in a sample of 12 alligators of body mass (MBd) range 11.3 to 276.9 kg, total length (TL) range 161.3-381.0 cm; and brain mass (MBr) range 4.47-10.51 g. Because there is little growth after 350 cm TL in males and 260 cm TL in females, and alligators can be sexually maturity at 160 cm, the sample represents the range from the smallest sexually mature size to the largest likely size. In this sample. the MBr/EV ratio decreases from 68% in the smallest to 32% in the largest alligators. The three largest males had TL range 361-384 mm; MBr range 9.82-10.71 g; and MBr/EV range 31.09-34.82%, with a mean of 32.6%. The largest female (TL 284.5 cm, MBr 8 g), had an MBr/EV ratio of 42.04%. EV increases faster than MBr relative to TL. The Least Squares (LS) log-log equation of MBr regressed on TL has a slope of 0.997 (95% cl. 0.890, 1.104; R=0.989), significantly different from the slope of EV regressed on TL, which is 1.811 (95% cl. 1.652, 1.978; R=0.992). For EV regressed on MBr, the log-log LS slope is 4.156 (R=0.963). I recommend use of the following for MBr estimates from EV in mature dinosaurs and crocodilians: the male ratio (33%) for undoubted males; the male-female mean (37%) when specimen sex is unknown; and the female ratio (42%) for undoubted females when sexual dimorphism is known.

A LARGE PRIMITIVE COELUROSAUR FROM THE YIXIAN FORMATION OF NORTHEASTERN CHINA

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Most of the theropods found in the Early Cretaceous Yixian and Jiufotang formations of Liaoning Province, China are relatively small animals, and include the smallest non-avian theropod known, *Microraptor*. The average length of theropods from these Jehol Group sediments is about 100 cm. Here we describe an unusual theropod almost twice the size of most Jehol theropods, which was recovered from the Yixian Formation rocks exposed at the quarry at Sihetun. The distal end of the theropod's tail is missing, but it is otherwise complete and extremely well-preserved. A conservative estimate places the animal's length at about 1.6 m, making it second in size only to *Beipiaosaurus* among Jehol theropods.

Preliminary study suggests this specimen is a primitive coelurosaur, which is interesting because most of the Liaoning theropods discovered to date are maniraptorans. It possesses coelurosaurian characteristics such as an elongate manus, flattened caudal chevrons, and teeth that are unserrated on the anterior carinae, but lacks typical maniraptoran features. Although the manus is elongate, the forelimb is only 49% of the length of the hindlimb. The semilunate carpal is small and subequal in size to the lateral distal carpal. The first twenty-five caudal vertebrae are preserved in the tail, the caudal centra are homogeneous in shape, and elongate chevrons are present on each one. The distal portion of the hindlimb is not especially elongated with respect to the femur. The general proportions of this theropod are very similar to those of *Sinosauropteryx*, another basal coelurosaur from the Yixian Formation. Both taxa have long tails, short forelimbs, and relatively short distal portions of the hindlimb. In addition, this theropod and *Sinosauropteryx* both have fan-shaped neural spines on the dorsal vertebrae, limited anterior expansion of the pubic boot, a robust digit I wider than the radius, elongate chevrons along most of the tail, and no ossified sternal plates, suggesting a close relationship between the two taxa. The phylogenetic position of this specimen was analyzed using the evolving theropod matrix created by our research group.

MORPHOLOGY OF A NEW SPECIES OF *MOSASAURUS* (REPTILIA: SQUAMATA) FROM SOUTH DAKOTA

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In 1941, James H. Quinn found a partial skeleton of a large mosasaur (Field Museum of Natural History P26956) from the Pierre Shale in Lyman County, South Dakota. The specimen consists of a partial skull, a dentary, several isolated teeth, most presacral and pygal vertebrae, complete pectoral girdles, some limb bones, and dorsal rib fragments. The well-preserved teeth are slender and strongly recurved making them similar to *Mosasaurus conodon*; however, the presence of anterior and posterior carinae with serrations is a character found in *M. maximus* and is unusual for *M. conodon*. The dentary is massive and wide like in *M. missouriensis* and *M. maximus*. The tall, blade-like neural spines on the presacral vertebrae and short, rounded transverse processes on the mid-posterior dorsals distinguish the specimen from other *Mosasaurus*. Two foramina are present in the left coracoid but only one in right. The extra foramen is probably due to individual variation and demonstrates that the double coracoid foramina in *M. conodon* are not diagnostic. The massive, heavily built humeri are morphologically similar to *M. conodon*; however, the lengths of the humeri suggest that this animal has much shorter forelimbs than *M. conodon* when compared to the body size. Reexamination of the South Dakota mosasaur suggests that the specimen is a new species of *Mosasaurus* that is closely related to *M. conodon* rather than *M. missouriensis*.

BONE INVASION: MICROBIAL FOCAL DESTRUCTION IN LATE MIOCENE MAMMAL BONE

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The taphonomic investigation of late Miocene fossil mammal bones from Kerassia (Euboea Island, Greece) was undertaken on material from seven different sites near Kerassia. These sites consist of roadside cuttings (K1 to K7) where at least two fossiliferous horizons occur. The taphonomical aspects highlighted here are the histological and biogeochemical alterations of bioeroded bones. Polished thin sections of fossil bone and teeth from both horizons of Kerassia and, for comparison, from eight other late Miocene Greek localities were studied under the SEM (using backscatter imaging) and analysed using a microprobe. In addition, from Kerassia only, fragments of bone and teeth on stubs were studied. All Kerassia bones and teeth (in dentine and cement) showed extensive microbial focal destruction (MFD). The MFD is seen as damaged zones around the perimeter of the bone, around the marrow cavity and as randomly scattered foci. The MFD foci are ellipsoid nodules with their long axes parallel to the long axis of the bone and generally following its development. The rims of these nodules are permineralised. Microprobe analyses show that the apatite in the rims is enriched in calcium phosphate relative to the whole bone and calcium phosphate is depleted in the foci. In longitudinal section the internal structure of the foci is manifest as a series of parallel microtunnels, parallel also to the long axis of the focus and streaming across the foci. The diameter of these microtunnels is between 150-400 nm, indicating that the invading microorganisms were bacteria. Contrary to the established ideas of bone preservation, in Kerassia extensively damaged bones and teeth have survived in the fossil record with quite good preservation of their histology and bioerosion features. The bone material from the other late Miocene Greek localities revealed the same or similar, extensive bacterial damage. Therefore, owing to extensive MFD in bones from Kerassia and other late Miocene Greek localities a temperate to warm and relatively moist climate during the late Miocene in the northeastern Mediterranean can be inferred.

A CERATOPSIAN DINOSAUR FROM THE UPPER CRETACEOUS KAIPAROWITS FORMATION OF THE GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, UTAH

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The Kaiparowits Plateau, located within the Grand Staircase-Escalante National Monument (GSENM) of south central Utah, preserves one of the best and most continuous, although largely unexplored, records of Late Cretaceous life. This study augments the faunal record from the Campanian Kaiparowits Formation of that area by describing a new dinosaurian specimen collected by the Museum of Northern Arizona as a joint project with GSENM, Bureau of Land Management. Preserved and collected bone elements include the syncervical, 11 post-syncervical vertebrae, three cervical ribs, 18 dorsal ribs, partial undetermined pelvic bones, weathered fragments of an undetermined leg bone, and nine undetermined bones. Of the prepared material, three centra show pathologies most likely caused by disease. Based on the presence of a syncervical and the characteristic shape of the vertebrae, the specimen is identified as part of the family Ceratopsidae (Ornithischia). Identification of all ceratopsian taxonomic levels is primarily based on cranial material. However, detailed study of ceratopsian post-cranial material has not yet been undertaken and may reveal distinguishing characters that would allow further identification of the specimen.

This study makes two primary contributions towards a better understanding of GSENM's paleontology. First, identification of the specimen, regardless of the taxonomic rank, increases the known paleodiversity and addresses ceratopsian paleogeography. Second, additional age constraints may be placed on the Kaiparowits Formation via correlation of the specimen with deposits of a similar age and a magnetostratigraphic analysis of a portion of the Kaiparowits Formation.

THE FIRST REPORTED ORNITHISCHIAN DINOSAUR POSTCRANIA FROM THE EARLY JURASSIC LUFENG FORMATION, CHINA

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Ornithischian dinosaurs are a rare component of the vertebrate fauna of the Early Jurassic Lufeng Formation, China. Previously reported specimens consist solely of cranial material of the taxa *Tatisaurus (=?Scelidosaurus) oehleri*, *Dianchungosaurus lufengensis*, and *Bienosaurus lufengensis*. A partial skull initially described as a small fabrosaur (sensu lato), *Tawasaurus minor*, is most likely a juvenile prosauropod. Many of these taxa are based on extremely fragmentary material, and thus any new material is desirable to help elucidate knowledge of Lufeng ornithischians.

Material collected in the late 1940s by Father E. Oehler S.V.D. for the Catholic University of Peking from the Zhangjiawa Member of the Lufeng Formation in Yunnan Province includes an articulated distal tibia, distal fibula, astragalus, calcaneum, and proximal metatarsals (CUP 2338). Although its plesiomorphic nature makes it difficult to identify synapomorphies for phylogenetic placement, features in the tibia and astragalus are consistent with it being an ornithischian dinosaur. The morphology of the insertion of the astragalus into the tibia and shape of the fibula suggest that CUP 2338 is closely related to the basal thyreophoran *Scutellosaurus lawleri*. Basal ornithischians such as *Pisanosaurus* and *Lesothosaurus* are distinguished from CUP 2338 by their distinctive tibia-astragalus articulation, and multiple differences in the structure of the tarsus make a close relationship with a more advanced thyreophoran such as *Scelidosaurus* unlikely.

Relationships with previously described ornithischians from the Lufeng Formation cannot be reliably determined because there are no overlapping elements. Association with the scelidosaurid forms *Tatisaurus* and *Bienosaurus* is unclear, as it is unknown whether they had a derived tarsus similar to *Scelidosaurus*. *Dianchungosaurus* is based on a few skull fragments, and is a nomen dubium. If CUP 2338 does not pertain to previously reported taxa, it represents a new ornithischian dinosaur from the Lufeng Formation.

FULL PLASTER JACKET: BATTLING TO GET YOUR FIELD JACKET OPEN? A COMPARISON OF CAST-CUTTING AND AUTOPSY SAWS

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You've just spent the summer collecting a crate load of spectacular fossils and have shipped them back to your lab. The last thing you want, then, is to have a major struggle opening your masterpieces to get started on preparation. Selecting the right tools is one of the keys to easing this process, and, arguably, a good saw is the most important tool of all. There are basically two types of power saws that are commonly used to open plaster field jackets—cast-cutting saws, as used in the doctor's office to remove little Jimmy's arm cast; and autopsy saws, as used in the coroner's office to remove big Jimmy's skull cap. Generally, cast cutting saws are suitable to open fairly small, thin-walled jackets that don't require the saw to be running for an extended period of time, or that will overwork the motor by cutting through many layers of burlap and plaster. But when the jacket to be opened is large and thick an autopsy saw may be just the ticket because, by being built to primarily cut through bone, they are larger and heavier duty. Where a cast-cutting saw may overheat on a large jacket—and even fuse some of the motor parts together—an autopsy saw may be able to handle the job easier.

This demonstration will compare and contrast cast cutters and autopsy saws. Viewers will be able to see the inner workings of each and be allowed to try their own hand at cutting a plaster jacket.

ASSESSMENT OF PHYLOGENETIC AFFINITIES OF POSSIBLE THEROPOD EGGS FROM THE TWO MEDICINE FORMATION OF MONTANA: CLADISTIC ANALYSIS OF EGGSHELL STRUCTURE

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The Two Medicine Formation of Montana is notable for the discovery of the first North American dinosaur eggs, including *Maiasaura*, *Hypacrosaurus*, and *Troodon*. Recent discoveries include a new egg type from the lower portion of the formation, approximately 80 Ma. These elongated eggs lack preserved embryonic remains, measure 75 x 30 mm, and display isolated, round, tuberculate surface ornamentation. The 0.73 mm thick eggshell is comprised of closely packed aggregates of rhombohedral crystals that exhibit three structural layers of calcite and permineralized cuticle. Similar features are also found in fossil and extant avian eggs. These new eggs, however, lack squamatic ultrastructure and would be classified as "Dinosaur prismatic" in current parataxonomy.

Although eggshell parataxonomy has proven useful for categorizing and comparing the myriad fossil eggs found worldwide, this non-phylogentic system is inherently limited. For example, *Troodon* eggs share several characteristics (blocky mammillae, prismatic shell units and structural layering of calcite) with modern neognathes, but are excluded from "Ornithoid" classification which includes both non-avian and avian theropods. Assignment of an unknown egg into this system provides only an eggshell title, rather than taxonomic understanding.

In an effort to assess the taxonomic affinities of the new Two Medicine eggs, we conducted a cladistic analysis of 15 taxa (7 extant and 8 extinct) using 15 egg characters. Results were largely consistent with current phylogenies, and the analysis defined a Maniraptoran clade consisting of Cretaceous theropods, modern birds, and the new Two Medicine eggs. Most problematic in the analysis were modern crocodiles because of the three structural layers of eggshell calcite found in this taxa but absent in some dinosaur groups. Recognition of additional eggshell characters and expansion of taxa used for analysis will further test these preliminary results.

IS *AZENDOHSAURUS LAAROUSSII* (CARNIAN, MOROCCO) A DINOSAUR?

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Azendohsaurus laaroussii is an archosaur from the Carnian of Morocco (Argana Basin) originally described on the basis of cranial elements (maxillae, dentaries, and isolated teeth). It was considered at first a close relative of the ornithischian *Fabrosaurus australis* from the Hettangian of Southern Africa. This view was nevertheless rapidly challenged. In fact, *Azendohsaurus* has been alternatively considered a prosauropod (or a basal sauropodomorph) or a taxon based on composite material (prosauropod + ornithischian). Yet, the second opinion has been demonstrated to be wrong and a newly prepared material casts doubt on the assumed dinosaurian nature of *Azendohsaurus*. This bears a particular importance since this taxon is usually considered as one of the earliest dinosaurs.

The new material is from the locality XVI of Dutuit's nomenclature, i.e. the *locus typicus* of *Azendohsaurus laaroussii*. It consists of various disarticulated post-cranial remains (presacral vertebrae, elements of the pectoral and pelvic girdles, and elements of the forelimbs and hind limbs) found closely associated with *Azendohsaurus* cranial fragments. No dinosaurian synapomorphy is found in this material that, in contrast, shows an assortment of plesiomorphic character-states suggesting a phylogenetic position outside the Dinosauria. Four of these, namely an imperforate acetabulum, the absence of a brevis fossa on the ilium, the fourth trochanter of the femur situated very proximally, and the head of the femur not distinctly set off from the shaft, may be considered to be the most significant.

Since these new post-cranial remains identified as *Azendohsaurus laaroussii* are disarticulated, this attribution is merely an inference from taphonomic circumstances. For that reason, discovery of articulated material is needed to settle convincingly the phylogenetic position of this taxon within the Ornithodira. Hopefully the Malagasy aff. *Azendohsaurus* (Carnian) material, still under study, comprises such specimens.

PATTERNS OF CHANGE IN MID-MIOCENE FAUNAS, AND IMPLICATIONS FOR PALEOENVIRONMENTAL CONDITIONS

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The numbers of ungulate species of different dietary specializations and dental morphologies in present-day faunas reflect environmental conditions. High-crowned (hypsodont) and medium-crowned (mesodont) species predominate in dry and open habitats such as grasslands and deserts; low-crowned (brachydont) species predominate in humid habitats, such as tropical forests. Brachydonts cannot endure high rates of tooth wear and most extant brachydont species are specialized browsers. In no modern habitat of any kind does the number of specialized browsing ungulates exceed 8 species. Since vegetation is strongly influenced by annual rainfall, the distribution of ungulates of different feeding types (and thus crown heights) also correlates with precipitation. Here we use a metric based on average ungulate crown height in a fauna and total (local) mammal species richness that shows a good correlation in present-day communities with mean annual precipitation.

Applying this metric to faunas from the Plio-Pleistocene of Africa and the late Miocene and Pliocene of North America yields predictions of rainfall that are consistent with apparent paleoenvironmental conditions. However, application of the metric to faunas of the mid Miocene of North America produces anomalous results. In aspect these ungulate assemblages appear to represent woodland savanna faunas, and estimates of rainfall from other proxies, such as paleosols and leaf floras, indicate levels of paleo-precipitation appropriate to present-day woodland savannas. However, for these faunas our metric reconstructs an extremely high annual rainfall equivalent to that found today in regions of wet tropical forests. The reason for these high (and evidently incorrect) estimates is the anomalously high numbers of brachydont species in the faunas (as many as 14 species in some localities). No modern woodland savanna fauna combines this dominance of low ungulate crown heights with such high species richness. We suggest that these results indicate levels of primary productivity in the browse component of mid Miocene woodland savanna vegetation that are significantly higher than in any present-day analogous habitat.

MORPHOLOGICAL TRANSFORMATION OF THE THEROPOD SCAPULOCORACOID: A THIN-PLATE SPLINE ANALYSIS

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Bipedalism decoupled the theropod shoulder girdle from its weight-bearing role, allowing the forelimbs to engage in functions other than locomotion. Within the theropod lineage, several morphological changes occurred in the shoulder apparatus that may correlate with changes in forelimb function, leading to the evolution of powered flight. Previous research addressing the theropod shoulder girdle has been qualitative and somewhat cursory. In this study, morphological differences in the scapulocoracoid of thirteen taxa of non-avian and avian theropods are examined quantitatively using thin-plate splines. This shape analysis allows the magnitude and direction of change of the landmarks in comparative taxa to be visualized as deformations of a grid, thereby allowing localized variation in form to be detected and their significance to be quantified. An average of the scapulocoracoid forms of *Coelophysis* and *Dilophosaurus* was used as the reference form to which all other species were compared. The areas of the scapulocoracoid shown to have undergone the most change, such as the posterior coracoid process, appear to coincide with modifications in the sizes and actions of muscles that arise in those areas. The morphological differences revealed by the thin-plate spline analysis are assessed within a robust phylogenetic framework of the Theropoda. Using square-change parsimony, the landmark configurations of the hypothetical ancestors at the internal nodes of the cladogram are estimated. These are used to estimate shape changes that occurred along branches of the cladogram, and to infer relative magnitude of the change between successive hypothetical ancestral nodes. These estimates of shape change are then compared with previous hypotheses of morphological transformation of the scapulocoracoid leading up to flight in birds. This will indicate whether previous hypothesized transformations between known taxa are feasible.

MORPHOLOGICAL VARIATION IN *LEMMISCUS* FROM KOKOWEEF CAVE, CA

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A late Pleistocene/early Holocene faunal assemblage from Kokoweef Cave (San Bernardino County, California) includes a diverse assemblage of gastropods, reptiles, birds, and mammals. Chronological control for the site consists of a single radiocarbon date of 9830 ± 150 Yr. B.P. taken from charcoal at approximately the mid-point of the stratigraphic excavation. *Microtus* and *Lemmiscus curtatus* are the only known arvicoline rodents from the locality. No extant populations of *Lemmiscus* are known from the vicinity of the cave, but they are common in the fossil deposit. We discovered three distinct morphotypes of the lower first molar of *Lemmiscus* from Kokoweef Cave, one of which is not known from any other *Lemmiscus* populations, living or extinct. The most common morphotype is typical of extant populations and includes a posterior loop with five alternating, closed triangles. An unexpected second morphotype includes only four closed triangles; this morphotype is generally restricted to Irvingtonian (early and middle Pleistocene) faunas and is known from deposits as old as 850 ka in Colorado and New Mexico. The four-triangle morphotype is not known from extant populations, but a late Pleistocene occurrence was previously reported from eastern Nevada. The Kokoweef Cave material thus represents the second record of this morphology from latest Pleistocene deposits in the western U.S. A third morphotype consists of a posterior loop, with only four closed triangles, but the fifth and sixth triangles are confluent with one another and closed off from the anterior cap of the tooth. This is a unique *Lemmiscus* morphology, known only from the Kokoweef Cave fauna.

MAMMALIAN FEATURES OF THE TRITYLODONTID POSTCRANIUM AND THEIR PHYLOGENETIC SIGNIFICANCE

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Tritylodontids have been widely recognized as having an extraordinary array of mammal-like, even mammalian features. Recent students of cynodont evolution have interpreted this suite of characters, many of which are postcranial, either as evidence of extraordinary parallelism among cynodonts or as evidence that tritylodontids are the sister-group of mammals. We re-examine the validity of 'mammalian' characters with reference to tritylodontid remains from the Lower Jurassic Kayenta Formation of Arizona, including a nearly complete presacral postcranial skeleton of *Kayentatherium wellesi*. Various features of the appendicular and postcranial axial skeleton previously interpreted as mammal-like in fact reveal structural inconsistencies with the mammalian pattern. The pyramidal dens and the presence of axial prezygapohyses represent a functional mechanism at the atlanto-axial joint that differs from that in basal mammals. The dorsal vertebral series is structurally gradational, and shows no distinct thoracolumbar differentiation; mammillary processes on the laminae and exostoses on the apices of neural spines are evidence of specializations of the transversospinalis musculature. The scapular spine is situated anterior to the glenohumeral joint, rather than closely aligned with the glenoid as in mammals. A protuberant facet on the radius indicates a pivotal mechanism for pronation/supination at the distal radio-ulnar joint, and differs from the radial translation about a curvilinear ulnar facet that occurs in mammals. The iliac blade is spatulate, not rod-like as has been interpreted for *Oligokyphus*, and bears a small but distinct posterior process as in the gomphodont cynodont *Exaeretodon*. These and other postcranial features of the tritylodontids from the Kayenta Formation, although clearly derived from patterns established in basal cynodonts, are not comparable to those developed among early mammals and provide no support for the hypothesis that tritylodontids are the sister-group of mammals.

DETAILED SEDIMENTARY AND TAPHONOMIC ANALYSIS OF A DINOSAUR QUARRY, HOT SPRINGS RANCH, WYOMING

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While excavating a new quarry on the Warm Springs Ranch near Thermopolis, Wyoming, paleontologists at the Wyoming Dinosaur Center discovered theropod teeth and tracks among scattered sauropod skeletal remains in the Morrison Formation, providing a potentially unique glimpse into the predatory behavior of carnivorous dinosaurs in the late Jurassic. Preliminary investigations of the site led workers to suggest that the area was either a theropod ambush site or den. These hypotheses were based on the uncommon combination of small and large theropod tracks, damaged bone material, and associated theropod teeth at the site. However, accurate interpretations of the assemblage relies heavily on recognition of how much it has been modified by destruction or disarticulation by scavenging, predation, or natural decay, time averaging, and diagenesis. A detailed sedimentary and taphonomic analysis was necessary to assess the impact of these processes on the assemblage.

Comprehensive site management techniques were employed at the site, integrating microscopic and macroscopic methods to enhance information about the local dynamics of depositional environments, drainage conditions, leaching, and soil formation. High-resolution sedimentary analysis along the length of the quarry was completed to evaluate closely the paleoenvironmental conditions and preservational processes leading to the assemblage. Detailed studies of the remains for evidence of desiccation, tooth damage, and post-depositional features were used to determine the conditions to which the remains were subjected. Relationships of bones and tracks were represented on a site map. All collected data was then synthesized to evaluate the information offered by the site.

Increased technology now makes it possible to improve the quality of our knowledge of paleoecology, paleoenvironments, and even dinosaur behavior. This study offers a unique glimpse into the paleoecology of late Jurassic dinosaurs while providing a framework for future studies.

A NEW SPECIMEN OF *EDENTOSUCHUS* FROM THE XINJIANG AUTONOMOUS PROVINCE OF CHINA

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Edentosuchus tienshanensis is an unusual crocodyliform from the Lower Cretaceous fluvial beds of the Tugulu Group (Xingjiang Prov., China). This taxon was known from two fragmentary specimens and its phylogenetic relationships were disputed.

New material was recently collected in the Tugulu exposures West of the village of Urho, the type locality. This material shares derived diagnostic characters with the holotype of *Edentosuchus tienshanensis* in their overlapping elements. Additionally, it shows previously unknown details on the cranial and dental anatomy of this taxon, providing new information on its phylogenetic relationships and paleobiology.

The dentition of the new specimen is one of the most remarkable cases of heterodonty within Crocodyliformes, showing a caniniform premaxillary tooth and three different multicusped tooth morphologies in the maxillary teeth. The lower jaw dentition also has a high degree of heterodoncy paralleling the changes present in the upper dentition.

The phylogenetic relationships of *Edentosuchus* are analyzed within the context of Crocodyliformes. Preliminary phylogenetic results depict this enigmatic taxon as a basal crocodyliform, clustered within the most basal crocodyliform clade (a group traditionally known as protosuchians). Furthermore, *Edentosuchus* shares some dental similarities with an unnamed taxon from the Early Jurassic Kayenta Formation of Arizona that tentatively suggest a close relationship. It is significant that *Edentosuchus* (and other basal Cretaceous crocodyliforms from Central Asia) are depicted as closely related to Late Triassic and Jurassic taxa from other continents, showing that basal crocodyliform lineages survived much longer in Central Asia than in the rest of the world.

FIRST PLIOCENE RECORD OF *HEMIAUCHENIA BLANCOENSIS* (MAMMALIA, CAMELIDAE) IN MEXICO.

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Hemiauchenia is known in Mexico by one species, *H. vera*, from late Hemphillian age deposits in San Miguel de Allende Area, central Mexico. There is just one tentative assignment for the genus in Blancan deposits from Las Tunas fauna, Baja California Sur. The extensive work done in the San Miguel de Allende graben generated a huge collection of artiodactyl material. Within the collection, we identified a different *Hemiauchenia* species associated with a typical Blancan fauna.

The specimens were recovered from sandy and silty clay floodplain deposits of the Rancho Viejo Beds, 12 to 17 km north of the city of San Miguel de Allende, Guanajuato. The fossil material consists of an adult mandible with right and left p3-m3, and the alveoli of the anterior dentition; a right and left partial rami with dp3-m1 probably of the same individual; a left ramus fragment with dp4-m1, a symphysis fragment with right i3 and c; a palate fragment with right DP2-M1 and left DP2-M2; and several isolated lower and upper premolars and molars.

The specimens possess the features that characterize *H. blancoensis*, such as mesodont teeth; canine laterally compressed and situated immediately behind i3; p1 separated from the canine by a short diastema; post-p1 diastema of moderate length; p2 absent; p3 laterally compressed and with two roots; p4 with deep anterolingual groove; lower molars with weak

anteroexternal stylids; and upper premolars and molars with strong styles. Among the most important associated fauna are *Paramylodon* sp, *Glyptotherium* sp, *Hypolagus mexicanus*, *Neochoerus* sp, *Borophagus diversidens*, *Equus (Dolichohippus) simplicidens* and *Nannipus peninsulatus*, which establish a Blancan age. This is also supported by a radiometric date of volcanic ashes that yielded a fission-track age of 3.36 Ma. This find in the Blancan of Guanajuato is the first record out of the USA faunas and extends the paleobiogeographic range of the species during the Pliocene from northern Texas to central Mexico.

EXCEPTIONAL LATE MIOCENE RODENT BURROWS, EAST-CENTRAL NEBRASKA

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A 2-3 m thick diatomite in the Ash Hollow Formation in Greeley County, Nebraska contains many large vertebrate burrows distributed within a few hectares. The very thinly laminated diatomite includes both planktonic and benthic diatoms; preliminary observations suggest that these sediments are seasonal deposits of a large, fresh to alkaline lake having very little siliciclastic influx. Fine sands with a weak calcareous paleosol overlie the diatomite, and appear to be the level from which the burrows were excavated downward, on the basis of the color and texture of the burrow fills. Ant galleries (1-2 m deep) appear with the burrows and frequently invade them. Burrows also contain dispersed, fine, whitish, siliceous rhizoliths or "root balls" of rhizoliths several centimeters long.

There are at least two distinct burrow elements at the site: (1) elongate, vertical to subhorizontal passages 6 to 12 cm in diameter (mostly 6-9 cm in diameter), and up to 2 meters long; (2) large chambers, up to 42 cm in maximum diameter and over 50 cm long (in one case 220 cm long), into which passages (1) lead. Passages that appear to be spatially isolated are common because of incomplete exposures of burrows, but a surprising number of single-exposure- plane chambers and connected passages can be seen. The walls of several burrows and chambers are covered with paired grooves (5-50 mm long, 3.8-5.6 mm wide) that were almost certainly produced by paired rodent incisors. A comparison of passage diameters from the site with estimated body diameters of modern North American burrowing rodents implicates a burrow-producer in the size range of *Cynomys* and *Spermophilus franklinii*. This body size range, the width of paired incisor marks, and the lack of individual incisor grooves strongly suggest that large sciurids, rather than geomyids or castorids, were responsible for the burrows. Larger cross-sections of passage-like and chamber-like features at the site may record other burrowing mammals, perhaps carnivorans.

LATE DEVONIAN FISHES FROM EASTERN GONDWANA (AUSTRALIA, ANTARCTICA) AND THEIR IMPORTANCE IN SARCOPTERYGIAN PHYLOGENY AND BIOGEOGRAPHY

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Three important sarcopterygian groups from the late Devonian of eastern Gondwana are the Canowindridae, Tristichopteridae and Rhizodontida. These taxa are part of the tetrapod stem group, being more closely related to the Tetrapoda than to either lungfish or coelacanths. Recent descriptions of faunas have provided important new morphological information, clarifying relationships within these groups and relative to other stem-tetrapods. Eastern Gondwanan tristichopterids represent the more derived nodes of the group, whereas the rhizodontids represent some of the more basal nodes. A redescription of the antarctic rhizodont *Aztecia mahalae* and a new tristichopterid from eastern Australia confirm phylogenetic affinities with Laurasian taxa, supporting the proximity of Laurasia and Gondwana in the late Devonian, contrary to palaeomagnetic evidence. This may be extended into the middle Devonian, based on a putative relationship between the rhizodonts *Aztecia* and *Sauripterus*, and the position of the Antarctic *Notorhizodon* among Laurasian and Gondwanan taxa within the tristichopterid clade.

GLOBAL DISTRIBUTION OF PERMO-TRIASSIC GENERA OF XENACANTHIFORM CHONDRICHTHYANS

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Triodus teeth bearing cristae on conical cusps occur in the Upper Triassic of North America, Europe, and India. Slightly older teeth with smooth conical cusps ("*Pleuracanthus*" *parvidens* Woodward, probably a new genus) occur in Australia. The next-oldest described xenacanth teeth occur in the Lower Permian of Europe (*Triodus*, *Xenacanthus*, *Orthacanthus*, *Plicatodus*) and North America (*Orthacanthus*, ?*Xenacanthus*, and a new genus [(*Xenacanthus*) *luedersensis* Berman] with cristated conical cusps but lacking an intermediate cusp). Fragmentary material, including a *Xenacanthus* spine, occurs in the Lower Permian of northeastern Brazil. All Permo-Triassic occurrences are freshwater, although some species of *Orthacanthus* (all having carinated compressed cusps, usually serrated) may have entered near-shore marine waters.

Upper Permian xenacanth teeth occur in the Paraná Basin of southern Brazil. *Triodus* teeth are similar to those from the North American Upper Triassic. A new genus is represented by teeth and spines that suggest a relationship to *Orthacanthus*. Teeth assigned to *Xenacanthus santosi* by Würdig-Maciel probably belong to a new genus.

Most of the genera found in the Permian and Triassic appear to be endemic to single present-day continents. *Triodus* and *Orthacanthus* are more widspread, and despite the Brazilian Upper Permian occurrences of xenacanths, reasons for their distribution remain unclear. Their absence from other well-known contemporary vertebrate faunas, such as those from Russia and southern Africa, are unexpected.

STRATIGRAPHIC DISTRIBUTION OF *PTYCHODUS WHIPPLEI*, A LATE CRETACEOUS SELACHIAN FROM THE UNITED STATES

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The holotype of *Ptychodus whipplei* Marcou, 1858 was the first vertebrate fossil described from New Mexico. Our efforts to relocate Marcou's type locality indicate it was in the lower Coniacian El Vado Member of the Mancos Shale in sec. 20, T14N, R10E, northeast of Galisteo, Santa Fe County, NM. Recently discovered New Mexico Museum of Natural History locality L-4705 in the Clay Mesa Member of the Mancos Shale in the Rio Puerco valley of central NM yields the oldest record of *P. whipplei*— ammonite biostratigraphy firmly places this occurrence in the middle Cenomanian. The middle Cenomanian teeth of *P. whipplei* teeth are nearly identical morphologically to the holotype. Late Cenomanian reports of *P. whipplei* from Kansas and Texas are based on teeth of a probable new *Ptychodus* species. The majority of the published occurrences of *P. whipplei* are in Turonian strata in Texas, New Mexico, Colorado, South Dakota, Wyoming and Kansas. There have been very few reports of Coniacian localities, and they are limited to the southern states of New Mexico and Texas. There is a Santonian report of *P. whipplei* from Texas, but it is based on teeth evidently reworked from immediately underlying Turonian strata. The stratigraphic range of *P. whipplei* thus is middle Cenomanian to early Coniacian. *P. whipplei* has long been thought to have evolved from *P. anonymus*. The discovery of middle Cenomanian *P. whipplei* that have nearly identical morphology to the Turonian and early Coniacian forms suggests that *P. anonymus* is not the ancestor of *P. whipplei* but instead a coeval sister species.

AGE DETERMINATION OF *ARCHAEOTHERIUM MORTONI* FROM TOOTH MEASUREMENTS, PIG DIG QUARRY, BADLANDS NATIONAL PARK, SOUTH DAKOTA

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The Pig Dig Quarry, in the Oligocene Brule Formation at Badlands National Park, South Dakota, contains numerous specimens of the entelodont, *Archaeotherium*. To date, twenty individuals of *Archaeotherium* have been found at the Pig Dig Quarry as determined by counting right femora. Of these individuals, 10 crania, 8 mandibles and 3 partial dentaries have been found. These specimens range in age from very young juveniles to old adults.

The purpose of this study is to interpret possible social structure of the *Archaeotherium*. Ages of the specimens at the time of death were approximated based on the measurement of tooth wear. Length, width and height measurements were taken of the upper and lower M1-M3 when available. The height measurements were taken from the enamel/dentine line to the top of the highest cusp. Stages of tooth eruption were also taken into consideration for juvenile specimens. While there is a preservational bias towards isolated teeth, this study will focus on the skulls and jaws only. This will insure that the study group is quantifiably identified. However, a cursory look at the isolated teeth shows representatives of mostly adult and sub-adult specimens.

Preliminary results indicate that all age groups including juveniles, sub-adults, adults and old adults are represented at the Pig Dig site with a slight partiality towards the sub-adults. The presence of a wide range of ages at this locality provides a snapshot of this taxon's social dynamics, and leads us to hypothesize that *Archaeotherium* may have displayed herding behavior.

SEM ANALYSIS OF FOSSILIZED INTEGUMENT FROM LIAONING ORNITHODIRANS

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Feather fossilization generally involves autolithification of bacteria associated with the decaying feather. The lithified bacteria form a mold, which is then infilled after the feather decays. Previously, identification of fossil feathers and reputed feather precursors often has been based on morphology alone. However, the presence of fossilized bacteria may allow for a more accurate identification of fossilized integumentary structures. We used scanning electron microscopy to analyze samples of integument from a variety of ornithodiran fossils (*e.g.*, *Confuciusornis*, *Beipiaosaurus*, *Sinosauropteryx*) from the Yixian Fm., Liaoning, China, to determine the presence or absence of fossilized bacteria. Results of this study are inconsistent with some previous interpretations of feather precursors in a number of Yixian specimens.

THE ECOLOGY OF THE ORIGIN OF TURTLES AS INFERRED FROM FORELIMB MEASUREMENTS

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The ecology of the origin of turtles has received some attention in recent years. According to the two most prominent morphology-based hypotheses, turtles either originated as the sister group of sauropterygians in an aquatic environment, or as the sister group of pareiasaurs or procolophonids in a terrestrial environment. A number of plausible arguments have been made that support an aquatic origin of turtles, thus underlining their alleged diapsid affinities; however, such points of view are purely speculative and cannot be given any weight when choosing between the two competing hypotheses.

Assessing the ecology of ancient turtles has always been problematic because only poor correlations exist between the habitat of a turtle and such commonly used indicators as shell morphology or depositional environment. For instance, highly domed turtles are not necessarily terrestrial (e.g., *Cuora amboinensis*), nor are all terrestrial turtles highly domed (e.g.,

Malacochersus tornieri). This study demonstrates a phylogenetically independent correlation between forelimb measurements and the habitat of extant turtles, which can be used to assess the habitat of fossil turtles. This correlation is probably caused by opposing selective forces that favor short hands in terrestrial environments for walking and long hands in aquatic environments for swimming or "bottom walking". Phylogenetic evidence indicates that these forces work much more effectively on the forelimb than on the hind limb. This method is not capable of distinguishing between marine and freshwater habitats but rather assesses the relative degree of terrestriality of a turtle taxon.

Based on phylogenetic bracketing, the common ancestor of all *living* turtles can be inferred to have inhabited a freshwater aquatic environment. In contrast, the only well known stem turtle, *Proganochelys*, must be considered highly terrestrial based on forelimb measurements. Thus, the ecology of the origin of turtles must currently be optimized as ambiguous, and neither of the two competing hypotheses regarding their origin can be falsified with ecological arguments.

EOMYID INCISOR ENAMEL MICROSTRUCTURE RECONSIDERED—NEW EVIDENCE FOR PHYLOGENY AND BIOGEOGRAPHY

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Eomyids are a family of extinct rodents which are thought to have originated in the late Eocene of North America but recent finds from Kazakstan and China may indicate an Asian origin. In Europe, eomyids first appear in the middle Oligocene and thereafter play an important role in biostratigraphic zonation. For a long time both the relationships between North American and European emomyids and those among the evolutionary lines in Europe have been under discussion. Although the incisor enamel microstructure of eomyids had been studied previously it did not shed light on these questions since the schmelzmuster seemed to be rather uniform.

Intensive study of new incisor material assigned to species from Europe reveals that the eomyid incisor schmelzmuster is more diverse than was previously thought, however. Even a new, highly evolved enamel type was found which proves the existence of at least one of the assumed migration events from North America to Europe. In addition, incisor enamel microstructure for the first time results in new ideas about the phylogeny of European eomyids.

THE CASE FOR *STEGOSAURUS* AS AN AGILE, CURSORIAL BIPED

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The mode of locomotion of *Stegosaurus* is reinterpreted in light of a review of its limb proportions, body shape, dorsal plate distributions, and aspects of its hypothesized neural development.

A striking feature of all stegosaurs is the great disparity in length between fore and hind limbs. Only the habitually bipedal theropods show a greater contrast in limb lengths. Mapping fore and hind limb length ratios, and ratios of trunk length to hind limb length, onto a cladogram for Thyreophora reveals a convergence with agile theropods. Additionally, it is the more derived thyreophorans such as *Kentrosaurus* and *Stegosaurus* sp. that show the greatest tendency of reversion towards bidepality.

The very small head, deep and wide posterior sections of the trunk, and deep muscular tail suggests that stegosaurs evolved this body shape to concentrate the body mass about the hips, and close to the longest limbs. This mass distribution results in the centre of gravity, C.o.G., being just in front of the hips, and greatly reduces the rotational inertia of the body about both transverse and vertical axes—low axial rotational inertia is a hallmark of agile cursors. The series of large bony plates on the back, when carried by a stegosaur in quadrupedal pose, would have the effect of displacing the C.o.G. anteriorly. However, if the animal was walking bipedally, the C.o.G. would be displaced towards and above the hips. This would result in a dynamically unstable body enabling agility.

With just the hindlimbs involved in locomotion, locating the neural tissue close to the main propulsive limbs would reduce nerve impulse travel times, which would have been an important adaptation for these less efficient, secondarily bipedal animals. The small heads of stegosaurs and the resulting small brains necessitated a transfer of neural control to the sacral plexus. The most likely mechanism was a posterior shift of motile neurons along glial tracts during embryogenesis, as occurs in the amniote brain.

THE MUSTERSAN INTERVAL AT GRAN BARRANCA

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The classic sequence of mammalian faunas at Gran Barranca, each with distinctive taxonomic composition, implied the presence of major temporal hiatuses within the Sarmiento Formation. Prior to 1999, the two lowest of these supposed temporal hiatuses were understood to occur between the Casamayoran and Mustersan levels within the Gran Barranca Member and above the Mustersan level within the Puesto Almendra Member. At Gran Barranca, the supposed temporal hiatuses below and above the Mustersan occur without marked erosional topography, nor change in lithology or depositional environment, circumstances that for fine-grained, unconsolidated tuffaceous sediments seems unlikely in view of the global record of climate and sea-level change between the Early Eocene and Late Oligocene. With the benefit of the recent discovery of new intermediate fossil levels, numerous new Ar/Ar age determinations, and more refined magnetic polarity stratigraphy, the unconformities between the Barrancan and "Astraponoteen plus superieur" are best described as parallel disconformities with little or no temporal duration. The temporal interval between the highest Barrancan level and the "Astraponoteen plus superieur" is now known to be on the order of 5 million years (from 38 Ma to about 33 Ma)and nearly all of this interval is represented by fossil-bearing sedimentary rocks at Gran Barranca.

TOWARDS A TOTAL EVIDENCE ANALYSIS OF THE AMPHISBAENIA

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The evolutionary history of the enigmatic, fossorial amphisbaenians has presented a problem for taxonomists and herpetologists for well over a century and has also contributed significantly to the conflict surrounding higher-level relationships among squamates. Despite decades of descriptive, functional, and taxonomic work on this group, no hypothesis of relationships based on an explicit phylogenetic analysis was available until very recently. The first cladistic analysis of amphisbaenian relationships was recently completed on the basis of morphological (mainly osteological) characters and this resulted in a revised classification of the group. However, several interesting problems persist, including conflict between the fossil and extant members of the group, and questions surrounding the origin of the group.

This group of animals poses a classic problem to phylogeny reconstruction due to extreme morphological transformation and due to morphological convergence associated with a fossorial lifestyle occurring in several non-related squamate clades. Therefore, separate sources of evidence such as molecular and behavioral data are highly desirable in order to test morphology-based cladistic results. However, tissues for the collection of molecular data are very difficult to obtain for these animals due to their rarity and the difficulty of collecting them. Techniques for the extraction of DNA from museum specimens are therefore being pursued. Also, independent sources of character data from soft tissues and behavior are expanding the initial data set. The results of phylogenetic analysis of the combined evidence will be discussed.

PREPARATION INNOVATION: PALEONTOLOGICAL PROSTHESES

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Temporary or permanent display of fossil specimens often involves reconstruction of missing or incomplete parts. The Prep Lab at the University of Chicago developed a novel technique while preparing and exhibiting a large specimen of *Sarcosuchus imperator*: fabrication of removable fossil prostheses.

After completely preparing the fossil skull, the missing features were modeled in place on the specimen using plasticene clay. The largest part of anatomy to be reconstructed, the premaxilla, was sculpted around an enlarged casting based on a premaxilla from a slightly smaller individual. Teeth were molded, and casts used to fill empty sockets. The reconstructed skull was then molded. After demolding, the modeled anatomy was cleaned off of the specimen. Resin was cast into the parts of the mold that reflected the sculpted anatomy, and the cured pieces were trimmed to fit onto the parts of the real skull that the clay modeling originally filled. The parts were painted to match the coloration of the fossil. Nuts were embedded in epoxy on the weathered or broken cross-sections of the fossil, so that bolts could be screwed through the prosthetics and into the nuts.

In this way, removable prostheses were created for several missing or damaged areas. Prostheses of this sort are excellent for important fossil specimens that are temporarily or permanently on exhibit. The skull is well displayed for the public while not damaging the specimen for future scientific scrutiny. Certainly, there are unlimited variations in technique and many materials available for use in creating paleontological prosthetics.

A LARGE SKIMMING PTEROSAUR (PTERODACTYLOIDEA, TAPEJARIDAE) FROM THE EARLY CRETACEOUS OF BRAZIL

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A pterosaur skull and mandible (DGM 1476-R; cast MN 6678-V) preserved in a calcareous nodule from the Romualdo Member (Aptian-Albian) Santana Formation, Araripe Basin, sheds new light on the function of cranial crests and the feeding strategy developed by those extinct flying archosaurs. The skull is very large (length: 1420mm) and bears a huge bony cranial crest that starts almost at the tip of the premaxilla and extends well behind the occipital region. This feature, allied with the large nasoantorbital fenestra (48.9% of the pm-sq length) allows its allocation to the Tapejaridae (Pterodactyloidea). The crest builds 3/4 of the lateral skull surface and is formed by the premaxilla, frontal, parietal and supraoccipital, the latter building the ventral edge behind the occipital region. The premaxilla contributes to most of it and, differing from other crested pterosaurs, extends to the posterior end with a "V" shaped termination. This structure likely had multiple functions (e.g., display, aerodynamics), including thermal regulation. The latter is based on the presence of a complex pattern of grooves, reported here for the first time, indicating that this crest was extensively irrigated by blood-vessels and could have acted as a cooling device. The rostrum is made by two blade-like laminae, which is unique among pterosaurs but analogous to the condition found in the bird *Rhynchops* (Laridae, Rynchopini). This avian taxon (wingspan<1m) skims over the water surface preying on fishes and crustaceans. Besides the rostrum, several other anatomical features consistent with this fishing activity (e.g., large occiput with developed muscle scars for powerful neck musculature) are present in DGM 1476-R and strongly support the hypothesis that this new taxon developed this feeding strategy. Within pterosaurs, only the primitive, long-tailed *Rhamphorhynchus* (average wing span: 800-1200mm, largest specimen:1750mm) shows a bony projection on the lower jaw, but among other differences) has the rostral end less developed. Based on other tapejarids, DGM 1476-R had a wingspan of 4200-4500mm, making it the largest skimming creature known to date.

COMPARATIVE TAPHONOMY OF SCREAMING *NEOTOMA* CAVE, EAST-CENTRAL ARIZONA, SOUTHERN COLORADO PLATEAU

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Screaming *Neotoma* Cave (SNC), located in Apache County, eastern Arizona, approximately 1 km east of the Little Colorado River, preserves a complex taphonomic history. SNC lies inside an inactive artesian spring mound formed of Neogene travertine deposits overlying the Chinle Formation. For at least 30,000 years SNC has been a natural trap, collecting faunal remains through several depositional mechanisms.

Two predominant depositional mechanisms were apparent at the site: (1) animals falling into the cave and (2) owl pellet accumulation. Further analysis has revealed diurnal raptors as an additional depositional contributor with the presence of acid-etched bone and fish vertebrae in the cave sediments. Analyses were conducted of both the cave sediments and owl pellets as to: (1) general animal communities, (2) skeletal elements preserved, (3) juvenile to adult ratios, (4) size biases, and (5) degree of preservation. Bone from the cave sediments was additionally analyzed by level to explore variation due to depth and time.

Both depositional settings were screen-washed through a 500 µm sieve to retrieve the smallest skeletal remains; a screen-washing process rarely employed in taphonomic studies. This micro screen-washing provides further understanding of how body size can influence which skeletal elements preserve and their preservation state. This comprehensive taphonomic analysis for this faunal assemblage provides a unique opportunity to reconstruct the depositional history and habitat use of SNC and should also contribute to the growing research in cave taphonomy.

MARINE SHARK AND FISH COPROLITES FROM THE YAZOO CLAY (LATE EOCENE) OF LOUISIANA

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Cartilaginous and bony fish coprolites collected from two localities in the marine clays and marls of the Yazoo Clay (late Eocene) in northeastern Louisiana have been analyzed. Although not common in the sediments, a large number (n=400) of marine coprolites have been obtained as a result of over 25 years of systematic collecting. A detailed description of the coprolites was conducted and included length, width, weight, density, appearance (external and internal when possible), and coloration. Of the total number collected, 370 coprolites were identified from sharks, and 30 were identified from bony fish. The shark coprolites were classified as spiral (168 specimens), scroll (188 specimens), and indeterminate (14 specimens) based on external and internal morphological features. Significant differences existed in the mean length, width, and weight of the spiral and scroll coprolites. The mean densities of the spiral and scroll coprolites were very similar and showed no significant differences. Selected spiral and scroll shark coprlites and bony fish coprolites were examined utilizing x-ray analysis to ascertain possible differences in composition. Results indicated that all of the coprolites consisted of moderately crystalline calcium fluoride phosphate (fluorapatite) with essentially no differences in the compositions.

Most previous studies of shark coprolites have not attempted classification more specific than the class because it is extremely difficult to relate shark coprolites to genera or even families. However, previous studies at the localities that included extensive collecting of shark teeth combined with information on modern shark anatomy allow for a more specific identification of the shark coprolites. The most likely originators of the spiral coprolites were the lamniform *Isurus praecursor* and the carcharhiniform *Abdounia enniskilleni*. The scroll coprolites were most likely related to the carcharhiniform *Carcharhinus gibbesi* with the exception of several large specimens, which may be related to *Galeocerdo latidens*.

NEW CERATOPSID CRANIAL REMAINS FROM THE LOWER CAMPANIAN WAHWEAP FORMATION, GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, UTAH

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Recent fieldwork in the lower Campanian Wahweap Formation of Grand Staircase-Escalante National Monument (GSENM) has resulted in the discovery of three specimens of ceratopsid dinosaurs. These specimens represent the first well-preserved ceratopsids from this formation, and some of the earliest fossils known for this group. Two partial skulls are from the upper part of the lower sandstone member of the Wahweap Formation, and were found as the largest elements of bone clast lags in channel sandstones. The first specimen consists of a mostly complete centrosaurine skull. Although mechanical weathering prior to discovery resulted in destruction of the anterior portion of the facial skeleton, this specimen includes most of the remainder of the skull, including part of a supraorbital horncore, complete squamosal, and partial parietal. The skull measures 75 cm from the rear of the preserved portion of the parietal to the anterior margin of the maxilla, resulting in an estimated total skull length of approximately one meter. The short, rectangular squamosal (characteristic of centrosaurines) lacks preserved epoccipitals though they are present on the parietal. Relatively large parietal fenestrae are present. A second skull, recently discovered at about the same stratigraphic level several kilometers to the east, may be the most complete of the three specimens. Although unprepared, the specimen is at least 90 cm in length, with an occipital condyle measuring 4 cm in diameter. The skull possesses relatively elongate, upright supraorbital horns. Once fully prepared, the specimen will likely represent a new species, and perhaps the first ceratopsid to be formally described from the lower Campanian of North America. A partial parietosquamosal frill bearing large, elongate and fused epoccipitals was recovered from the upper sandstone member of the Wahweap Formation. The elongate epocipitals suggest that it is a chasmosaurine. It would seem to represent a significantly larger skull than those from the basal Wahweap. These discoveries demonstrate the great potential for GSENM to yield important new materials of dinosaurs from this poorly known time interval.

FIRST RECORD OF PHYTOSAURS IN THE UPPER TRIASSIC OF SOUTH AMERICA

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Phytosaur fossils are known from North America, Europe, India, Thailand, Turkey, North Africa and Madagascar, but no diagnostic phytosaur material has been described from the long known and extensive Upper Triassic tetrapod faunas of Brazil and Argentina. We document the first South American record of phytosaurs, a specimen from the upper Carnian (Adamanian) Caturrita Formation at the Botucarai locality, Rio Grande do Sul, Brazil. The phytosaur fossil is a snout fragment and 7 other disarticulated fragments. Points of detailed resemblance to Chinle Group phytosaur jaws are: (1) long, parallel-sided tooth rows; (2) numerous, closely spaced, bicarinate, serrated and asymmetrical teeth with nearly round basal cross sections; (3) thecodont implantation; (4) long and large rostrally converging splenials that medially separate the dentaries on ventral surface; and (5) external surface of dermal bones ornamented by diffuse pattern of parasagittally-oriented grooves and pits. The Brazilian fossil displays 3 characters that are uniquely derived features of phytosaur lower jaws: (1) a symphyseal platform, which is the long, flat, horizontal plane formed by the dorsal aspect of the mandibular symphysis; (2) an alveolar ridge and intermaxillary groove; and (3) labiolingually asymmetric teeth, a feature unique to phytosaurs among archosauromorphs. The presence of these apomorphies of phytosaurs in the Brazilian fossil demonstrates that it is a phytosaur, and not another long-snouted archosauromorph, such as a proterochampsid.

The previous absence of phytosaurs in South America has generally been attributed to facies differences, with the South American Triassic tetrapods supposedly coming from drier or upland habitats in which phytosaurs did not live, or to paleolatitudinal (paleoclimatic) differences between Late Triassic tetrapod faunas north and south of 30 degrees south paleolatitude. These previous explanations of the absence of phytosaurs in Late Triassic South America can now be abandoned.

A NEW DIADECTID (TETRAPODA: DIADECTOMORPHA) FROM THE LOWER PERMIAN OF GERMANY

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Located within the Upper Rotliegend (Lower Permian) Tambach Formation of central Germany, the Bromacker locality has produced a unique assemblage of terrestrial vertebrates that is characterized by the relative abundance of diadectid fossil remains, with one species, *Diadectes absitus*, described thus far. Reported here is the presence of a second diadectid taxon. This new form is known from three complete skulls with associated postcranial skeletons, two of which are articulated and nearly complete, and an isolated tooth-bearing jaw fragment. The skull is relatively longer and lower than that of *Diadectes*, with the mediolateral width and dorsoventral height of the skull increasing only slightly posteriorly. As in all diadectids, the upper and lower marginal dentitions include transversely expanded, molariform-like cheek teeth, but those of the new form are distinctly different in that: 1) the long axis of each tooth is more strongly angled away from the transverse plane; 2) they are much thinner in longitudinal width and more closely spaced; and 3) the medial and lateral shoulder-like cusps are significantly reduced, producing a high, triangular, spade-like crown. A secondary palatal shelf formed by the ectopterygoid and palatine, a unique hallmark feature of diadectids in which the palate is adequately known, is absent. The recognition of this new form and its abundance at the Bromacker quarry further establishes the herbivorous Diadectidae as a dominant component of the Bromacker assemblage.

CHIROTHERIANS AND GRALLATORIDS FROM LOWER TO UPPER TRIASSIC DEPOSITS IN CENTRAL EUROPE

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Triassic outcrops in southern Thuringia and northern Bavaria, Germany, display an outstanding, complete record of tetrapod tracks in marginal sequences of the Buntsandstein, Muschelkalk and Keuper. The track bearing marginal facies of fine to coarse-grained sandstones of the Germanic Basin was paleogeographically distributed along the western slope or coastline of the Vindelician-Bohemian Massif. Extensive track surfaces of fluviatile sand-siltstone complexes are recorded from 10 horizons within the Solling Formation of the Buntsandstein up to the Loewenstein Formation of the Middle Keuper, strata of Olenekian to Norian age. Recent investigation closed a former gap in the succession of the track record by the discovery of track horizons in siliciclastic equivalents of the Muschelkalk. The dominant elements at all surfaces are footprints of archosaurs—the ichnogenera *Chirotherium, Isochirotherium, Brachychirotherium, Synaptichnium, Sphingopus, Rotodactylus, Parachirotherium, Atreipus* and *Grallator*. The vertical succession of the ichnofaunas shows a stratigraphically significant content of archosaur track types. A character-analysis of track morphology and trackway pattern compared with the known skeletal foot morphology and overall anatomy presents significant track evidence for the transition from Dinosauromorpha to Dinosauriformes to early Dinosauria during the time period from Olenekian to Carnian.

THREE-DIMENSIONAL COMPUTERIZED RECONSTRUCTIONS OF THE EMBRYONIC CHONDROCRANIUM OF *SPHENODON PUNCTATUS*

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Sphenodon, as the only survivor of the formerly much more diverse Rhynchocephalia, is regarded as an "archaic" diapsid that still retains the primitive morphology of the temporal region of the skull with the associated soft tissue structures. *Sphenodon* is thus by preference employed for outgroup comparison to polarize character state transformations in phylogenetic studies of not only its sister group Squamata, but of all diapsids.

However, despite many studies on the anatomy of *Sphenodon* confusion about the homologies of the trigeminal and facial innervated muscles groups still persist. To clarify the relationships of these muscle groups and the innervating nerve branches, three-dimensional computerized reconstructions of a complete, nearly fully developed chondrocranium of *Sphenodon punctatus* are presented, including all soft- and hardtissue structures such as bones, cartilage, muscles, blood vessels and nerve branches. Special attention is given to the orbito-temporal region with particularly detailed reconstructions of the trigeminal and facial nerve branches and the innervated muscles groups. The reconstructions of the entire chondrocranium of *Sphenodon punctatus* are employed to test homologies of muscle groups and their relationship to the trigeminal nerves that are traditionally regarded as landmarks.

The trigeminal-innervated muscle groups in the chondrocranium of *Sphenodon punctatus* could not be identified by the spatial configuration of the trigeminal nerve branches and muscles in the orbito-temporal region, but differs substantially from descriptions of these structures in the adult skull of *Sphenodon punctatus*. This suggests that nerves may not always represent the reliable landmarks they are usually taken for, because they may shift position during ontogeny. The reconstructions document the soft- and hardtissue morphology of this intriguing and phylogenetically crucial species. These findings can be further employed for anatomical reconstructions in extinct rhynchocephalians and basal diapsids.

COMPARISON OF VERTEBRATE MICROFOSSIL COLLECTION METHODS IN THE LATE CRETACEOUS HELL CREEK FORMATION OF NORTH DAKOTA: SURFACE COLLECTION VS. SCREEN WASHING

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For the past fifteen years, geologists and paleontologists have extensively studied the Late Cretaceous Hell Creek Formation of southwestern North Dakota. This work has produced a high-resolution stratigraphic framework in which numerous fossil sites have been tied to the K/T (Cretaceous/Tertiary) boundary. Microfossil sites consisting of teeth and small bone accumulations have been surface collected by the Pioneer Trails Regional Museum (PTRM). However, sole reliance on this collection method may bias the fossil sample. This study compared fossil collections produced by surface collection and screen washing of bulk sediment from the same sites. A coarse screen size of 3.30 mm was used in conjunction with a fine screen of 0.425 mm. It was hypothesized that each collection method would sample different elements of the fauna. Two sites were evaluated in this study: PTRM V86002 and PTRM V89003.

PTRM V86002 produced 1,180 specimens in eight seasons of surface collection. Screen washing of 167 kg of sediment has produced 489 specimens to date. PTRM V89003 produced 715 specimens in eight seasons of surface collection. Screen washing of 140 kg of sediment has produced 1,642 specimens to date. Both sites show marked disparity of faunal proportions between the two collecting methods. Sharks were 60 percent of the screen washed specimens in PTRM V86002, while they represented one percent of the surface collected specimens. In PTRM V86002, dinosaurs represented one percent of the screen washed specimens and 28 percent of the surface collected specimens. Similar variations also occurred in PTRM V89003. Here, sharks represented 23 percent of the screen washed specimens and one percent of the surface collected specimens. Dinosaurs represented less then one percent of the screen washed specimens in V89003 and 24 percent of the surface collected specimens. These differences could result from collection bias, erosional bias, or unknown factors. Reliance on one method of collection could severely bias paleoecological interpretations.

NEW FIELD WORK IN THE UPPER TRIASSIC-LOWER JURASSIC OF LESOTHO: PRELIMINARY RESULTS

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Field work conducted by the Muséum national d'Histoire naturelle de Paris in Lesotho (southern Africa) during austral winter 2000 and 2001 provide new data on the paleontology and ichnology of the 'Stormberg Group' of the Karoo Basin. The campaign was led in western and southern Lesotho from Morija (Maseru District) to Qacha's Nek (Qacha's Nek District) areas. All the three formations of the 'Stormberg' (Molteno, Elliot, and Clarens sandstone formations) were prospected. The Molteno Fm. has only yielded poor plant remains at Morija. All identifiable specimens from the Lower Elliot Formation consist of large prosauropod bones among which is part of the hind limbs of an individual found at Likhoele Mountain (Mafeteng District). The Upper Elliot Fm. has revealed a much more diversified fauna. Many prosauropod remains of heterogeneous size have been excavated at this horizon. The most interesting prosauropod specimen is what may be a baby, including part of the skull, found at Likhoele. The cynodonts are represented by a complete skull with mandibles of a presumable tritylodontid (Likhoele) and a partial skeleton with the skull of a possibly new tritheledontid (Thabana Morena, Mafeteng District). Besides prosauropods and cynodonts, a few specimens still awaiting identification were also collected (in particular at Likhoele). New vertebrate (mainly dinosaur), as well as invertebrate, traces were brought to light in the Morija area and at Likhoele. The Clarens Fm. only yielded unidentifiable fragmentary bones and invertebrates traces at Likhoele. The supremacy of prosauropods in the Lower Elliot Fm. is particularly striking in the field. This is considered an argument of correlation with the Apachean LVF. Therefore, contrary to previous statements, the Lower Elliot Fm. is most likely not older than Late Norian.

A NEW PRIMITIVE ORNITHOMIMOSAUR FROM THE EARLY CRETACEOUS OF MONGOLIA AND THE EARLY EVOLUTION OF ORNITHOMIMOSAURIA

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The disarticulated skeleton of a non-ornithomimid ornithomimosaur was found at Khuren Dukh, south of Ulaan Baatar, Mongolia, in the Lower Cretaceous conglomeratic sandstone. The material includes most of the postcranial elements from a single individual; a sub-adult based on its unfused neurocentral sutures. It is relatively uncrushed compared to the other Early Cretaceous forms (*Pelecanimimus* and *Harpymimus*), allowing us to understand its anatomy and to compare it with other primitive ornithomimosaurs.

The Khuren Dukh ornithomimosaur shows affinities with other Mongolian non-ornithomimid ornithomimosaurs. In the new taxon, the proximal end of metatarsal III is exposed anteriorly (non-arctometatarsalian condition) as in *Harpymimus* and *Garudimimus*, the first pes digit is present as in *Garudimimus*, strong flexor tubercles occur on the pedal unguals, and like *Harpymimus*, short prezygapophyses occur on the caudal vertebrae.

A phylogenetic analysis of Ornithomimosauria (eleven ornithomimosaur taxa) using 26 cranial and 18 postcranial characters supports the monophyly of Ornithomimidae, which consists of all the Late Cretaceous taxa except *Garudimimus*. The Khuren Dukh ornithomimosaur is more derived than *Pelecaniomimus* and *Harpymimus* but is more basal to the clade of *Garudimimus* and Ornithomimidae. The character distribution in the analysis shows that the features in the Khuren Dukh ornithomimosaur, mentioned above, are plesiomorphies in Ornithomimosauria and are lost in Ornithomimidae. Some previous studies suggest that Tyrannosauridae, Troodontidae, and Ornithomimosauria form a monophyletic Arctometatarsalia, in which the arctometatarsalian condition is one of its synapomorphies. This further would indicate that the non-arctometatarsalian condition in primitive forms is a reversed acquisition; however, the phylogenetic analysis in this study implies that the arctometatarsalian condition evolved convergently in Ornithomimosauria.

DENTAL FORMULA AND TOOTH REPLACEMENT PATTERN IN *DESMOSTYLUS* AS REVEALED BY HIGH-RESOLUTION X-RAY CT

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The enigmatic Miocene North Pacific tethythere *Desmostylus* species are characterized by the columnar "desmostylodont" cheek teeth with elephant-like sequential eruption of molars during life. Because of this peculiarity, the dental formula, especially the numbers of incisors and premolars, and the patterns of tooth replacements have not been fully understood. Examinations of the re-prepared holotype of *Desmostylus japonicus* from Japan as well as ontogenetically successive individuals of *D. hesperus* from Japan, California, and Oregon using high-resolution X-ray CT reveal that the dental formula of *Desmostylus*, previously considered as 0.1.3.3/1.1.3.3, should be 0.1.2.3/2.1.2.3 for *D. japonicus* and 0.0.2-1.3/2.1.1.3 for *D. hesperus*, respectively. The same sample also reveals that the lower second, third incisors and canine and also independently the premolars might have erupted sequentially just like the molars throughout their life. Although they were distinctly diphyodonty, this sequential eruption of both first and second generation teeth led the under- and over-estimate of incisor and premolar numbers in the previously suggested dental formula of *Desmostylus*.

LATE PALEOCENE ARCTOSTYLOPIDAE (MAMMALIA, NOTOUNGULATA) FROM MONGOLIA

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The rich mammalian fauna from the Zhigden and Naran members of the Naran Bulak Formation at Tsagan Khushu and Naran Bulak localities includes several hundred jaws of representatives of the Arctostylopidae. Arctostylopids are known from both Asia and North America. Two species of the genus *Paleostylops* were described from the Gashato Formation in Mongolia: *P. iturus* and *P. macrodon*. Cifelli et al. later referred *P. macrodon* to a separate genus, *Gashatostylops*. The same authors proposed non-notoungulate affinities of arctostylopids and assigned them to a new order, Arctostylopida. Based on the study of hundreds of specimens from Mongolia and China housed at the Paleontological Institute, Moscow and American Museum of Natural History, New York, we offer the following conclusions: (1) *Gashatostylops* is a subjective junior synonym of *Palaeostylops*, so *"G." macrodon* should be *P. macrodon*; (3) *P. macrodon* and *P. iturus* are valid species that can be distinguished based on their size; (4) *P. iturus* is most abundant in the Zhigden Member of the Naran Bulak Formation, which is older than the Naran Member; (5) *P. macrodon* is more abundant in the Naran Member; (6) *P. iturus* and *P. macrodon* thus can serve as index fossils for the Gashatan land-mammal "age," and the former can indicate an older, Zhigden-equivalent interval, whereas the latter indicates a younger, Naran-equivalent interval; (7) based on the analysis of the dental and ankle characters and tooth wear patterns, we consider Arctostylopidae a family within Notoungulata and thus abandon the term Arctostylopida.

A COMPARISON OF THE PELVIC GIRDLE FROM A NEW JUVENILE HYPSILOPHODONTID FOUND IN THE MORRISON FORMATION OF NORTHEASTERN WYOMING TO DESCRIBED SPECIMENS

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In 1997 the University of Kansas collected several Late Jurassic dinosaurs from the Morrison Formation in northeastern Wyoming. One of the specimens collected is clearly a hypsilophodontid and a juvenile due to the neural spines being completely detached from the vertebral centrum, is similar to *Othinella rex* in having an utmost proximal position of the obturator process. When compared to the Early Cretaceous juvenile *Hypsilophodon foxii* specimens described by Galton, the Wyoming specimen differs in lacking striations on the prepubic process and the proximal position of the obturator process. Galton's specimens show both an open and closed condition for the pubic process. The Wyoming specimen has a closed pubic foramen, although it seems more juvenile than any of the specimens described by Galton.

NEW FOSSIL LAGOMORPH MATERIAL FROM THE HSANDA GOL FORMATION, VALLEY OF THE LAKES, MONGOLIA

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In 1922 and 1925 the American Museum of Natural History (Central Asiatic Expedition) conducted the first fossil expeditions within the Oligocene and Miocene of Mongolia. Since that time numerous paleontological expeditions have continued work within central Mongolia. Through a joint American-Mongolian effort (Mongolian-America Expeditions (MAE)), fieldwork resumed during 1991. Material described here was collected during 5 expeditions completed since renewed efforts began by the MAE. To date, nearly 14,000 specimens have been collected and curated. Although full faunal analysis is still underway, I present here previously undescribed lagomorph material from the Oligocene Hsanda Gol Formation. Radioisotopic dating of the Khoroo Lava Member placed the formation within the early Oligocene (28.5-33.5 Ma). Analyses were conducted on over 700 lagomorph specimens from 3 localities within the Hsanda Gol Formation; Sota, Tashgain Bel, and Dike localities. The Sota locality is stratigraphically high, the other two are lower. The exceptional quality and abundance of the sample allows for the first population-level assessment of Oligocene lagomorphs from this area. Among the patterns are the abundance of *Desmatolagus* at all localities, and the occurrence only at one of the stratigraphically low localities of a highly derived ochotonid. Upper and lower jaws of this ochotonid may be attributable to *Ochotonalagus argyropuloi*, a previously described species or a previously undescribed species. This appearance is particularly interesting in light of the geographic location, which may be near the cradle of ochotonid origins.

FIRST DEFINITIVE RECORD OF PRE-LATE PLEISTOCENE LIZARDS FROM MADAGASCAR: A ?CORDYLID CORDYLIFORM FROM THE UPPER CRETACEOUS MAEVARANO FORMATION, MAHAJANGA BASIN

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We report here the first unequivocal record of a pre-Late Pleistocene lizard from the island of Madagascar, based on a partial skeleton including a nearly complete lower jaw, elements of both the pectoral and pelvic girdles, several vertebrae and ribs, and numerous osteoderms. The specimen, recovered from the Upper Cretaceous (Maastrichtian) Anembalemba Member, Maevarano Formation, Mahajanga Basin, northwestern Madagascar, is identified as a scincoid scincomorph and, more specifically, as a new genus and species of ?Cordylidae (Cordyliformes). This new taxon represents the first identifiable lizard from the Late Cretaceous of Africa.

The new taxon, if correctly attributed to the Cordylidae, constitutes a significant temporal and geographic range extension for the clade since cordylids have no definite representatives in the fossil record and extant forms are restricted to sub-Saharan Africa. Its presence indicates that cordylids, after their occurrence in the Maastrichtian, became extinct on Madagascar, leaving only zonosaurine Gerrhosauridae as extant representatives of Cordyliformes on the island. Owing to limited knowledge concerning the time of divergence for cordylids and gerrhosaurids relative to the tectonic separation of mainland Africa and Madagascar, and in light of the paucity of Mesozoic lizard fossils in general, and from Gondwana in particular, the discovery of the new taxon in the Late Cretaceous of Madagascar does little to otherwise contrain scenarios concerning the biogeographic history of early cordyliforms.

Lizards appear to have been much less speciose than snakes in Late Cretaceous faunas of Gondwana, whereas the reverse is true in Laurasia.

CLAW GEOMETRY IS AN INDICATOR OF THE TERRESTRIAL HABITS OF PTEROSAURS

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The geometry of bird claws has been shown to be correlated with birds' habits. Significant differences exist in the amount of arc described by the pes claws exist between walking, perching, and climbing birds, regardless of their taxonomic affinities. We have expanded on this work to include additional groups of birds (seabirds and wading birds) and bats and here use this expanded database to interpret the terrestrial habits of pterosaurs based on their claw morphology.

A study of over 100 pterosaur specimens from museums in Germany, London, and New Haven revealed some distinctive patterns. A significant difference was observed between the manus claws of rhamphorhynchoids and the pterodactyloids, with the rhamphorhynchoids showing a significantly greater claw curvature, but not between the pes claws of the two groups. Both groups exhibited mean pes claw measurements within the range typical of walking birds (rhamphorhynchoids, mean 76°; pterodactyloids, mean 73°) while their manus claws were in the range for perching birds or raptors (rhamphorhynchoids, mean 118°; pterodactyloids, mean 100°). In bats, which primarily hang from their feet, but also use their thumb claws in moving on the branches, it was found that both pes and manus claws exhibit a high degree of curvature (mean = 125°) while in pterodactyls the pes claws are significantly straighter than the manus claws. It appears that while manus claws could have been suitable for perching in trees the foot claws would not have been useful for such an activity. Based on claw geometry it seems unlikely that pterosaurs were arboreal in habit. We suggest a model of pterosaur locomotion in which they primarily engage in a bipedal walking habit on the ground and use their manus claws for prey manipulation.

LATE CRETACEOUS FISH FAUNAS FROM THE ANTARCTIC PENINSULA

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Late Cretaceous fishes from Antarctica are not well known. So far, Late Cretaceous fish remains have been recorded from several localities on NW James Ross Island (Santa Marta Fm., Santonian–uppermost Campanian/early Maastrichtian) and Seymour Island (López de Bertodano Fm., mid-Maastrichtian and K/T boundary). Examination of new fossil fish remains recovered from the Late Cretaceous of James Ross Island allows reconstructing the Late Cretaceous fish assemblages in more detail. The material comes from the Asociación VII (uppermost part of the Beta Member below the base of the Gamma Member) and the Asociación Superior (Gamma Member). A late Campanian age is confirmed for the Asociación VII, whereas Asociación Superior is of latest Campanian to earliest Maastrichtian age based on ammonite associations. The fish material from the Beta Member consists mainly of isolates vertebrae and scales of teleosts, which are associated with abundant plant remains. A conglomeratic bed at the base of Asociación Superior (Gamma Member) yielded isolated teeth of selachians and teeth, bones, and scales of actinopterygians. New material of the selachians *Chlamydoselachus thomsoni* and *Notidanodon dentatus* gives new informations of their stratigraphic range. The presence of the lamniform *Scapanorhynchus* in Late Cretaceous strata of the Antarctic Peninsula is reported for the first time. Other material represents several taxa of selachians (e.g., *Squatina*) and teleosts. The diversity of the Late Cretaceous Antarctic fish faunas and their relationships to other southern hemisphere associations (e.g., Argentina) is discussed. The temporal and geographical distribution of these taxa provides new paleozoographic and paleoenvironmental informations.

CYANO ACRYLATES: MY OWN EXPERIENCES; THE GOOD, THE BAD, AND THE UGLY

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This poster will further demonstrate that any use of CyA on vertebrate paleontological specimens should be done so with extreme care. Photographs will help to show the use/misuse of a sometimes helpful product. The removal of excessively applied CyA was performed and documented at USNMNH on a specimen of *Odobenocetops peruvianus*. Coincidentally salts had to removed from all of the bones through typical methods but only after CyA was successfully removed because the salts were essentially trapped by the CyA. The title is of course from the 'Spaghetti western' with Clint Eastwood and Lee van Cleef but pertains directly to The Good (use of CyA); which actually enabled the specimen to be collected in Peru, I assume there were no other consolidants available; The Bad (use of CyA) as other consolidants would have served better as a field preservative; and The Ugly (use/removal of CyA) and it is an ugly, ugly job, back in the lab to allow further preparation, scientific study, molding and casting on a very important whale from the salt deserts of Western Peru. Limited successful CyA use at USNMNH is also documented and reported here.

FOSSIL VERTEBRATES FROM THE GANNETT GROUP (KIMMERIDGIAN-APTIAN) OF EAST IDAHO

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The Gannett Group occurs in eastern Idaho and western Wyoming and represents primarily terrestrial deposition from the Late Jurassic through the Early Cretaceous. Defined in 1927, the Gannett Group has never been systematically surveyed for fossil vertebrates. But previous scattered reports do indicate the presence of fragmentary dinosaur remains. Recently discovered localities in the Caribou Range of east Idaho indicate the presence of various vertebrate and invertebrate faunas. One locality appears to represent a nearshore environment and contains the remains of pycnodontid fish (?*Lepidotes*), crocodyliforms, turtles, sharks, a possible dinosaur trackway, gastropods, ostracods, bivalves and fragmentary plant remains. A nearby locality contains the remains of crocodyliforms, turtles, lizards, unidentified bone fragments and gastropods. Ongoing research at known localities and the search for new localities promises to add significantly to our knowledge of the Late Jurassic/Early Cretaceous of Idaho and western North America.

FOSSIL SNAKE ASSEMBLAGE FROM THE UPPER CRETACEOUS OF MADAGASCAR.

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Cretaceous strata from Madagascar have previously produced a single species of snake: the giant madtsoiid, *Madtsoia madagascariensis.* Recent collections by David Krause and others from the Mahajanga Basin have provided additional snake material, including at least three newly recorded taxa. Material of *M. madagascariensis* in the new collections allows for a more detailed description of the species, including previously unreported skeletal elements.

Newly reported taxa include *Madtsoia* cf. *M. laurasiae*, *Madtsoia* sp. indet., and an undescribed genus and species of nigerophiid. Most of the recovered material represents

Madtsoia madagascariensis. Much intracolumnar vertebral variation can here be described for the first time, with anterior, middle and posterior trunk vertebrae as well as single cloacal and caudal elements present. *Madtsoia* cf. *M. laurasiae* is moderately abundant, and includes a partial skeleton with vertebrae, ribs and a basioccipital. A single vertebra represents an indeterminate species of madtsoiid. Two vertebrae, one in nearly perfect condition, represent an undescribed species of nigerophiid.

This is one of only five reports of multispecies terrestrial snake assemblages from the Mesozoic. Three of the others are also Gondwanan. The present assemblage bears some resemblance to others reported from mainland Africa and India. Thus the occurrence of *Madtsoia* cf. *M. laurasiae* on Madagascar is not surprising. However, The presence of this same species, or one that is currently indistinguishable from it, in Europe, is remarkable.

In view of the fact that most Mesozoic snake fossils are Gondwanan, and represent extinct higher taxa, the further elucidation of the early evolution of terrestrial snakes will likely depend on continued exploration of the Mesozoic fossil bearing strata of Gondwanaland.

VARIATION AND DIAGENESIS OF THE OXYGEN ISOTOPIC SIGNATURES IN INCREMENTAL GROWTH OF CENOZOIC SHARK CENTRA

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The application of stable isotopes to vertebrates has rapidly become widespread within the past two decades. So far, most of these studies have been on teeth and terrestrial vertebrate bone. Fossil bone studies are rare compared to tooth enamel studies due to the problem of potential diagenesis in porous bone. This study seeks to characterize and quantify the extent of diagenesis developed in fossilized lamnoid shark centra, which grow incrementally, and to develop criteria in which the oxygen isotopic signal can be used to age fossil lamnoid sharks. Three centra from the Eocene shark, *Otodus obliquus*, will be used to determine (1) whether diagenesis is variable within an individual, (2) how diagenesis affects the $\delta^{18}O$, (3) if the $\delta^{18}O$ along the growth axis is consistent within an individual, and (4) if the $\delta^{18}O$ variation, which represents the warm and cold seasonal cycles, can be used for age determination in fossil lamnoid sharks. The ontogenetic age established from the $\delta^{18}O$ variations along the growth axis will be compared to the ages counted on contact prints of each of the three centra. Contact prints are produced from x-rays taken of each of the centra and clearly show characteristic light and dark alternating growth rings. The counts on the contact prints will be used to cross-check the age determination based on the $\delta\ ^{18}O$. The techniques developed in this new application of $\delta^{18}O$ will allow for the study of heterochrony, i.e. the evolution of longevity and growth rates, of fossil vertebrates in which incremental bone growth is preserved.

WHO KILLED *MAMMUTHUS*? AN ALTERNATIVE SCENARIO OF SABERTOOTH CAT ATTACK

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A widely supported scenario of the killing attack exhibited by sabertooth cats (e.g., *Smilodon*) posits a modified version ("canine shear-bite") of that used by extant large felines. The present study offers an alternative mode, "stabbing and slicing". This idea, proposed in part long ago, was criticized because of the presumed risk of breakage of the upper canines ("sabers"). The scenario proposed herein envisions the sabertooth attacking with the lower jaw fully elevated, leaving only about half the saber exposed. The exposed part of the saber would measure perhaps 6-7 cm, likely sufficient to penetrate the thick skin of a large prey animal such as the proboscidean *Mammuthus* and to continue for 4-5 cm into muscle. This distal half of the saber is the only part of the tooth encased by enamel. A stab to the hindquarters of the prey after the initial leap by the sabertooth would shift to slicing as the predator descended to the ground. The slicing action would cut the vertically oriented musculature probably easily, and the skin, tightened by pressure from the appressed mandibular flanges and the prognathous incisor batteries (and/or by a stout pad possibly present on the anterior face of the mandibular symphyseal region), would be sliced from the inside by the downward-curved sabers. The lower jaw, in its elevated position would limit and control penetration of the prey by the sabers. The sabers could be disengaged quickly at any time by depressing the lower jaw a short distance. Several such attacks to the rump of the prey by members of a group of sabertooths surrounding the prey likely would have disabled it. Once the prey was brought to the ground, the same adaptations facilitating stabbing and slicing would allow the sabertooth to create strips of skin and muscle that could be torn from the prey by means of the prognathous incisors that extend beyond the sabers. Numerous features of the skull and postcranial skeleton appear adapted to forceful stabbing, slicing, and pulling. The primary prey of sabertooths probably was adult proboscideans and other large mammals that may have been safe from all other predators.

CONCENTRATION AND PRESERVATION POTENTIAL OF VERTEBRATE FOSSILS WITHIN COASTAL LITHOSOMES: EXAMPLES FROM THE UPPER CRETACEOUS BAHARIYA FORMATION OF EGYPT

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The sea level highs of the Jurassic and Cretaceous inundated vast continental regions, creating unprecedented and unsurpassed areas of coastal environment. These epeiric coastlines were flanked by barrier islands, herbaceous salt marshes, and mangroves. Coastal ecosystems were possibly the most productive non-marine biomes during the Mesozoic and were inhabited by dinosaurs and other vertebrates.

The ability of coastal lithosomes to concentrate and preserve significant quantities of vertebrate fossils is evident in Upper Cretaceous Bahariya Formation (Egypt) mangrove system deposits. This formation preserves a rich faunal record in which dinosaurs (*Paralititan*, *Aegyptosaurus*, *Carcharodontosaurus*, *Bahariasaurus*, and *Spinosaurus*), a diverse fish assemblage, crocodilians, and turtles are represented.

There is significant variance between Bahariya Formation lithosomes with respect to concentration of fossil material and degree of bone association. This reflects the wide variety of hydraulic conditions under which coastal facies are deposited. Additionally, the preservation potential of coastal lithosomes themselves varies greatly by environment. As marine transgression proceeds across the coastal plain, a ravinement surface, created by breaking waves, "bevels off" all higher pre-existing deposits. As a result, there is a strong correlation between the depth of depositional sub-environment and long-term preservation potential.

SKELETAL ANATOMY OF THE GIANT TITANOSAUR *PARALITITAN* (DINOSAURIA: SAUROPODA) FROM THE EARLY LATE CRETACEOUS OF EGYPT

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Continued study of the holotype of the giant titanosaur *Paralititan stromeri* from the Upper Cretaceous (Cenomanian) Bahariya Formation of Egypt has provided additional information regarding its anatomy and evolutionary affinities. Known skeletal material includes a dorsal centrum, dorsal neural arch, dorsal ribs, two fused caudal sacral centra, right sacral rib 6, first and second caudal vertebrae, scapulae, right coracoid, a probable sternal plate fragment, humeri, radius/ulna fragments, right metacarpal II, right ilium, and left ischium. Cancellous tissue is preserved in the dorsal centrum and probably the ilium. The dorsal neural arch possesses centropostzygapophyseal, posterior centroparapophyseal, and multiple diapophyseal laminae. Dorsal ribs are apparently hollow. The neural spine of the first caudal preserves robust laminae on its lateral surfaces, as well as postspinal and spinopostzygapophyseal laminae. A lamina on the dorsal surface of the transverse process connects the distal extremes of the prezygodiapophyseal and posterior centrodiapophyseal laminae of the first caudal. Well-defined foramina are present ventral to the caudal transverse processes, a character previously postulated as an autapomorphy of *Alamosaurus*. The scapula possesses a dorsomedial prominence, as in several saltasaurid titanosaurs, and an additional medial eminence more distally, near the dorsoventral midpoint of the blade. The coracoid has an infraglenoid lip and a craniomedially positioned foramen. The sternal plate fragment preserves a craniodorsal ridge, as in several titanosaurians.

Several skeletal elements in *Paralititan* are approximately 20-30% larger than corresponding material in USNM 15560, a large saltasaurid skeleton referred to *Alamosaurus*, further establishing the exceptional size of the Egyptian sauropod. Improved resolution of the phylogenetic position of *Paralititan* will provide insight into the poorly known paleobiogeographic affinities of Late Cretaceous Africa.

LOOKING BACK AT THE RECORD: G.G. SIMPSON AND PALEOMAMMALOGY

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At age 74, George Gaylord Simpson (1902-1984) observed that he had been "unable to work steadily on one subject or even in a single field," yet was clearly pleased by all that he had accomplished ("The compleat paleontologist?," 1976). A quarter of a century later, one must agree with that personal judgment for two reasons. First, Simpson's contributions catalyzed the belated reconciliation of paleontology with contemporary biology. Second, they had great heuristic value in serving as guides to subsequent research for the discipline.

Using the rubrics from Simpson's own retrospective assessment, we can briefly summarize his contributions as follows. Methodology—using biostatistics to describe fossils, thereby moving from the typological to populational approach to characterize species (e.g., *Quantitative Zoology*, 1938). Evolution—refuting internal evolutionary mechanisms (such as aristogenesis, orthogenesis, inertia, and momentum) and embracing modern population genetics and ecology to interpret rates and patterns of micro- and macroevolution (e.g., *Tempo and Mode in Evolution*, 1944). Systematics—clarifying the relationships of Mesozoic mammals to their presumptive Cenozoic descendants and classifying extinct and living mammals at generic and higher levels (e.g., *The Principles of Classification and a Classification of Mammals*, 1945) as well as codifying his self-described "eclectic evolutionary approach" (e.g., *Principles of Animal Taxonomy,* 1961). Biogeography—indicating the ways terrestrial organisms can disperse by "corridor," "filter," and "sweepstake" routes over geologic time, thereby explicating historical, as well as ecological, patterns of geographic distribution (e.g., "Probabilities of dispersal in geologic time," 1952; *The Geography of Evolution,* 1965).

Just as Darwin didn't get everything right in the 19th century, Simpson made his own share of mistakes in the 20th, as present-day paleobiologists can no doubt attest. Nevertheless, Darwin blazed a fresh path for understanding the world of animate nature, and Simpson was able to illuminate a small portion of that world with similar originality, insight, and persistence.

NEW EVIDENCE OF THE EVOLUTION AND DEVELOPMENT OF BIRD WING DIGITS

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The issue of the homology of bird fingers with those of pentadactyl amniotes has been a topic of contention for nearly 200 years. Data from the fossil record and phylogenetic systematics ascribe bird digit homologies to digits I, II, and III of pentadactyl amniotes while embryological evidence supports digital homologies of II, III, and IV. Using a molecular marker specific for condensation competent mesenchymal cells, we describe a pentadactyl arrangement of prechondrogenic digital anlagen in the wings of stage 29 chick embryos. Only the middle three anlagen develop into mature fingers. This pattern supports the hypothesis that bird fingers develop from digital anlagen II, III, and IV of pentadactylous amniotes. In addition, this

result rejects a model assuming a shift in the primary axis in bird digit development and shows that a prechondrogenic digital anlage has been maintained in the bird lineage for at least 220 million years since the last known pentadactylous ancestor of the lineage. Such a vestige suggests that strong constraints are maintaining a pentadactyl ground state in amniotes. The pattern also suggests a homeotic transformation of digit identity has occurred in theropod evolution. This model of digit evolution is discussed within the context of the fossil record and current molecular developmental biology.

SPEED POTENTIAL OF TYRANNOSAURS GREAT AND SMALL

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Estimates of leg extensor mass by Hutchinson and Garcia limit *Tyrannosaurus* to an energy expensive walk. However, they overestimate the leg extensors needed for a juvenile tyrannosaur to run fast by a factor of over two (42% of total mass compared to under 20% observed in similar sized ostriches), and their methodology is even less reliable when extended to giants. Both muscle power delivery and power needed to move at a given speed scales to mass to the 2/3s power, and is similar regardless of limb number or posture. The power per gram of leg muscle needed to reach high absolute speeds is too high in small animals for them to do so, while flexed limbed giants both bipedal and quadrupedal can run with very low mass specific muscle power output. Ostriches consequently run much faster than small chickens with no relative increase in leg extensor mass and similar limb flexion, and 2 tonne rhinos can fast gallop even though they are bulky herbivores with short, lightly muscled, but flexed limbs. Tyrannosaurs of similar mass should have been at least as fast because the predators' small bellies, air filled bodies and reduced arms allowed a high portion of total mass to be dedicated to very large leg muscles anchored on large pelves and prominent cnemial crests, and their flexed legs were very long. Elephants are massive herbivores that cannot run not because of their size, but because they have small leg extensors, inflexible ankles and abbreviated feet. Adult *Tyrannosaurus* had the adaptations for body weight reduction, oversized leg muscles, and bird like flexed legs seen in smaller examples. The question is not whether the great theropod could achieve an energy efficient run, but how much faster it was than elephants, which are far from maximum mechanical limits since they are an order of magnitude smaller than super sauropods.

NEW DATA AND NEW METHODS ON AN OLD PROBLEM: THE CHOANA REVISITED

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Interrelationships among sarcopterygians and among osteolepiforms have been the focus of numerous analyses and debates during the past 20 years. Differences among phylogenetic hypotheses resulted from (1) different methodological approaches, (2) the selection of taxa, and (3) the selection and homology of characters. In numerous sarcopterygian phylogenies, the Late Devonian tristichopterid *Eusthenopteron foordi* (Escuminac Formation, Miguasha, eastern Canada) was selected as the sole representative of osteolepiforms; a few osteolepiforms with a choana have been recently described. The presence of a choana (a character considered by different authors as a "key" character in relation to the origin of tetrapods) in *E. foordi* has been frequently questioned. Various critics and scenarios have been suggested to negate the presence of a choana in this species; the palatal opening has been interpreted as (1) part of a mobile joint between the snout and the cheek/palate unit, (2) a duct for nerves and blood vessels, (3) a pit to accommodate a coronoïd fang during mouth occlusion, and (4) an artefact owing to mechanical or acid preparation of the specimens. New material of *E. foordi* has been prepared in order to display the palatal anatomy. In addition, non-invasive CT-scans have been performed on three dimensional unprepared specimens. The presence of a choana in *E. foordi* is confirmed. However, the size of the palatal opening, the detailed relationships among surrounding bones (i.e., premaxilla, maxilla, vomer, and dermopalatine), and the relative position of coronoid fangs differ from previous interpretation. Independently from the presence of a choana, the coding of *E. foordi* (with or without a choana) and the deletion or addition of the choanal character have little impact on the length of the trees, number of trees, and the resolution of sarcopterygian and osteolepiform interrelationships.

A NEW CRETACEOUS DINOSAUR NESTING SITE OF SOUTH KOREA

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A colonial dinosaur nesting ground (16 km^2 was found in the southern part of the reclaimed intertidal flat within the Shiwha Lake, Gyeonggi Province, Korea, in 1999. To date, 139 dinosaur eggs including 20 clutches have been discovered in the reddish conglomeratic sandstone beds (tentatively named Shiwha Formation) of six small islands. The islands consist of a series of alternating poorly sorted medium or coarse sandstones and conglomerates, gravels up to a boulder size. These sediments were deposited mainly in alluvial fan environment, an inference supported by compositionally immature sediments, having a great range of pebble/grain types. According to K-Ar dating of included volcanic clasts, the fan had been formed between 79.0 ± 2.4 Ma and 89.9 ± 2.6 Ma.

At least three egg types are present. The first type is the largest (average 11 cm in diameter with 1 mm thickness) and most abundant (95%) in the site. They are subspherical and randomly arranged in a single layer within a clutch. The tops of many eggshells are missing and their fragments are observed in the bottom of the egg. It probably indicates that the tops were broken and filled by clastic sediments of high-density, high-viscosity flows rather than predation or hatching. These eggs have multicanaliculate pore system structurally similar to the faveoloolithid-type eggs. They are found within at least ten different stratigraphic levels within five islands, suggesting multiple laying events. Smaller, at least seven spherical eggs are also found in two different stratigraphic levels of one island where the first type egg is not found. They are 8 cm in diameter and have thick eggshells ranging from 3.4 to 4.0 mm. Based on the microstructure and surface ornamentation, they represent new dendroolithid-type eggs. The third type of egg is represented by several pieces of eggshells in one spot. These eggshells are 1 mm thick and have linearituberculate surface texture, which differs from sagenotuberculate ornamentation of the first type of egg.

AVIAN EGGSHELL FRAGMENTS FROM THE CALICO MOUNTAINS: BARSTOW FORMATION, MOJAVE DESERT, CALIFORNIA

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This is the first report of avian eggshell fragments from the middle Miocene Barstow Formation of southern California. Most of the eggshell fragments occur in a widespread limestone marker unit near the base of the middle member of the Barstow Formation in the Calico Mountains. A second eggshell site occurs 24 m lower in the section. The limestone marker unit can be correlated with the type section of the Barstow Formation in the Mud Hills (about 17 km northwest of the Calico Mountains). Lateral facies changes within the limestone marker unit include: 1) lacustrine layered limestone, 2) beach flat pebble conglomerate, 3) spring-deposited tufa mounds, 4) tufa-coated branches and 5) microbial bioherms up to 2 m in diameter. These varied facies suggest a nearshore, lacustrine paleoenvironment. The eggshell is not associated with any vertebrate bones or embryos at the study sites.

Eggshell fragments from both study sites were evaluated by light microscopy (LM), by polarized light microscopy (PLM) and by scanning electron microscopy (SEM). The photomicrographs were compared with published reports of modern and fossil "ornithoid", "crocodillioid", "testudoid" and "geckoid" eggshell. The Calico Mountains fossil eggshell shows the following microstructure zones (from internal to external): 1) an organic core, 2) a zone of radial calcite plates, 3) a zone of tabular crystallite plates, 4) a zone of squamatic aggregates and 5) an external zone of vertical crystals. Macrostructure zones (from internal to external) are: 1) wedges of the mammillary layer (diverging outward from the central core), grading into 2) long vertical columns of the prismatic layer. These findings are consistent with modern neognathous eggshell. The absence of associated vertebrate bones or embryos provided few clues to the origin of the Barstow Formation eggshell. This SEM study suggests that the eggshell from both study sites is of avian origin.

THE ENIGMA OF ENDOTHERMIC INFANT HERBIVOROUS DINOSAURS

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If infant herbivorous dinosaurs were endothermic, they required a high energy food resource on or close to the ground, as for example in fallen seeds or fruits. Moreover, if infant dinosaur herbivores were abundant in their environments, they would have required a voluminous supply of such food. Food of this type was, however, largely unavailable in Cretaceous ecosystems. Probably owing in part to the inavailability of such food resources, the adaptive radiation of small endothermic herbivores (rodents, primates, bats, birds) did not take place until Paleogene time, coincident with the advent of biotic dispersal of large fruits and seeds in tropical forest dicots, and later in Neogene time with diversification of annual grasses and "weeds" in grassland ecosystems. If infant herbivorous dinosaurs were the ecological equivalents of rodents, lagomorphs, or birds in modern ecosystems, then their "rookeries" must have presented a circumstance akin to modern rodent "plagues" in demanding large amounts of plant tissues with high energy value on or close to the ground. Prior to the widespread development of biotic dispersal of seeds among dicots, fruits of monocots may have been an important food resource for small herbivores in tropical ecosystems. The association of juvenile herbivorous dinosaur remains with palm fruits at several sites in the Cretaceous of West Texas may provide circumstantial evidence for this relationship.

A TETRAPOD ICHNOFAUNA FROM THE MIDDLE PENNSYLVANIAN (DESMOINESIAN) MCALESTER FORMATION (KREBS GROUP), HASKELL CO., OKLAHOMA

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New Mexico Museum of Natural History locality 4399, in the Middle Pennsylvanian (Desmoinesian) Keota Sandstone Member, McAlester Formation (Krebs Group) of Haskell County, Oklahoma, yields an extensive tetrapod ichnofauna. Well-preserved trackways occur in a 0.8-1.5-m-thick unit of thinly laminated sandstone at the base of the Keota Sandstone Member. These deposits represent a lagoonal setting in a deltaic paleoenvironment. The tetrapod tracks are assigned to two ichnogenera: *Pseudobradypus* Matthew and *Notalacerta* Butts. Tracks of *Pseudobradypus* are pentadactyl plantigrade prints of a quadruped in which the manus is distinctly smaller than the pes, and digits III-IV are the longest. Tracks of *Notalacerta* are pentadactyl lacertoid prints of a quadruped that lack sole impressions and in which digit IV is the longest. This is the first record of *Pseudobradypus* in western North America, and the second of *Notalacerta*. Both ichnotaxa are also known from the Pennsylvanian of eastern North America. *Pseudobradypus* tracks at the Oklahoma site outnumber those of *Notalacerta* by a ratio of 5:1 (N=400), providing insight into the relationship within this facies between temnospondyl amphibians and protorothyridid captorhinomorphs, the presumed respective trackmakers.

There is also a diverse invertebrate ichnofauna at locality 4399 that includes arthropod tracks, resting traces and feeding trails. We record the second occurrence of *Tonganoxichnus buildexensis* Mangano, Buatois, Maples & Lanier, previously known only from the lower Virgilian Tonganoxie Sandstone Member (Stranger Formation) of eastern Kansas. *Paleohelcura tridactyla* Gilmore is present, extending the North American stratigraphic range of this ichnospecies from the Lower Permian to the Middle Pennsylvanian. A single body impression of a rare arachnid belonging to the order Palaeoricinulei is also known from this site.

BIOGEOGRAPHIC VARIATION IN LATE PLEISTOCENE AND HOLOCENE *BISON*

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Bison remains are a common and important component of many Quaternary paleontological and archaeological sites in North America. Due to the rapidly changing climate of the Quaternary and the introduction of humans to the continent during the time when bison ranged in North America, several interesting questions regarding evolutionary change within the lineage can be addressed. However, despite relatively large sample sizes and good dating of specimens, the taxonomy, phylogeny and causes for evolutionary change in the bison lineage have yet to be agreed upon. The preponderance of research thus far has been focused on specimens from the Northern Plains. Likewise, horns and overall body size, two characters whose variability do not lend themselves to taxonomic and phylogenetic studies, have been relied upon heavily.

Current research attempts to study the geographic timing of the early Holocene change in bison species, from *Bison antiquus* (in the broadest sense) to *Bison bison*, through a morphometric analysis of the metapodials and including new data from the Southern Plains. The metapodials are integral in locomotion and studies of their variation indicate they are more conservative than cranial features. By studying the pattern of the spread of morphological features associated with *B. bison*, a better understanding of the taxonomy, phylogeny, and cause of change can be gained.

Preliminary results indicate that the change in size occurred first on the Southern Plains. The transition is complete no later than 6,500 BP in the Southern Plains. This stands in opposition to the paradigms that suggest modern bison originated in northern latitudes around 5,000 BP or were a late arriving group from Asia. A more complex picture of late Pleistocene/Holocene bison is implicated.

DIVERSE DINOSAUR-PTEROSAUR-BIRD ICHNOFAUNAS FROM THE CRETACEOUS OF GANSU PROVINCE, CHINA

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Diverse vertebrate track assemblages excavated from the Hekou Formation (Lower Cretaceous) in the Yellow River (Huang He) valley, about 50 km west of Lanzhou City, Gansu Province, occur at multiple stratigraphic levels in fluvio-lacustrine sequences of paleosol mudstones and sandstones with mud cracks and wave ripple marks. Small discovery exposures at three sites were hand excavated to expose more than 600 m^2 of bedding plane surface revealing about 30 trackways, attributable to pterosaurs, birds, theropods, sauropods, ornithopods and an unknown vertebrate. Development and preservation of the sites for tourism and education is in progress. The pterosaur trackway (cf. *Pteraichnus*), the first reported from China, consists of 24 consecutive footprints, and is the longest, well-preserved trackway on record. Bird tracks (cf. *Aquatilavipes*) are also very well-preserved. Theropod tracks range in size from about 5 to >30 cm in length and include at least two distinctive morphotypes (cf. *Grallator* sensu lato, an unnamed form), and at least one other morphotype. Wide-gauge sauropod tracks (cf. *Brontopodus*) range in size from 25–90 cm (pes length) and are the best preserved examples known from China, with clear claw impressions. One trackway suggests an accelerating/running individual. Parallel ornithopod trackways indicate gregarious behavior. Another trackway type indicates an unidentified trackmaker. This minimum ichnodiversity of eight is the highest reported from the Cretaceous of China. The saurischian component (theropods and sauropods) compares well with Inner Mongolia ichnofaunas from the Jing Chuan Formation. However, the Gansu co-occurrence of ornithopod and sauropod tracks is rare, except in South Korea, which was at a similar Cretaceous paleolatitude (ca. 30°).

INTERACTIVE FIELD MAPPING: USING THE PENTAX TOTAL STATION AND ARCVIEW FOR THE ANALYSIS OF FOSSIL BED ACCUMULATIONS.

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During the summer of 1993, two visitors discovered a paleontological site in the Big Badlands of South Dakota, an Oligocene bone-bed located in the Scenic Member of the Brule Formation now known as the Big Pig Dig. To date, over 6,000 fossils have been recovered from this site with the following taxon represented: *Archaeotherium, Subhyracodon, Mesohippus, Leptomeryx, Merycoidodon, Ischyromys*, and a nimravid. The bone density at the site can be as high as 100 elements per square meter. This can make interpretation problematic at best. An interactive field map with both two and three dimensional capabilities was development to aid in the fossil analysis.

The Pentax Total Station and Arcview where used to created field maps with millimeter accuracy. These maps reveal details not visible in typical field maps. Entering bone coordinates and identifiers directly into a table allowed for rapid assimilation and interpretation of the data. These tables were then converted into shape files and used to develop overlays in Arcview, a spatial modeling program. By isolating and examining the data files for a single taxon, it is now possible to determine the extent of an individual animal within the quarry. This method has proven successful in showing the association between fossils elements at the Pig Dig with a high degree of certainty.

A PTERODACTYLOID BONE FROM THE EARLY CRETACEOUS OF KOREA

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Pterosaurs are very rare in the fossil record because their skeletons are not preserved well. The record of pterosaurs is generally represented by incomplete bones. An isolated pterosaur bone was collected from the Early Cretaceous Hasandong Formation in the Gyeongsang Supergroup of South Korea. The Gyeongsang Supergroup, a 900-m-thick sequence of non-marine deposit, has produced dinosaurs, plants, freshwater shells, fishes, turtles, crocodiles, insects, bird tracks, including web-footed species. The Hasandong Formation has known for dinosaur remains such as sauropod teeth, theropod teeth, a theropod claw, coprolites, eggs.

Based on its morphological characteristics, the pterosaur bone is an incomplete wing-phalanx, comprising 247 mm of preserved length. The thickness of the cortical bone of the shaft is approximately 0.9~1.5 mm. The shaft of the bone is dorso-ventrally compressed which is a typical characteristic for wing phalanges. The cross-sections of wing phalanges of pterosaurs are much flatter than those of the limb bones. Because of its stratigraphic position and size, the bone is considered to belong to a pterodactyloid. The overall construction is similar to the first wing-phalanx of *Dsungaripterus weii*from China. Like *Dsungaripterus* from China, the wing-phalanx has relatively thick bone walls. If the bone is the first wing-phalanx, its proximal end is missing but the other end and most shaft are preserved well. The pterosaurs has been discovered from more than twenty localities from the Asian continent including India, China, Mongolia, Kazakhstan, Uzbekistan, and Japan. The discovery of a pterodactyloid pterosaur suggests that the Early Cretaceous of South Korea was a unique Mesozoic fauna consists of sauropod dinosaurs, theropod dinosaurs, birds, web-footed birds, crocodiles, fishes, and pterosaurs in non-marine environment.

FAUNAL COMPARISIONS OF THE EASTLAKE LOCAL FAUNA (OTAY FORMATION) WITH OTHER EARLY ARIKAREEAN FAUNAS.

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The Eastlake Local Fauna was recovered from the Otay Formation in San Diego County. Although located in San Diego, the Otay Formation has traveled from its original location in Baja California as a result of movement along the San Andreas Fault. The Eastlake Local Fauna is the most southern late Oligocene fauna of North America. This early Arikareean (late Oligocene) fauna contains 26 mammalian taxa including hypertragulids, oreodontids, canids, nimravids, aplodontids, geomyids, and leporids, among others. The age of the assemblage was determined by the presence of several taxa that are definitive of the early Arikareean and K/Ar dating on the bentonite of the sandstone-mudstone member. The fauna is represented by hundreds of specimens that are often well preserved and have been prepared at the San Diego Natural History Museum. Larger-bodied mammals are preserved in the form of whole skulls, upper and lower dentitions, and some post-cranial material while microfossils are commonly represented by individual dentitions. The taxonomic identifications of Eastlake taxa are preliminary. This fauna will be compared with other faunas of similar age and diversity. Faunal lists currently reveal that the mammals of this fauna are similar to other late Oligocene faunas from the John Day (Oregon), Sharps (South Dakota), Gering (Nebraska) and the Sespe (California) formations. Preliminary results indicate that the diversity of Eastlake mammals is most similar to faunas from the Gering and the Sharps formations, perhaps because of the lack of richness in the other Pacific Coast localities. Specimens are currently being identified and described and taxonomic revisions are being done. These may reveal new taxa or taxa not previously known from the Arikareean. A comparison of the Eastlake and other Arikareean faunas will provide information for paleoenvironmental differences between the faunas and an age assessment for their associated rock units.

A SPINOSAURID FURCULA: A TETANURAN INVENTION

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A recently discovered skeleton of the African spinosaurid *Suchomimus tenerensis* confirms the presence of an ossified furcula at the base of the tetanuran radiation. The flattened, V-shaped bone has a width of approximately 31 cm and has a short, tongue-shaped hypocleideum approximately 2 cm in length. An elliptical scar about 8 cm in length is present at the distal end of each epicleideal ramus for attachment to the anterior margin of the coracoid and acromion. The intrafurcular angle is 111 degrees.

The furcula most closely resembles that of *Allosaurus*. Both have V-shaped furculae in contrast to the U-shaped furcula in tyrannosaurids. The articular scar for the acromion and the length of the hypocleideum, in addition, are well developed as in *Allosaurus*. The presence of the furcula in the spinosauroid *Suchomimus* suggests that this composite bone (fused clavicles) first arose at the base of the tetanuran radiation at least 180 million years ago in the Middle Jurassic. The unfused clavicles in several tetanuran outgroups (e.g., coelophysoids) and the absence of any clavicular ossification in the basal theropods *Herrerasaurus* and *Eoraptor* now strongly reduce the interval of time and the phylogenetic level for the evolution of this unusual adaptation.

COMPARATIVE ANATOMY OF THE HETEROCERCAL TAIL OF FIVE SPECIES OF SHARKS FROM THE NORTHERN GULF OF MEXICO (CHONDRICHTHYES: ELASMOBRANCHII).

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In the last five years, an intensive sampling program conducted at the Dauphin Island Sea Lab/Alabama Deep Sea Fishing Rodeo has generated more than 600 new skeletons of fishes from the northern Gulf of Mexico. In this paper, we present new illustrations and report new descriptions of the anatomy of the heterocercal tail of five species of sharks represented by multiple adult specimens in our collection (tiger shark, *Galeocerdo cuvieri*; bull shark, *Carcharhinus leucas*; dusky shark, *C. obscurus*; bonnethead, *Sphyrna tiburo*; and greater

hammerhead, *S. mokarran*). Our most interesting observations concern anatomical relationships of the hemal arches and hypural elements that support the ventral fin-web of the hypochordal lobe of the caudal fin and the modified neural arches and spines that support the epichordal portion of the caudal fin. The patterns of these skeletal elements differ in many details from patterns described previously for the heterocercal caudal fin of actinopterygians such as paddlefishes. The differences offer insight into general aspects of the anatomy of heterocercal caudal fins. This paper is a contribution to a symposium honoring Hans-Peter Schultze and his many contributions to the anatomy and systematics of fossil and living actinopterygian fishes.

THE RELATIONSHIP BETWEEN TRACKS AND THE WHOLE ANIMAL: NEW MORPHODYNAMIC APPROACHES

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Recent studies show that all major vertebrate groups are structured as complex or integrated organic systems, obeying predictable morphodynamic laws. Thus, animals with long narrow bodies typically have short legs but long feet (L-S-L), and those with short rotund bodies have long legs but short wide feet (S-L-S). Not only is this true for mammals, birds, dinosaurs and other reptiles, but can be demonstrated consistently for lower taxonomic groupings such as rodents, carnivores, ungulates, ornithischians, Charadriformes etc., It even applies at the intraspecies level of sexual dimorphism.

Because such S-L-S-L-S relationships pervade the vertebrate body, we learn to recognize that morphology is a coherent complex system, not an organ by organ "functional" adaptation. Morphology is a dynamic physical expression of physiology to which it has fundamental reciprocal relationships. (Students of heterochrony already recognize these reciprocal relationships as compensations or "trade offs" intrinsic to biologic systems). Thus, animals with well-developed nervous systems (anterior physiological emphasis) have a posterior physical emphasis, (long tails, hind legs etc): e.g., rodents, small theropods, songbirds. The reverse is true for those with well-developed, posterior, digestive physiologies (metabolic systems): they have large heads, necks, horns etc (anterior physical emphasis): e.g., ungulates, ceratopsians, cranes, ratites etc. Intermediate groups emphasize the central physiological systems (lungs and circulation) with more-balanced (less-polar) morphology.

Thus, both body shape and reciprocal physiology can be read from major organs such as feet (and tracks). Rodents, theropods and song birds have long narrow tracks, with heel or hallux to match the tail. By contrast ceratopsians, ungulates, cranes, etc have short wide tracks. Quantitative studies of tracks reveal that these narrow-wide, and posterior-anterior) gradients can be measured across all major clades. Thus, the foot (and track) is a mirror or microcosm of the whole animal.

ONTOGENETIC CHANGES IN HINDLIMB MUSCULATURE AND FUNCTION IN THE LATE JURASSIC THEROPOD *ALLOSAURUS*

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Studies of ontogenetic change in large theropod dinosaurs have generally been limited by small sample sizes. The Cleveland-Lloyd Dinosaur Quarry has yielded an extensive sample of well-preserved *Allosaurus* material from a wide range of size and age classes (femur lengths 234 mm to 885 mm). This sample, combined with articulated specimens from other localities, presents an unprecedented opportunity to study ontogenetic changes in hindlimb osteology, myology, and function in this large theropod.

Osteologic analysis of articulated specimens demonstrates that the hindlimb exhibits negative allometry with respect to the ilium. The femur shows strong negative allometry in length, whereas its cross-section reveals strong positive allometry in circumference, thickness and second moment of area. There is a dramatic decrease in femoral midshaft circularity corresponding to changes in the insertion of the major femoral retractors. Overall, these osteological changes reflect an ontogenetic decrease in relative hindlimb length from juveniles to adults.

The hindlimb musculature of *Allosaurus* was reconstructed using the extant phylogenetic bracket method. Ontogenetic shifts in hindlimb proportions were then combined with data on shifts in the relative positions of muscle origins and insertions. Results indicate significant relative shortening of several hindlimb muscles during ontogeny, including both protractors (M. ambiens and Mm. iliotibiales 1–3) and retractors (Mm. caudofemorales brevis et longus).

Such osteologic and myologic changes were almost certainly linked to changes in locomotor function during growth, including shifts in loading regimes. One hypothesis consistent with the above findings is that juvenile allosaurs—bearing relatively longer limbs, more circular femoral cross-sections, and relatively longer muscles—experienced a less predictable range of loading and stress regimes. By contrast, adults—exhibiting shorter, more robust hindlimbs and more elliptical femora—may have experienced more predictable loading patterns consistent with regular forward progression.

NEW RECORDS OF PALEOCENE VERTEBRATES FROM THE GOLER FORMATION OF CALIFORNIA

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The Goler Formation is the only rock unit on the west coast of North America to yield a diverse assemblage of Paleocene continental vertebrates. New sites in the upper member (Member 4) yielded shell fragments of turtles (macrobaenids, baenids, and trionychids), skulls of new genera of Baenina and Trionychinae, a ray tooth, fragments of Lacertillia (cf. *Paleoxantusia*, cf. *Proxestops*, and an indeterminate large taxon), crocodilian teeth, and dental remains of multituberculates, marsupials, plesiadapid and paromomyid primates, mesonychids, and arctocyonid, hyopsodontid, phenacodontid, and periptychid ungulates. The presence of one or both of *Plesiadapis* and *Phenacodus* at Laudate Locality, Edentulous Jaw Site, and Land of Oz site indicates that the mammal-bearing part of Member 4 is probably early Tiffanian. The plesiadapid present is most similar to *P. rex* and *P. anceps*, further constraining the age interpretation to zone Ti2 or Ti3.

Vertebrate producing sites in Member 4 span about 1000 m of stratigraphic thickness but no obvious faunal differences are apparent between sites based on the small samples available. In general, the Goler vertebrate assemblages are similar to those from early Tiffanian rocks located in the Rocky Mountain states. Although California may not have been a dramatically different faunal province during the mid-Paleocene, the presence of endemic taxa, even at this early stage of analysis, suggests a notable degree of geographic or latitudinal difference.

SYSTEMATICS OF *SINOSAUROPTERYX*

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A revised systematic study of Theropoda is presented to explore the relationships of *Sinosauropteryx*. "Compsognathidae" is found to be polyphyletic: *Compsognathus* is a derived coelurosaurian, and *Sinosauropteryx* appears to be an allosaur-grade theropod (e.g. quadrangular obturator process, >50 caudals, >15 caudal transverse processes, bifurcate caudal neural spines), perhaps allosaurid or basalmost Coelurosauria.

NGMC 2124 is not *Sinosauropteryx*; it represents a new genus of coelurosaur which differs from *Sinosauropteryx* in numerous characters, e.g. caudal neural spines short, simple; chevrons short, expanded, and changing shape after caudal 12; caudal centra longer, ?fewer; dorsals elongate; tibia and metatarsus elongate; manus gracile, penultimate phalanges elongate, pollex ungual not enlarged; ilium with strongly arched dorsal margin, large anterior hook and broad pubic peduncle. The affinities of NGMC 2124 seem to lie with advanced coelurosaurs, perhaps basal Maniraptora; in particular possible connections to *Ornitholestes*, *Coelurus*, and *Compsognathus* are examined.

As *Sinosauropteryx* is the most primitive feathered theropod, and more basal dinosaurs bore scales (e.g. *Carnotaurus*, *Ceratosaurus*, sauropods, ornithischians) insulatory fibers appear to be a tetanuran novelty. Given the general similarity to *Sinosauropteryx*, allosaurids were likely feathered, more primitive theropods such as *Torvosaurus*, Spinosauridae, and Yangchuanosauria (*Yangchuanosaurus* <- Aves, incl. *Sinraptor*; these theropods are more primitive than avetheropods in possessing 4 metacarpals, a fenestrate pubis, and a robust astragalar ascending process) might have borne either filaments or scales.

Dark stains on the tail of *Sinosauropteryx* are too regular to represent an artifact; these seem to correspond to integumentary pigments, i.e. striping camouflage. This interpretation supports their identification as insulatory fibers. Stains present dorsally but not ventrally may correspond to countershading camouflage rather than fiber distribution.

STENOCRANIUS GREGALOIDES (RODENTIA, ARVICOLINAE) IN THE IBERIAN PENINSULA: A COLD INDICATOR FOR EUROPE

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Stenocranius gregaloides is an extinct arvicoline that gave way during the Middle Pleistocene to the extant *Stenocranius gregalis*, namely the Siberian vole. The latter is typical of the Siberian tundra, but occupies steppe areas in eastern and central Asia as well.

Stenocranius gregaloides disappeared from the Iberian Peninsula (Gran Dolina, Atapuerca) in the Early Pleistocene but remained in the Middle Pleistocene across northern and eastern Europe. In many Lower and Middle Pleistocene European sites, *Stenocranius gregaloides* is associated with cold and even boreal faunas including the arvicoline species *Dicrostonyx torquatus*, *Dicrostonyx simplicior*, *Lemmus lemmus*, and *Microtus nivalinus* (supposed ancestor of the extant *Microtus oeconomus*). In addition, some authors relate the numerical decrease of *Stenocranius gregaloides* with an increase of *Mimomys savini* and *Microtus arvaloides*, both typical of interglacial periods.

In the same line of thought, the decrease of the *Stenocranius* lineage from the Early Pleistocene to modern day is quite remarkable. Towards the end of the Pleistocene and during the Holocene, *Stenocranius gregalis* went extinct across most of Europe, only persisting in isolated nuclei in the northernmost areas of the Urals and western Siberia.

During glacial periods, *Stenocranius gregaloides* most probably reached more southern areas, where the climate, although not being excessively harsh, was cold enough. During the interglacials it would have withdrawn northwards in search of lower temperatures. Therefore, its presence in the Iberian Peninsula might indicate a period of cold climate in whole Europe.

COCCOLEPIDS FROM SOUTH AMERICA AND THE EARLY HISTORY OF CHONDROSTEI

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Chondrostei was redefined as a monophyletic group in 1982, including the Acipenseriformes and fossil taxa more closely related to them than to other actinopterygians. Previously, the term was used for a paraphyletic assemblage of basal actinopterygians in general. Recent studies of acipenseriforms confirmed the monophyly of Chondrostei, which so far only includes

the Acipenseriformes and their proposed sister-group, the Triassic *Birgeria*. However, it was already noted that many fossil taxa might meet the character definition of Chondrostei. Furthermore, almost nothing is known about the relationships of Chondrostei with other basal actinopterygians. For example, phylogenetic affinities between Chondrostei and Coccolepidae, one of the youngest ?palaeoniscoids?, has been indirectly suggested though never tested.

The Chondrostei probably originated during the Triassic. The known fossil record indicate that they begin to radiate (2 gen.: 2 sp.) in the Jurassic and have an important diversification during the Late Jurassic (4 gen.: 5 sp.). A few new genera and species (3 gen.: 3 sp.) originated in the Upper Cretaceous. However, chondrostean diversity decrease during the Middle Cretaceous with the disappearance of the two basal fossil groups, Chondrosteidae and Peipiaosteidae. Nowadays Chondrosteans are represented by only twenty seven species (2 polyodontid, 25 acipenserids).

The Jurassic Cañadón Asfalto Formation in central Patagonia has yielded coccolepid fishes previously identified as *Coccolepis groeberi*. *C. groeberi* was also reported from the Lower Cretaceous La Cantera Formation in western Argentina. The fishes from both localities have been revised in order to study their phylogenetic relationships and to further explore the phylogenetic relationships between coccolepid and chondrostean fishes, and within Chondrostei. The fishes from Cañadón Asfalto do not belong to *Coccolepis*, but represent a new coccolepid genus. Several features indicate that they represent stem group Chondrostei. The fishes from La Cantera are not coccolepids; they might represent basal, non-acipenseriform chondrosteans.

THE PECTORAL GIRDLE AND THE FORELIMB OF A NEW OVIRAPTOROSAUR

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A new oviraptorosaur found in the Upper Cretaceous of Dalangshan Formation, Guangdong Province, southern China, provides characters of the pectoral girdle and wrist that support the hypothesis that oviraptorosaurs are secondarily flightless birds. A well-preserved pectoral girdle shows that the glenoid faces laterally, like that of *Archaeopteryx*, differing from most nonavian theropod dinosaurs, in which the glenoid faces posteroventrally. The semilunate carpal is fused with metacarpals I and II, and metacarpal III does not contact the distal carpals, similar to *Archaeopteryx*. Metacarpals I and II are fused proximally.

The postcranial evolution of birds more derived than *Archaeopteryx* may have followed two directions, one being a path of increasing body size and loss of flight, characterized by an obtuse angle of the scapula and coracoid in the scapulocoracoid, coracoid with well developed biceps tubercle, glenoid laterally facing, sternum without keel, metacarpals incompletely fused, and a relatively long tail. A second direction involved reduced body size and active flight, characterized by an acute angle between the scapula and the coracoid, coracoid with well developed acrocoracoid, glenoid facing dorsolaterally, sternum with a keel, completely fused metacarpals, and tail reduced to a pygostyle. Our phylogenetic analysis supports oviraptorosaurs as secondarily flightless birds. The structure of scapulocoracoid, the shape of the coracoid and sternum, and the laterally faced glenoid of the new oviraptorosaur indicate that the new oviraptorosaur may represent a ratite-like morphology.

TOWARD A PHANEROZOIC TETRAPOD FOOTPRINT BIOSTRATIGRAPHY AND BIOCHRONOLOGY

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Tetrapod footprints occur as ichnofossils in rocks of Devonian-Recent age. However, the use of tetrapod footprints in biostratigraphy and biochronology (local, regional and global) is fraught with problems, and most students of fossil footprints have overstated their value as index fossils. There are three principal problems: facies control, slow apparent turnover rates, and invalid ichnotaxa. The tetrapod footprint record is much more facies-controlled than the tetrapod body fossil record. The relatively narrow facies window for track preservation thus both restricts and biases the facies that can be correlated with any track-based biostratigraphy. Tracks rarely allow identification of a genus or species known from the body-fossil record. Indeed, almost all tetrapod footprint ichnogenera are equivalent to a family or a higher taxon (order, superorder, etc.) based on body fossils. This means that ichnogenera will almost necessarily have much longer temporal ranges and therefore slower apparent evolutionary turnover rates than body-fossil genera. Thus, the tracks will not allow as refined a subdivision of geological time as do the body fossils. The single largest drawback to using tetrapod footprints for biostratigraphy and biochronology is their ichnotaxonomy, which has been grossly oversplit, largely due to a failure to appreciate extramorphological variation. Indeed, many tetrapod footprint ichnogenera and most ichnospecies are useless phantom taxa.

At best, a Devonian-Recent global biochronology based on tetrapod footprints resolves geologic time about 20-40% as well as does the tetrapod body fossil record. The following globally recognizable time intervals can be based on the track record: (1) Devonian; (2) Mississippian; (3) Pennsylvanian; (4) Early Permian; (5) Late Permian; (6) Early Triassic; (7) Middle Triassic?; (8) Late Triassic; (9) Early Jurassic; (10) Middle-Late Jurassic; (11) Early Cretaceous; (12) Late Cretaceous; (13) Paleogene; (14) Neogene. Ironically, tetrapod body fossils (those of mammals) provide the basis for their most precise biochronology in the Cenozoic, but footprints only discriminate two intervals of Cenozoic time.

THE ANATOMY OF *HARPACANTHUS FIMBRIATUS* TRAQUAIR FROM THE BEAR GULCH LIMESTONE OF MONTANA, USA.

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Harpacanthus fimbriatus Traquair 1886 (type *Tristychius fimbriatus* Stock 1883) was initially described from isolated spines from the Lower Carboniferous of Scotland and the Mississippian of Illinois, USA. We now introduce whole body evidence of a Bear Gulch euchondrocephalan that is entirely consistent with the described material of *H. fimbriatus*. The greatest significance of this new holomorphic data concerns the resolution that *Harpacanthus* now brings to analyses of Chimaeramorpha relationships. The class Chondrichthyes has historically been classified into two distinct crown groups, Elasmobranchii and Chimaeramorpha. Several other clades have been associated with the Chimaeramorpha and within the subclass Euchondrocephali, but incomplete data has rendered the relationships of these clades, and the phylogenetic structure of the euchondrocephalans, obscure. With the inclusion of *Harpacanthus* in an analysis of chondrichthyan relationships (97 characters, 36 chondrichthyan species; theoretical, coelacanth, and actinopterygian outgroups), however, a stable resolution of the relations of the chimaerimorphs to other Euchondrocephali is reached. The new information on dental features, cranial proportions and postcranial characters renders *Harpacanthus* as the autodiastylic sister group of the Holocephali.

ANCIENT DIETS AND ECOLOGY OF CENOZOIC SIRENIANS FROM FLORIDA: EVIDENCE FROM STABLE ISOTOPES

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Cenozoic sediments of Florida contain a rich sequence of sirenians spanning from the Eocene (~40 Ma) to the Recent. Stable isotopes were analyzed for 100 teeth of fossil sirenians and extant *Trichechus* from Florida to reconstruct diets, habitat preferences, and test previous hypotheses based on morphological characters and associated floral and faunal remains. A pilot study of captive manatees and their known diet revealed an isotopic enrichment in $\delta^{13}C$ of 14.2 per mil, indistinguishable from that previously reported for medium to large terrestrial mammalian herbivores. Variation in tooth enamel $\delta^{18}O_{PDB}$ is interpreted to indicate habitat preferences, with depleted values (~ –6 per mil) representing freshwater, whereas enriched values (~ 0 per mil) indicate marine environments. Eocene to late Miocene sirenians (Protosirenidae and Dugongidae) differ significantly in both $\delta^{13}C$ and $\delta^{18}O$ from Pleistocene and Recent manatees (Trichechidae). In general, *Protosiren* and the fossil dugongs from Florida have more positive carbon isotopic values (mean $\delta^{13}C = –0.9$ per mil) that range from –4.8 to 5.6 per mil, interpreted to represent a specialized seagrass diet. The oxygen isotopic values (mean $\delta^{18}O_{PDB} = –1.7$ per mil) are relatively positive, indicating a principally marine habitat preference. These interpretations correlate well with the degree of rostral deflection and known ecology of modern *Dugong dugon*. In contrast, fossil and extant manatee *Trichechus* teeth from Florida have more negative carbon isotopic values (mean $\delta^{13}C = –7.2$ per mil) that range from –18.2 to 1.7 per mil, interpreted as a more generalized diet including C3 plants and seagrasses. The relatively negative oxygen isotopic values (mean $\delta^{18}O_{PDB} = –2.7$ per mil) are interpreted as a diverse array of freshwater and marine habitat preferences. This study of Cenozoic sirenians from Florida further demonstrates that stable isotopes can test previous hypotheses based on morphology and associated floral and faunal remains.

ONTOGENETIC VARIATION IN ENDOCASTS OF *MONODELPHIS DOMESTICA* AND IMPLICATIONS FOR THE FOSSIL RECORD

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Cranial endocasts have long been used as proxies for studying the evolution of brain and behavior in mammals. In fossil specimens, endocasts provide the only primary data for studying these questions. Previous researchers typically assumed naturally occurring fossil endocasts belonged to adults, but this assumption is unfounded and can be a source of interpretive error. Standard comparative measures such as encephalization quotient and the relative sizes of different brain centers vary ontogenetically.

To examine these issues, we isolated digital cranial endocasts from high-resolution X-ray CT scans of a growth series of the extant species *Monodelphis domestica*, the gray short-tailed opossum. We compared these endocasts to the brains removed from other specimens of comparable age to evaluate how faithfully mammalian endocasts represent actual surficial structures of the brain. In addition, we measured how standard comparative properties vary during ontogeny.

We found that endocasts at different developmental stages fail to record features visible on the external surface of the brain. For example, even in adults, the rhinal fissure, a prominent feature often used to infer the presence or absence of the neocortex in fossils, may not be visible. However, different parts of the brain grow at disparate rates at different times in ontogeny, and much of this relative growth is accurately recorded in endocasts. Relative growth of different parts of the brain can affect how the boundaries of the cranial cavity are determined and how the neurocranium ossifies. Potentially, these ontogenetic variations can affect how brain and cranial characters are scored for phylogenetic analyses. Thus, it is important to consider the developmental stages of mammalian endocasts that are used to study the evolution of the brain, behavior, and intelligence.

EOCENE TRIONYCHOID SKULLS FROM THE LOWER KULDANA FORMATION OF PAKISTAN

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We present two nearly complete skulls and isolated postcranial remains of two large trionychoid turtles from the early-middle Eocene Kuldana Formation of the Kala Chitta Hills. Specimens were recovered from H-GSP Locality 62, a conglomerate representing a fluvial environment. It has produced a vertebrate assemblage including primitive artiodactyls and cetaceans. Eocene chelonia from the Lower Kuldana formation have been described from three nearby localities, Jhalar and Lammidhan of the Kala Chitta Hills, and Chorlakki of the Kohat district. These postcranial remains have been attributed to the carettochelyid *Chorlakkichelys*, and an undetermined trionychine. Other trionychines from the region include *Trionyx* from the marine Lower Subathu Formation of India and *Drazinderetes* from the marine Drazinda Formation. These were also identified on the basis of carapace and plastron features. The first skull presented here likely represents the carettochelyid *Chorlakkichelys* based on occipital and palatal morphology. The second trionychid has affinities to extant cyclanorbines rather than the trionychines in features of the palate, parietal, and squamosal. The presence of a cyclanorbine in the Eocene of the Indian subcontinent would be the earliest record of this subfamily; its presence there was predicted previously by de Broin.

MIDDLE TO LATE MIOCENE PALEOENVIRONMENTS OF EQUATORIAL SOUTH AMERICA

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The Miocene fossil record from the Andean intermontane basins of southern Ecuador is remarkably diverse. The record includes rich leaf macrofloras and fossil mammals, represented throughout a temporal interval ranging from 18 Ma to 9 Ma. During this interval, the equatorial Andes are thought to have undergone significant rock uplift leading to the formation of the modern Amazon basin with its high rainfall and rich tropical forest biota. Leaf fossil floras from the Nabon basin allow estimates of mean annual temperature and mean annual precipitation. The plant record reveals a temperature decline of ~6°C, corresponding to about 1000 meters of rock uplift between 11.6 and 11.2 Ma as calibrated by Ar/Ar geochronology. Precipitation estimates coupled with floristic analyses do not suggest the coincident development of dryer, more open or mosaic habitats, but suggest a continuation of moist forest vegetation through 11.2 Ma. Subsequent to 11.2 Ma, changes in phylogenetic sister-group relationships suggest an influx of mammalian taxa known from older deposits farther south in the central Andes. Features of the mammal record interpreted against broad patterns of mammalian community organization along altitude gradients in tropical South America, indicate a change in composition between pre-uplift assemblages from the Cuenca and Girón basins and the post-uplift assemblage of the Nabon basin. These suggest dryer and possibly more open habitat that by analogy with modern vegetation in the equatorial Andes, would have required an orographic rainshadow. Comparing the plant and mammal sequence in the Nabon basin indicates this rainshadow formed after 11.2 Ma. Oxygen isotope results from the enamel of hypselodont molars of fossil Toxodontidae (Notoungulata) are consistent with more than 1500 meters local relief.

NEONTOLOGICAL PERSPECTIVES ON TETRAPOD SKIN FOSSILS

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Skin form diversity in living tetrapods becomes comprehensible if three fundamental features are understood: (a) the scaled, mucogenic, lissamphibian system is derived; (b) amniote skin is always geometrically organized whether it comprises only scales [reptiles] or predominantly epidermal appendages [hair, feathers]; (c) epidermal cells have the capacity to synthesize only α-keratins [anamniotes and theropsid amniotes] or both α- and β-keratins [sauropsid amniotes]. Formed as folds of the embryonic surface, all scales (flattened, tuberculate, or overlapping) have an epidermis enclosing a dermal core. The latter may house osteoderms [a primitive anamniote character, reduced or lost independently in many clades], the presence of which permits inference of a scaled organization in fossils. Both scaled and non-scaled are flexible and thus facilitate locomotion. Both serve primary barrier roles protecting the organisms in mechanical, physiological, and antipathogenic contexts, as well as various secondary roles including insulation, communication, offense, and defense. Critical to evolving true terrestrialism is the need to reduce transcutaneous water loss. Waterproofing the skin involves keratins and lipogenic lamellar bodies (an amniote synapomorphy) within α-keratinocytes together forming barrier tissues. However, the latter are delicate and are protected from environmental abrasion by overlying "hard keratinized tissues." In sauropsid amniotes, β-keratogenic scale coverings and/or feathers provide this protection; in mammals, α-keratogenic hairs do so. Because lipids in barrier tissues may leach out even in aqueous media, the superficial β-keratogenic components of reptile scales are readily lost post-mortem: this could explain their relative rarity in fossil impressions. Strongly keeled and/or sculptured scales with tough dermal components, resembling those seen in some living squamates or crocodilians, may be freed from this taphonomic constraint. All these features must be considered when skin characters are interpreted in fossils.

WORK-RELATED INJURIES AND ILLNESSES RELATED TO PREPARATION AND FIELDWORK

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Results of a survey distributed to professional preparators at SVP 2001 will be presented. Questions were designed to characterize; range of duties performed in the field and lab; time spent performing these duties; equipment used; some physical attributes of the respondents (age, years in service); safety equipment and work habits; institutional support for health and safety matters. Additional questions sought data on the types of injuries and illnesses, body parts injured and duration of trauma.

Results show a highly committed (and aging) workforce that spends a great deal of time directly engaged in field and lab work. Though personal protective equipment is generally available and used by respondents, high-dollar equipment such as lab dust/fume evacuation systems and heavy lifting equipment are lacking. 75% of respondents have been injured on the job. The great majority is repetitive stress injuries (tendonitis) to the forearms (especially elbows and hands), and these tend to be the most recurrent. Back strains are the second most common injury. Possible hearing loss and respiratory problems were the next most common ailments. The appearance of a question mark ("?") behind many entries suggests a need for baseline data on respondents (only 1 in 5 had such data).

Though a "can-do" attitude by many preparators (and their employers) clearly puts them at risk, a common complaint was the lack of institutional support and funding for upgrading facilities.

SAUROPOD DINOSAUR EGGS AND EGGSHELLS FROM THE MARÍLIA FORMATION (BAURU BASIN, UPPER CRETACEOUS), MINAS GERAIS STATE, BRAZIL

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Five groups of eggshell fragments, and two eggs of dinosaurs from fluvial sedimentary successions of the Marília Formation (Bauru Basin, upper Maastrichtian), were analysed. The material comes from Peirópolis and Ponte Alta localities, Uberaba County, Minas Gerais State, Brazil. The taphonomical aspects showed that these fossils are well preserved, although some of them had suffered re-elaboration for fluvial transport.

The analysis and observation of superficial and histostructural characters focused on the size and shape of the eggs, on the ornamentation of the outer surface, on the thickness of the eggshells. We also observed the diameter of nodes, mamilla and the pore openings, the pattern of the pores, the shape and arrangement of the shell units and the pore system.

The Marília fossil eggs and eggshells were classified as the dinosauroid-spherulithic, discretispherulitic morphotype and the tubocanaliculate pore system associated with sauropod dinosaurs and related to the oofamily Megaloolithidae. Concerning this oofamily, the analysed specimens show morphologic correlation with some described specimens found in Maastrichtian strata of Argentina, France, India, Spain, and Romania. However, our material presents different morphological features that distinguish it from the other oospecies of this oofamily.

REPORT OF A NEW *PLATYPTERYGIUS* (REPTILIA: ICHTHYOSAURIA) SPECIMEN FROM THE LOWER CRETACEOUS ROCKS OF TARRANT COUNTY, TX

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A new record for the ichthyosaur *Platypterygius* is reported. The material was found within the Grayson Marl (Lower Cretaceous: Albian) in Tarrant County, Texas. Recovered from this site were numerous disarticulated cranial and post- cranial skeletal elements. A total of sixty-six skeletal elements were recovered from this site: several skull elements including a dentary, maxilla, teeth and jugal along with the following postcranial material; scapula, coracoid, a near complete left paddle, ribs and forty vertebrae.

The genus designation is based on a nearly complete left fore fin, which shows two features diagnostic to the genus. These features are a general broad shape, due to distal phalanges and pre-axial phalanges being similar in size and the presence of three pre-axial accessory digits. The humerus also has prominent dorsal and ventral trochanters.

Though *Platypterygius* is a common Cretaceous ichthyosaur, good associated skeletal material is rare. Most records are based on isolated elements, assumed to be this genus. This is the first record of this genus based on reasonably complete skeletal material from the Lower Cretaceous of Texas.

THE POTENTIAL UTILITY OF POSTNATAL SKELETAL DEVELOPMENTAL PATTERNS IN SQUAMATE PHYLOGENETICS

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The postnatal mineralization of the squamate skeleton involves the development of epiphyseal secondary centers, ossification centers, apophyseal ossifications, calcifications, sesamoids, and fusions. This phase of development has received little attention in squamates, but preliminary investigations indicate that the sequence in which these postnatal events occurs is both highly conserved within species and highly variable among them—qualities suggesting that postnatal skeletal development is a potentially rich source of characters for phylogenetic analysis.

Two preliminary analyses, based on 21 squamate species representing 14 crown clades, are presented. In the first, the sequence of postnatal skeletal developmental events is coded into characters using the sequence unit approach. The results suggest that postnatal mineralization sequences are potentially informative at the level of crown clades, but evolve too quickly to aid in resolving deeper divergences. The second analysis employs discrete data, such as the number of secondary centers in each epiphyseal cartilage and the presence/absence of sesamoids. The discrete characters appear to be more capable of recovering deeper divergences, but evolve too slowly to help resolve relationships at the level of crown clades. Thus, pending more extensive taxonomic sampling and comparable outgroup data for *Sphenodon*, postnatal skeletal development appears to be an as-yet untapped resource for characters that could help to illuminate relationships throughout the squamate tree.

PATTERNS OF ENDOCRANIAL MORPHOLOGY IN EARLY CHONDRICHTHYANS

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It has long been supposed that cranial morphology in modern chondrichthyans (especially elasmobranchs) is close to that of primitive crown gnathostomes, and has remained relatively unchanged since the late Paleozoic. That view is now challenged by new CT-scanning observations of some remarkably well-preserved chondrichthyan fossils. The most primitive chondrichthyan braincases (e.g., *Pucapampella* from the Early and Middle Devonian of South Africa and Bolivia) are remarkably similar to those of early osteichthyans such as the Early Devonian *Ligulalepis*, suggesting that modern chondrichthyan patterns are highly derived. Until recently it seemed that all chondrichthyans are platybasic (with the brain and cranial cavity in contact with the basicranium), but CT-scanning of a Pennsylvanian symmoriid shark braincase unexpectedly revealed a tropibasic pattern (with the cranial cavity elevated above the basicranium), similar to the arrangement in many actinopterygians. CT-scanning has also revealed many other unusual endocranial features in early sharks which are undetectable from external anatomy alone (e.g., the structure of the dorsum sellae and hypophyseal cavity, and the extent of the saccular chambers). Cranial morphology in early chondrichthyans was clearly very different from their modern counterparts, and in many respects the braincases of modern chimaeroids and elasmobranchs are highly specialized, making them poor paradigms for a primitive chondrichthyan or gnathostome morphotype.

DISCOVERY OF A DIVIDED INITIAL CHEVRON IN *CAMARASAURUS* (DINOSAURIA, SAUROPODA)

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Three specimens of *Camarasaurus* were collected by the University of Kansas from the Morrison formation of northeastern Wyoming in the summers of 1997 and 1998. These consisted of two adults of robust and gracile morphotype, as well as a juvenile. During preparation, the gracile and juvenile specimens produced divided initial chevrons, the first recognized from camarasaurids. These consisted of a complete right and left element from the adult, and a complete right element from the juvenile. The chevrons are nearly identical in morphology, differing only in size, and increased rugosity and cross section in the adult. They are only about half the size of the following chevron and lack the symphysis and shaft that all proceeding chevrons possess. These differ substantially from typical Y-shaped chevrons. They differ from other described sauropod bifurcated initial chevrons by having unfused caudal attachment points. These similarities suggest a persistant feature rather than the result of development, much like that seen in modern crocodilians.

A NEW GENUS OF PERCICHTHYIDAE FROM LOWER EOCENE OF PATAGONIA, ARGENTINA

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Percichthys hondoensis is the oldest representative of the family Percichthyidae. It was recovered from a laminated tuff at the base of the lower Eocene Casa Mayor Formation (Casamayoran land-mammal-age) at Cañadón Hondo in central Patagonia. New material from the type locality permitted the completion of a detailed morphological description of the fish. New anatomical information indicates that "*P.*" *hondoensis* represents a new genus within the family. In particular, the complete absence of teeth on the vomer is an important autapomorphy of this fish, since toothed vomers are the generalized condition among lower percoids.

Percichthyidae is one of the most primitive families of Percoidei, the largest and most diverse of perciform suborders. As currently defined, Percichthyidae is restricted to Australian and South American continental environments. The fossil record of Percichthyidae is poorly known. It starts the lower Eocene of Argentina, the family is especially well represented in the Miocene of Chile, one taxon is known from the Upper Tertiary of Brazil, but with the exception of some isolated remains from the Pleistocene of Argentina, percichthyids are missing in Quaternary sediments. Similarly, no fossil percichthyids are known outside South America. No phylogenetic analysis of the family has ever been made and detailed anatomical descriptions are still missing for most of its members, living and fossils. Therefore, the study of "*P.*" *hondoensis* will certainly be an important contribution to our understanding of the evolutionary history of this relatively ancient Gondwana group.

RATES AND PATTERNS OF MORPHOLOGICAL AND MOLECULAR EVOLUTION IN THE RUMINANTIA (MAMMALIA: ARTIODACTYLA)

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Elucidating the relationships among ruminant artiodactyl families remains one of the most challenging problems in mammalian systematics. Neither rigorous studies of fossil taxa, nor tens of thousands of base pairs of DNA sequence data have yielded any robustly supported phylogenetic estimate—particularly with respect to the horned pecoran ruminants. In addition, many of the families have few, if any, diagnostic synapomorphies. It has been suggested that this pattern is a result of a rapid divergence between the families, leaving little time for synapomorphies to accumulate in a slow and gradual manner.

Several recent studies have addressed the correlation between morphological and molecular change in a variety of organisms. The Ruminantia is a well-studied clade of mammals, with an abundant fossil record and many living representatives. It is therefore an excellent group in which to compare rates and patterns of morphological and molecular evolution. To date, tests of the "molecular clock" in this group suggest that molecular change has proceeded rather continuously in the group, and estimates of divergence times within the clade using molecular data generally match estimates from the fossil record.

In this study, I estimated rates of morphological and molecular change in ruminant artiodactyls to determine if the two datasets shared similar patterns of evolution. The molecular data used in this study consists of DNA sequences of several nuclear and mitochondrial genes obtained from GenBank. The morphological data set is composed of nearly 200 discretely coded cranial, dental and skeletal characters. These data were then mapped onto a genus-level phylogeny of the clade. Associations between the two data sets were evaluated using non-parametric rank correlation tests on the numbers of changes along each branch of the phylogeny.

In general, morphological and molecular branch lengths were strongly correlated. This was true for both nuclear and mitochondrial DNA datasets. Such strong correlation could suggest that similar processes affect the evolution both types of data.

THE ONES THAT GOT AWAY: FISH SWIMMING TRACES FROM THE CARBONIFEROUS (WESTPHALIAN A) OF ALABAMA, AND THEIR PALEONTOLOGICAL VALUE

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Carboniferous deposits are not known for abundant vertebrate body fossils, but such shortcomings are partially alleviated by their vertebrate trace fossils. Although tetrapod tracks receive more attention in this respect, fish trails, made by ventral fins of a fish that swam just above (and touched) substrate surfaces, are also important Carboniferous vertebrate trace fossils. In this study, I will show how fish trails (*Undichna* isp.) from the Pottsville Formation (Lower Pennsylvanian, Westphalian A) can provide insights on individual behavior, functional morphology, paleoecological parameters, and interactions with other fish.

More than 30 specimens of *Undichna* were used in the study; members of the Birmingham Paleontological Society recovered the specimens from the Union Chapel Mine site in northwestern Alabama in 2000-2001. These trace fossils co-occur with a large number of amphibian tracks (*Cincosaurus cobbi*), and invertebrate traces (*Kouphichnium*, *Treptichnus*) in a 2-3 m thick interval of shale. Paleoenvironmental analyses of the deposit indicate that it was formed in the upper reaches of an estuary. The majority of *Undichna* specimens show two overlapping (but offset) waveforms, a result of caudal and anal fins touching a muddy surface. The higher-amplitude waveform is likely from the tracemaker's caudal fin because of its greater range of movement lateral to the body. Direction of movement is discernable where caudal fins pushed against the substrate. Fish body sizes can be estimated by a quantitative analysis of the waveforms and derived values then can be used to calculate minimum water depth needed for the fish to have swum. Lastly, intraspecific schooling behavior is strongly suggested by parallel, closely spaced, and similarly sized trails on the same bedding plane surfaces. Data suggesting such behavior demonstrate one of the advantages trace fossils have over body fossils, in that they can result in meaningful evidence-based hypotheses about intraspecific behavior.

LATE CRETACEOUS ANTARCTIC VERTEBRATE FOSSILS IN THE BRITISH ANTARCTIC SURVEY COLLECTIONS, CAMBRIDGE, ENGLAND

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Vertebrate fossil collections accumulated by the British Antarctic Survey derived from the Lopez de Bertodano Formation (Campanian through Maastrichtian) from Seymour Island, Antarctica, include a diverse marine assemblage. Within the collections, sharks, teleosts, plesiosaurs, and mosasaurs are represented, but birds and sea turtles are absent. Neornithine birds have been found by other collectors, but marine turtles have yet to be found in the Late Cretaceous deposits of Antarctica. Shark teeth are relatively abundant in the Survey collections, but teleosts are seemingly underrepresented. Plesiosaurs (Elasmosauridae) are more abundant and complete than are the mosasaurs, and juveniles of both marine reptile groups are relatively common. Mosasaurs ("Russellosaurinae" and Mosasaurinae) are taxonomically diverse as elsewhere in the world, and although more common numerically, plesiosaurs are taxonomically limited. Some of these abundances and appearances may be due to collection bias, particularly due to difficult collecting conditions and the high degree of weathering of fossils upon subaerial exposure, but certain distributions, such as the lack of sea turtles, may be the result of high latitudes.

THE NEW AND IMPROVED SAUROPOD

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The discovery of two partially articulated skeletons of *Camarasaurus* permits speculation about the appearance and ecology of these sauropod dinosaurs. Both skeletons were found in fluvatile sediments of the Upper Jurassic Morrison Formation in Wyoming and may have been killed in a single flood event. One skeleton has been almost completely prepared and is on exhibit in the University of Kansas Natural History Museum. This skeleton reveals a slender deep body much like those restored by Gregory Paul and offering little body cavity space for the types of fermentation chambers and air sac systems that are sometimes ascribed to sauropods. No gastroliths were found with either skeleton nor are there isolated occurences of gastroliths in the surrounding sediments. A small fragment of skin impression reveals an integument of pebble scales close to a centimeter in diameter and forming rosette patterns. The neck was articulated and mostly three-dimensional. It is about a meter wide at the base and massive so that the body grades into it with little demarcation. Very long cervical ribs (over 1.5 meters) overlap each other and allow little opportunity for bending. As has been suggested for other sauropods, the neck was held nearly straight (with a slight upward inclination). We suggest that camarasaurs stood in stream channels and used their long necks to provide access to a broad semicircle of vegetation on the shore.

SEXY TETRAPODS: AMPLEXUS AND THE ORIGIN OF LIMBS

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Recent studies of the morphology of the Late Devonian tetrapod *Acanthostega* by Jennifer Clack shows that this animal was exclusively aquatic, retaining internal gills and a complete lateral line system. Available evidence suggests that other Late Devonian and Early Carboniferous tetrapods were likewise primarily aquatic. A terrestrial acoustic system, with a slim, freely movable stapes, has not yet been identified in these animals. These observations throw serious doubt on the hypothesis that limbs evolved to aid in the process of terrestrialization. Another idea is provided that tetrapod limbs evolved to promote a higher probability of egg fertilization through the mating behavior of amplexus. Although briefly mentioned in a paper by Jennifer Clack in 1995, this explanation has been basically ignored since that time. The amplexus model is compared with other hypotheses (e.g., enhanced locomotion in various aquatic habitats, increased foraging ability) and, based on available circumstantial evidence, is favored because of its widespread appearance in living Amphibia and its closer and more obvious connection to fitness, as measured by potential reproductive success. Testing any of these ideas will be difficult, but perhaps not impossible.

DESCRIPTION OF *MAMMUT AMERICANUM* AND *MAMMUTHUS COLUMBI* OF THE LATE PLEISTOCENE OF MEXICO

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Taxonomic revisions are made of the systematics of *Mammut americanum* (Proboscidea: Mammutidae) and *Mammuthus columbi* (Proboscidea: Elephantidae). Inside the original localities (Palpan State of Morelos, Apaxtla, Guerrero State and Axamilpa, Puebla State, México), the age of the consistent deposits of lacustrine and alluvial units, dissected for rivers, contains flora and faunal remains of Pleistocene. The pattern of those reported specimen, reflective environments of forests and prairies of that epoch.

Since the nineteenth century, the classification of the fossil Proboscidea of México has been confused. Starting from the reappraisal of the historical species, is possible to recognize the relationship of the valid taxa. The present reclassification, includingthe phylogeny, age, and distribution, documents part of the evolutionary development of the group.

The recorded specie, reach the variation indices comparable with other described populations. This way, a specimen of *M. americanum* (var. rough) was carbon-14 dated at 13,710 ± 430 years b.p) suggests a telative sge of the late Pleistocene. Adapted by selection through their teeth, the mastodon inhabited a great variety of environments. During the late Pleistocene, *M. columbi* is the most advanced evolutionary state in wider distribution and abundance.

THE MONOPHYLY AND INTERRELATIONSHIPS OF PROSAUROPODA

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Although the monophyly of Prosauropoda has been accepted in the most recent cladistic analyses, character evidence supporting this hypothesis has not been decisive, and the interrelationships of prosauropod genera remain obscure. A cladistic analysis of 46 cranial and postcranial characters in sixteen basal sauropodomorph taxa is presented here that identifies synapomorphies defining Prosauropoda and its principal lineages.

The results of the cladistic analysis strongly support the monophyly of Prosauropoda on the basis of five diagnostic characters: loss of contact between the lacrimal and maxilla on the dorsal margin of the antorbital fenestra; axial centrum length exceeding the distance separating the pre- and postzygapophyses; dorsal neural arch height subequal to that of the centrum; manual digit I at least 40% wider than the others; and reduction of metatarsal V. In addition, the presence of a horny beak in several prosauropods suggests extra support for their monophyly.

Although the majority of relationships within Prosauropoda are only weakly sustained, some ingroup structure was recovered. Specifically, this analysis provides support for a basal split between the two main prosauropod lineages, melanosaurids and plateosaurids. The monophyly of plateosaurids, which include *Massospondylus* (*Sellosaurus* (*Lufengosaurus* + *Plateosaurus*) is supported by two diagnostic characters: reduction in skull size and increase of the anteroposterior length of the external naris. The melanorosaurid clade (*Anchisaurus* + *Riojasaurus*) is supported by one synapomorphy: increase of the length of the dorsal vertebral column relative to hindlimb length.

A NEW MAP FOR THE LATE TRIASSIC CANJILLON QUARRY (PETRIFIED FOREST MEMBER, CHINLE FORMATION), AND THE ONTOGENY OF *TYPOTHORAX COCCINARUM* (ARCHOSAURIA, STAGONOLEPIDIDAE)

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Charles Camp and his assistants excavated Canjillon Quarry in north-central New Mexico in 1933, yielding a large collection of aetosaur (*Typothorax coccinarum*) remains. Careful perusal of the field notes and maps made at the time of the excavation, combined with the field numbers of specimens in the UCMP collection, yields considerable information about the placement of material in the quarry. Many elements with different specimen numbers may be plausibly assigned to the same individual. This information is used to examine ontogenetic allometry of the femur and tibia in *Typothorax*.

A partial skeleton of a sub-adult *Typothorax coccinarum* is known from the Post Quarry, located in the Cooper Canyon Formation of west Texas. The specimen's immaturity is evidenced by incompletely fused neural arches, and an incompletely ossified laterosphenoid. The Post Quarry specimen shows several differences from material of *T. coccinarum* collected from Canjillon Quarry, which are probably due to ontogeny. During ontogeny, the dorsal paramedian scutes of *T. coccinarum* become relatively larger, lose a faint longitudinal ridge at the center of ossification, and those of the dorsal region develop lateral edges that are straight rather than curved. The lateral flanges of the lateral scutes develop weaker ornamentation, which consists of elongate grooves with minor pitting. The length of the tibia relative to the length of the femur decreases, and all limb bones become more robust.

Comparison of *Typothorax coccinarum* scutes with those assigned to *Redondasuchus reseri* indicates that the alleged differences between these taxa are questionable. Flexion at the center of ossification and a discontinuous ventral keel are present in both taxa. Moreover, the interpretation of downward-turned lateral edges of the paramedian scutes of *Redondasuchus* is based on a misinterpreted orientation of the holotype scute. *Redondasuchus* is therefore referable to *Typothorax*, though its consistently smaller size indicates it may be a separate species from *T. coccinarum*.

JUVENILE ENANTHIORNITHINE SKELETON FROM MONTSEC (CATALONIA, SPAIN) LOWER CRETACEOUS REVISITED: TAPHONOMY AND MORPHOMETRICS TO ASSESS ONTOGENETIC STAGE

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The fossil bird from the lithographic Limestones in the Sierra El Montsec (province of Lleida) is revisited in order to cope with a detailed recognition of each bone element that it is preserved. Accounting for significant absences of elements within the preserved skull, pectoral girdle and wings will lead to either taphonomic or ontogenetic assumptions in order to get a close approach on its biological age. This will be accomplished with a comparative study on the periosteal architecture of avian embryos and posthatchling individuals. The density and pattern of grooves and foramina present in several bones on the Montsec fossil will be estimated (i.e. proximal, distal and mid diaphyses of ulna and humerus, coracoid, articular area of the scapula, inner part of the mandible, quadrate, and ventral side of the cervical vertebrae). Since the Montsec enanthiornithine displays a clear pattern of juvenile skull proportions, a morphometric approach over skull and wing will be also contrasted with the ontogenetical trajectories of modern forms.

TOUGH STUFF: THE CHEMICAL AND MECHANICAL CHALLENGE OF PREPARING A DICYNODONT FROM KINGORI SANDSTONE OF TANZANIA

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Specimens of dicynodonts have been described since 1845. These fossils have greatly expanded our terrestrial ecological knowledge of the Permo-Triassic boundary, a remote time with notoriously poor preservation. Dicynodont material commonly resides in sandstones and mudstones that are highly indurated and have a large quartz component.

Early preparation on such specimens was done with hammer and chisel, grinders, and other mechanical means; this was exceedingly labor intensive and often poorly or incompletely performed. Acid etched specimens—-which require constant vigilance to prevent future deterioration—-were not always successful. Current techniques include air scribes, separating discs, angle grinders, electric engravers with gramophone needles, and chemical means.

I am exploring a combination of new and old tools and techniques with UMZC specimen T 761, which is imbedded in very resistant Kingori Sandstone from Tanzania. Initial heavy consolidation with reversible ButVar and a cushioning jacket of layered colored wax, foil, and FGR plaster, spares the specimen during the considerable rock and roll that occurs during preparation and offers protection to already exposed bone. Use of a MicroJack air scribe under a microscope removes the bulk of the matrix. I am currently working with DMSO (Dimethylsulfoxide) to disaggregate and soften the remaining matrix for removal with a needle. The DMSO is painted on the matrix and exposed to a heat lamp for several hours. This procedure is repeated until the matrix moves with the needle. In this manner the bone will be exposed with minimal stress to the fossil and preparator.

ADDING STRENGTH TO REAL AND CAST FOSSIL SPECIMENS BY THE USE OF VACUUM IMPREGNATION OF ACRYLIC RESINS

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For the last twenty years the automobile industry has been using a low viscosity liquid sealant designed for sealing micro voids and porosity in metal castings. This is applied with a vacuum impregnation process that removes the air from the porosity and then saturates the part with a NON-REVERSIBLE cross-linked sealant. Parts processed are sealed internally, but remain cosmetically and dimensionally unchanged. This technology has made its way into modern paleontology as a way to 1. Strengthen fragile and brittle fossil material, 2. Substantially strengthen Plaster of Paris castings.

Shipping a plaster cast, no matter how much care is taken to ensure its safe arrival, usually results in a damaged specimen. In a recent exchange of cast specimens with the Shanghai Natural History Museum in June of 2001, the Science Museum of Minnesota treated a plaster cast of *Thescelosaurus neglectus* (SMM P 69.18.1c) with this technique in preparation for shipment to China. The cast took 15% resin by volume, increasing its strength twelvefold. In contrast the plaster cast of *Lufengosaurus huenei* arrived severely damaged and in need of extreme repair and restoration. This technique has been used successfully by the University of Kansas to prepare a *Camptosaurus* specimen for mounting. By adapting proven techniques that have strengthened and prolonged the life of automotive castings, you can render the most fragile specimens virtually indestructible and breathe new life into humble plaster casts.

BONE MICROSTRUCTURE OF *PLATYPTERYGIUS AMERICANUS* (REPTILIA, ICHTHYOSAURIA)

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The bone microstructure of *Platypterygius americanus* from the Cretaceous Mowry Shale of northeastern Wyoming was examined in several individuals, including the type specimen. Two thin sections, cut perpendicular to each, were made from paddle bones and vertebrae. *P. americanus* has only a thin layer of cortical bone; most of the bone is trabecular bone. The trabeculae define elongated, cylindrical or tubular vacuities that are aligned parallel to one another. The vacuities are larger at the center of the bone, and become progressively thinner towards the outer margins. Among mosasaurs, bone microstructure is sufficiently distinct that it enables the identification of genera, and this may be the case for ichthyosaurs as well.

Bone porosity has also been used as an indicator of ecology for mosasaurs. Species that frequent the deeper portions of the water column have higher bone porosities. Porosity measurements on these thin sections show that the paddle bone is denser than the vertebrae, the result of thicker trabeculae in the paddle bone. Furthermore, considerable variation in porosity occurs in similar bones from different individuals, suggesting that porosity may change with growth. The porosity of *Platypterygius americanus* bone was greater than 45% for all of the bones examined, suggesting that this species frequented the deeper portions of the water column.

CROUCHING DINOSAUR, HIDDEN TAXA: A NEW LOOK AT EARLY JURASSIC ICHNOFAUNAS FROM CHINA

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Sino-Japanese-American expeditions (1999-2002) restudied a majority of Chinese Jurassic tracksites and type specimens. Previous studies of Early-Middle Jurassic ichnofaunas from Yunnan and Sichuan provinces reported many new ichnogenera and ichnospecies, that apparently differ from those in the United States, Europe and Africa. Provincial taxonomies, however, make the differences more apparent than real. Thus, many theropod tracks (14 ichnogenera) are easily accomodated in four well-known ichnotaxa (*Grallator, Eubrontes, Kayentapus* and *Gigandipus*), which have priority over most Chinese names. *Anomoepus*, representing Ornithopoda, is also present.

Ichnospecies from the Lower Jurassic Lufeng Formation, of Yunnan Province assigned to the theropod ichnogenera *Grallator, Eubrontes* and *Schizograllator* represent morphologies close to North American *Grallator, Eubrontes* and *Kayentapus* respectively. Similarly, poorly-preserved *Paracoelurosaurichnus, Youngichnus* and *Zhengichnus* can probably also be accomodated in the former three ichnogenera.

Well-preserved *Chongqingpus* (ichnosp.1) and *Weiyaunpus*, respectively from the Lower Jurassic Lower Saximiao (LS) and Zhenzhuchong formations of Chongqing and Sichuan Provinces closely resemble *Kayentapus* and *Eubrontes*. Three Lower Jurassic Xin Tian Gou Formation (XTG) sites in Sichuan Province have yielded the following named theropod tracks (with inferred senior synonyms): *Jinlijingpus* (= *Eubrontes*), *Chongqingpus* (ichnosp. 2 = *Grallator*), *Chuanchengpus* (type unlocated), *Megaichnites* (= *Kayentapus*), *Tuojiangpus* (unlocated) and *Zizhongpus* (= cf. *Gigandpus*). We identified *Anomoepus* (inferred ornithopod) from several (LS and XTG sites) and evidence of a large crouching theropod with metatarsal and ischial callosity traces (XTG site). The Zhenzhuchong Fm. yields a sauropod trackway but no prosauropod traces (e.g *Otozoum*). Chinese Early Jurassic track assemblages resemble classic New England ichnofaunas.

DIGITAL MAPPING OF DINOSAUR TRACKS IN THE GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT, UTAH

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In Utah's Grand Staircase-Escalante National Monument, an exciting story is developing around an intriguing Middle Jurassic dinosaur tracksite. The Twentymile Wash Dinosaur Tracksite (TWDT) is located approximately 25 km southeast of the town of Escalante. Here dinosaur footprints are preserved in the upper part of the Entrada Sandstone. The main 2-m thick, track-bearing horizon crops out at the top of a 400 m-long east/west trending bench, exposing tracks and trackways from multiple levels. Track preservation occurs as darker sediment infillings and as alternating light and dark underprinted sand laminations. When initially reported in 2000 the number of tracks recorded was around 300. Both tridactyl tracks (ranging in length from 15 to 45 cm) and unique sauropod tracks and traces were noted. Over 30 trackways were reported ranging from 2 to 30 steps. Due to the number, extent and complexity of tracks and trackways the TWDT has an intriguing story waiting to be told.

To aid in telling this story and to preserve the value of this unique paleontological resource, the BLM is applying close-range photogrammetric techniques that have been successfully utilized at dinosaur tracksites in Wyoming and Colorado. These techniques combine precise GPS ground control coordinates with aerial photography at a scale of 1:3000 and images taken from a low-altitude blimp. The result is an orthorectified digital photomosaic of the track-bearing surface. Analysis of the digital images using GIS and softcopy photogrammetry produce mapped outlines of individual tracks (good to +/- 2 cm). Initial analysis of a 2160 square meter area (1/8 of the track-bearing surface) has identified 134 tracks in 16 trackways, indicating that well over 600 tracks may be present. Calculations made automatically from the digital map will provide track size, step/stride lengths, and trackway geometry. The digital map and photomosaic will be used in the field to collect additional information about the tracks and the track-bearing surface. This technology is providing information that will aid in the understanding of interactions between dinosaurs and their environment during the Jurassic.

PRELIMINARY SURVEY OF GEOCHEMISTRY OF LOWER HELL CREEK FORMATION SEDIMENTS NEAR JORDAN, MT.

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This project is a small part of the larger Hell Creek Project headed by Jack Horner (MOR) and Bill Clemens (U.C. Berkeley) to interpret the paleontology and paleoecology of the Hell Creek Formation in Garfield County, MT. Correlated sediment samples from measured sections of three hills in close proximity were analyzed for geochemical and mineralogical characteristics. The analyzed sediments from the bottom 190 feet of the section consisted of sandstones, siltstones, mudstones and shales. Unconsolidated sandstones were sieved, thin sectioned, and analyzed petrigraphically for composition and mineral distribution. Fine grain sediments were analysed for composition using X-ray diffraction techniques. Statistics gleaned from sieving were combined with observed sedimentary structures to identify environmental lithofacies (sensu Miall).

Basal sandstone may have an estuary influence, at least in the lower part of the section (organic rich mud drapes are common). Laterally extensive, lithic-rich crossbedded sandstone units of varying sorting, interpreted to be associated with relatively high energy environments, i.e., river channels and or point-bar type deposits, are pervasive in mid-section, and at the top of the section. Between are numerous mudstone-siltstone layers interpreted to be relatively low energy environments, with various changes in sediment influx, and oxygen availability. The organic shales-low grade coals are probably the result of standing water-swamp, lagoon or lake bottoms are possibilities, with reducing conditions, while the grey, less organic mudstones and siltstones probably had more oxygen available (higher energy currents, or sub-aerial exposures). Soil slickensides are present in several horizons. Carbonate layers are present at several levels. Not all of the carbonate is attributable to diagenesis. Laterally extensive presence of thin shelled clams, varved clays and leaf impressions suggests that at least some of these standing bodies of water were temperate climate lakes.

REANALYSIS OF THE ORNITHISCHIAN DINOSAUR *EOLAMBIA*

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The ornithischian dinosaur *Eolambia caroljonesa* was posited upon discovery to be a basal, crestless lambeosaurine, but it has since been re-described as a derived iguanodontian outside of Hadrosauridae. The analyses utilized adequate but often poorly preserved material, which resulted in misidentifications of certain elements and the compromised interpretation of certain phylogenetically significant features. The status of *Eolambia* as either a basal hadrosaurid or an advanced igunaodontian makes it a genus of particular interest in that it may represent the oldest hadrosaurid in North America.

New material of *Eolambia* is now known. The remains of at least eleven individuals were recovered from several Oklahoma Museum of Natural History sites in the uppermost Mussentuchit Member of the Cedar Mountain Formation (Albian-Cenomanian) of central Utah. Virtually every element of the appendicular skeleton is known, often in abundance (for example, 14 humeri, 12 femora, 15 tibae), although the girdle elements are less abundant and often fragmentary. These include seven scapulae, one coracoid, three pubes, five ischia, and two ilia. Every region of the axial skeleton is well represented, with excellent preservation of a number of cervical vertebrae.

Cranial elements are less well known, but recovered elements include eight partial dentaries, three maxillae, one of which is virtually complete and free of distortion, three predentaries, two surangulars, a parietal crest, one squamosal and one quadrate.

Final preparation of a number of important elements will allow a comprehensive reanalysis of the morphology and phylogentic position of this important genus.

TO PEE OR NOT TO PEE: EVIDENCE FOR LIQUID URINATION IN SAUROPOD DINOSAURS

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One of North America's most significant dinosaur trackway localities is in the Upper Jurassic Morrison Formation within the Comanche National Grasslands along the Purgatoire River, south of the town of La Junta, Colorado. The sedimentary rocks at this locality are interpreted as having been deposited in a lacustrine environment. The Purgatoire Tracksite includes five stratigraphic levels containing more than 1300 footprints attributable to about 100 individual sauropod and therapod dinosaurs. At the top of Bed 2 is a surface that is marked with 40 sauropod trackways and 43 therapod trackways. At the same stratigraphic level is an enigmatic bilaterally symmetric bathtub-shaped depression approximately 3 m long, 1.5 m wide, and 25-30 cm deep whose origin has heretofore remained obscure. Based on examination of a cross sectional view of the structure and comparison to similar experimental scours formed in laminated sand at St. Catherine's Island, Georgia, this structure is interpreted as a scoured basin formed by a stream of fluid impinging on the sediment from above and filled with sediment derived from within the basin itself. On the nearly flat lake shore, the only source of such an elevated fluid stream would be animals crossing the area. The volume of fluid required to form a scour structure as large as the one in question suggests it may represent the expulsion of liquid urine from one of the sauropod dinosaurs crossing the tracksite.

FORELIMB IMPRESSIONS ASSOCIATED WITH A LARGE THEROPOD TRACKWAY FROM THE GATES FORMATION (LOWER CRETACEOUS: ALBIAN) OF WESTERN CANADA

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During the course of the summer 2001 field season, a new vertebrate tracksite (Barrett Wall) was discovered within the coal lease area of the former Smoky River Coal Mine near the town of Grande Cache, Alberta. Footprints have been found on two exposed bedding planes at the Barrett Wall tracksite. There is a patchy, friable upper horizon composed of relatively fine-grained, organic sediments and an extensively exposed underlying horizon that is slightly shaly but more consolidated than the upper horizon.

Two vertebrate ichnotaxa, *Tetrapodosaurus borealis* (presumed ankylosaur) and *Irenesauripus mclearni* (large theropod, possibly allosaurid), have been recognised from the in situ footprints and trackways at the Barrett Wall site. *Tetrapodosaurus* prints and partial trackways have been observed on the uppermost track-bearing horizon, while a solitary *Irenesauripus* trackway marks the otherwise featureless surface of the underlying horizon. The single *Irenesauripus* trackway is continuous for several tens of meters across the face of the Barrett Wall site and is normal in most respects. However, some unusual traces were found in association with the trackway between the last two exposed footprints (right pes–posterior, left pes–anterior). These traces appear consistent with the interpretation of simultaneous and parallel strikes or drags of both of the animal's forelimbs while it was walking. Both of the forelimb impressions are composed of three long and narrow claw marks. The morphology of the traces indicates that the animal possessed a tridactyl manus, an observation that is consistent with the identification of the trackmaker as an allosauroid.

This unique trackway is particularly significant as it reveals a great deal about the walking posture, forelimb length and positioning and biomechanics of large theropods, aspects of their paleobiology that otherwise would have remained in the realm of speculation.

A FAUNAL REVISION AND OVERVIEW OF RECENT RESEARCH OF THE BLANCAN 111 RANCH FOSSIL BEDS IN GRAHAM COUNTY, ARIZONA

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The 111 Ranch fossil beds of the Gila Conglomerate in Graham County, Arizona are notable for their record of Pliocene animals living in and around the time of the faunal interchanges between North and South America. First described in the 1930s, the beds have proven to be very scientifically productive, but research over the years has been sporadic. Fortunately, recent collaborations between federal agencies and museums have created resources affording increased field activity and new research opportunities involving ichnology, paleoecology, taphonomy, faunal distribution, and taxonomy. Animals new to the 111 Ranch fauna are continually being described, and an updated faunal list is introduced with emphasis on recently discovered taxa. New additions include the first 111 Ranch felid cranial material, a bear (cf. *Tremarctos*), and two deer (cf. *Bretzia* and *Cervus*), the first cervids found in the area. Related work has focused on aspects of animal behavior and environmental reconstruction. Unique mammalian trackways have been discovered and are being interpreted, offering a rare and dynamic glimpse of animals in life. 111 Ranch researchers have attributed the trackways to camels, carnivores, and three-toed horses. Paleoecological issues have been approached using several analytical methods. The results from these separate analyses are complementary and indicate a generally warm, arid environment with perennial freshwater sources. Taphonomic, taxomic, and sedimentary data support this conclusion. Preliminary statistics using faunal composition have been employed to investigate similarities among sites and the suitability of their inclusion as members of one paleocommunity. Thus far, statistical results have supported the interpretation of a related and contemporaneous 111 Ranch fauna. Further research is pending, and involves many individuals from several institutions and disciplines. Opportunities for future research are constantly being discovered, effectively opening a new era of North American Pliocene and 111 Ranch studies.

ESTIMATING BODY MASS OF MULTITUBERCULATE MAMMALS

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Body mass estimation for extinct animals, such as the rodent-like multituberculates, is fraught with difficulty and cannot be tested by direct measurement. Having confident body size estimates is important for studying evolutionary trends. For most multituberculate taxa, which are known only from teeth and jaws, body mass must be estimated from tooth dimensions. In a few cases where skulls and partial skeletons are known, however, tooth-based estimates of body mass can be compared to those based on other cranial and post-cranial measures. We compared body mass estimates for multituberculates using previously published predictive equations based on long bone lengths and diameters, skull length, and m1 area as well as a new equation predicting body mass from upper cheek tooth row length (TRL) in rodents. Among post-cranial predictors, long bone diameters consistently produce larger body mass estimates than long bone lengths. Long bone lengths, skull length, m1 area, and TRL (rodents) compared to length of the M1-M2 series (multituberculates) all produce reasonably concordant mass estimates. In contrast, TRL (rodents) compared to the length of the P4-M2 series (multituberculates) consistently produced larger estimates. Across a much larger sample of multiberculates, estimates based on m1 area and M1-M2 length largely agree. It is possible that the relatively poor predictive ability of long bone diameters may reflect differential allometric scaling; a predictive model based on mammals with short, robust limbs (e.g., rodents and fossorial forms) may be more appropriate. The strong size signal in TRL (rodents) compared to M1-M2 length (multituberculates) suggests that the molar series of multituberculates, that is excluding the bladed premolars, is functionally equivalent to the cheek tooth row of rodents. Confidence in m1 area as a predictor of body mass is upheld.

TWO NEW ICHTHYOSAURS FROM ENGLISH LIAS CAUSING A POLYTOMY

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Rhaetian (latest Triassic) and later ichthyosaurs have traditionally been considered to form a natural group (sometimes referred to as "post-Triassic" ichthyosaurs for convenience). Discoveries of Norian ichthyosaurs in 1990s by ROM field crews, showing typically Jurassic features, brought the first indication that such grouping may be biased. These species and post-Triassic ichthyosaurs together form the clade Parvipelvia, which marks a significant stage of ichthyosaurian evolution when the size of the pelvic girdle was dramatically reduced (indicating the change of caudal muscle insertion, and hence swimming biomechanics).

Now we report two new ichthyosaurs from the Lias of England that enables a test of post-Triassic ichthyosaurian monophyly. One of the new species is a medium to large ichthyosaur that shows mixed characteristics of *Temnodontosaurus*, *Ichthyosaurs*, *Leptonectes*, and *Shastasaurus*. This species retains the anterior terrace of upper temporal fenestra, a plesiomorphic feature that is presumably lost in post-Triassic ichthyosaurs. It also exhibits a modest overbite. The other species is slightly smaller, and shows a mosaic of *Stenopterygius*, *Ichthyosaurus* and *Leptonectes* features.

When the two species are included in phylogenetic analyses, the resolution near the base of Parvipelvia is largely lost, whereas the clade Parvipelvia is still present. Post-Triassic ichthyosaurs are no longer recognized as a clade. It seems reasonable to infer that many major groups of "Jurassic type" ichthyosaurs were established in the Norian. It is advisable to stop using the expression "post-Triassic" to refer to certain types of ichthyosaurs. They do not form a clade, and ichthyosaurs were not affected by the end Triassic extinction event: the same species are found in the Rhaetian and Hettangian. It is possible that the establishment of the parvipelvian body plan in the Late Triassic may have been the key to the survival of ichthyosaurs during the end-Triassic event.

THE SEARCH FOR EXTINCT RELATIVES OF MODERN MAMMALS: THE CASE OF SORICIDS AND *APTERNODUS*

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The extinct mammalian family "Apternodontidae" is best known from two genera, *Apternodus* and *Oligoryctes*, most diverse in North America during the Chadronian NALMA (late Eocene). Previous authors have noted the similarity of the zalambdodont dentition of these taxa to that of extant Caribbean Solenodon and Afro-Malagasy tenrecs. Opinions on the relationships to other groups range from modern zalambdodonts to extinct creodonts. New specimens of *Apternodus*, *Oligoryctes*, and other extinct, zalambdodont taxa, include eight relatively complete crania, some of which are associated with postcrania. Several of these specimens show remarkable attributes also seen in the Soricidae, including a complete absence of an ossified auditory bulla; a large piriform fenestra; an internally pocketed coronoid process of the mandible; a procumbent, enlarged anterior incisor; a premolariform p4; and a dorsally flat connection between the greater trochanter and femoral head. A phylogenetic analysis of these and other osteological characters in fossil and Recent taxa leads us to conclude that the "Apternodontidae" sensu lato is not a monophyletic group. Instead, soricids nest within a North American zalambdodont clade. Branch support for this group is not strong, however, and a more complete knowledge of the anatomy of early Eocene North American zalambdodonts is needed to further test this association.

REARTICULATING EXHIBITION MOUNTS: NEW PERSPECTIVES AND OPPORTUNITIES; A CASE STUDY ON *ANHANGUERA*

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It is essential that exhibition mounts be accurate, aesthetically pleasing, durable, and entertaining. Whether the mount is generated in-house, or purchased ready-made, a preparator must have adequate technical skill, time, understanding of the subject animal's morphology, and a critical mind. This leaves the preparator with an important function and frequently offers the opportunity to participate in original research. The planned inclusion of an *Anhanguera* rookery in the new dinosaur exhibit at the Museum of Texas Tech necessitated the understanding of pterosaur posture in a number of poses for flight and take-off. In addition, the acquisition of a three-dimensional *Anhanguera* skeleton (from the Museu Nacional, Brazil) offered a unique opportunity to reconsider posture and to reexamine its morphology since the cast consisted largely of uncrushed, original bones. Although the specimen had been nicely sculpted, changes were necessary. Therefore, the skeleton was completely dismantled, wing and femoral affects were corrected, and the external armature was internalized. Critical analysis of *Anhanguera's* skeleton during remounting led to a new interpretation of its biomechanics, including wing affect, posture, and take-off. This investigation suggests that humeral rotation defines gait, and restricts body angle during wing flapping, indicating that large pterosaurs, such as *Anhanguera*, initiated the take-off sequence by running bipedally with wings folded, then crouching, and leaping into the air at a 45 degree angle. Also, the screw-shaped knuckle (MC IV), the main wing-folding joint in pterosaurs, causes the wings to cross when folded.

Animation and drawing programs, i.e. Photoshop (TR), the Graphire 2 mouse (TR), and iMovie (TR), offer excellent tools for the preparator. They facilitate the selection of a dynamic pose by allowing a frame to be withdrawn from sequence and used as a blueprint, and they can help test the accuracy of a biomechanical hypothesis.

RESOURCE PARTITIONING IN TWO SYMPATRIC PLEISTOCENE LLAMAS FROM FLORIDA USING STABLE ISOTOPES AND POST-CRANIAL MORPHOMETRICS

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The two Pleistocene llamas *Hemiauchenia macrocephala* and *Palaeolama mirifica* co-existed at several fossil localities from the Florida Pleistocene. We analyzed specimens from the Leisey Shell Pits in Hillsborough County, Florida, because of the abundance of fossil llamas that occur at this locality. These llamas existed approximately 1.6–0.8 Ma. The co-existence of these two lamines during the Pleistocene is unique to Florida.

We conducted morphometric analyses of post-cranial elements from two sympatric llamas, *Hemiauchenia macrocephala* and *Palaeolama mirifica* to correlate body proportions to feeding behavior. We conducted PCA analyses to characterize the morphospace occupied by the post-cranial elements. We found that these two species are easily identified based on differences in their limb proportions, with *H. macrocephala* typically displaying longer more gracile limbs which may be correlated with greater cursorial ability. Alternatively, *P. mirifica* has shorter, more robust limbs.

In order to determine if the visible differences in limb proportions was associated with differences in resource partitioning, we conducted stable carbon isotopic analyses on the tooth enamel of these two species. Previous researchers have demonstrated that *H. macrocephala* is a mixed feeder, although no isotopic studies have previously been conducted on *P. mirifica* of Florida. Based on differences in the hypsodonty index between these two species, we propose that *H. macrocephala* is a mixed feeder to grazer and *P. mirifica* is a browser.

Previous research has demonstrated that limb proportions have correlated to feeding behavior in extant artiodactyls. Carbon isotopes can be used to identify the feeding strategies used by fossil ungulates. By correlating the isotopic analyses with analyses of limb proportions in fossil herbivores, future analyses based solely on morphometrics of limb elements are more robust.

A NEW MIDDLE PLEISTOCENE LOCAL FAUNA FROM SOUTHWESTERN FLORIDA.

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The Tri-Britton local fauna was discovered in February of 2001, when a cow-pond on a large ranch in central Hendry County, Florida was enlarged and deepened during a drought. A rich concentration of vertebrate fossils was recovered from a two to three meter-thick bed of shelly, medium- to coarse-grained, quartz sand. Aquatic taxa are common, including *Lepisosteus*, and other bony fish, while semi-aquatic taxa include *Alligator*, *Apalone*, and *Pseudemys*. Terrestrial vertebrates dominate the fauna, with medium- to large-sized taxa very abundant, especially *Hesperotestudo*, *Mammut*, *Mammuthus*, *Paramylodon*, *Megalonyx*, *Tapirus*, *Equus*, and *Palaeolama*. Large browsers and grazers occur in approximately equal numbers. Absence of diagnostic specimens of carnivorans and small rodents hinders a precise age determination, however, a middle or early Late Irvingtonian age is inferred from several well-studied lineages, including *Holmesina*, *Mammuthus*, *Megalonyx*, and *Tapirus*, as well as the absence of *Bison*. Terrestrial vertebrate sites of this age are very rare in Florida, and Tri-Britton is the first from southwestern Florida. The site probably represents a high energy fluvial deposit formed during an interval of relatively low sea level, as the marine mollusk shells and chondrichthyan teeth appear to be re-worked from an earlier period of higher sea level. Excavation of this new fauna from below the current water table required extensive cooperation from the landowners and assistance from the Paleontological Society of Lee County over the past two field seasons.

OVERVIEW OF THE TRIASSIC FOOTPRINT RECORD FROM ARGENTINA

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This contribution reviews the present knowledge on the Triassic tetrapod ichnofaunas from Argentina, including recent discoveries, and compare them with footprint assemblages from North America and Southern Africa. Triassic tetrapod footprints from Argentina are restricted to Middle to Late Triassic successions and occur in three basins: the Ischigualasto-Villa Unión (northwest Argentina), Cuyo (west Argentina), and Los Menucos (northern Patagonia, Argentina). The study of the ichnotaxonomy, probable producers, and the paleoenvironmental setting of these ichnofaunas is in progress, though some preliminary results can be advanced.

Footprints have been recorded from different units in two time intervals separated by a footprint-poor tract: a Middle to earliest Late Triassic assemblage (from Ischigualasto-Villa Unión and Cuyo basins) and a late Carnian-Norian assemblage (from Ischigualasto-Villa Unión and Los Menucos basins). The first assemblage includes small "grallatorids" (Theropoda), *Rigalites* (Rauisuchidae), *Dicynodontipus* (Therapsida), *Tetrasauropus* (Prosauropoda), *Chirotherium* (Thecodontia), *Brachychirotherium* (Pseudosuchia), *Rhynchosauroides* (Sphenodontidae), and cf. *Apatopus* (Phytosauria). The younger assemblage comprises a number of therapsid footprints (*Dicynodontypus*, *Gallegosichnus*, *Calibarichnus*, *Rogerbaletichnus*, and *Stipanicichnus*), a few thecodont footprints (*Shimmelia* and cf. *Chirotherium*), prosauropod footprints (*Pseudotetrasauropus*), and small tetradactylous footprints with avian-like features.

The footprint assemblages share many taxa with Triassic footprint faunas from North America, Southern Africa, and Europe; however, some important differences become apparent. Therapsid footprints and those of purported primitive mammals characterize the late Carnian (222 ± 2 Ma) ichnofauna from Los Menucos. "Grallatorid" footprints are present in the older assemblage from different Triassic units of Argentina but they are much less common than in North America and Southern Africa.

GLIRES (MAMMALIA) PHYLOGENY AND DIVERGENCE—AN OVERVIEW OF MORPHOLOGICAL AND MOLECULAR HYPOTHESES

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Glires was originally referred to Rodentia plus Lagomorpha; various stem taxa commonly termed eurymylids and mimotonids are now also recognized. Early morphological studies were conflictingly related rodents to multituberculates, mixodectids, tillodonts, taeniodonts, primates, leptictids, and eurymylids. Lagomorphs, on the other hand, were variously linked with triconodonts, artiodactyls, condylarths, pseudictopids, anagalids, macroscelidids, zalambdalestids, eurymylids, and mimotonids. Numerous recent phylogenetic analyses based on new material of basal gliroid mammals and large morphological data sets have consistently demonstrated the monophyly of Glires. By contrast early molecular studies challenged not only the monophyly of Glires, but also even that of Rodentia. Molecular studies also predict much earlier divergence times of Rodentia and Lagomorpha than is documented by the fossil record. More recent molecular results, based on a broader sampling of taxa and genes, are congruent with current morphological results regarding the monophyly of Glires and Rodentia. Molecular and paleontological data on divergence time of Glires remain widely discrepant. Explanations commonly offered to explain this inconsistency include 1) poor preservation of Cretaceous mammals; 2) lack of morphological diagnostic features in Cretaceous taxa; 3) hidden Cretaceous fossil records in southern continents; and 4) deep branching of superordinal clades of placental mammals. Gliroid mammals are pivotal to resolving the disputed divergence times of modern placental mammals because 1) the enormity of the differences between estimates of divergence times within Glires based on fossils versus molecular dating; 2) they are the most diverse placental mammals and have a dense fossil record extending from the early Paleocene to Recent; and 3) most species are small (obviating arguments about their preservation potential in sediments of Mesozoic age). Phylogenetic and stratigraphic information argues for Cenozoic divergences of Glires, a finding fundamentally inconsistent with much more ancient times of divergence postulated on the basis of molecular data.

MADTSOIID SNAKE MATERIAL FROM THE OLIGO-MIOCENE ETADUNNA FORMATION OF SOUTH AUSTRALIA

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The Madtsoiidae are an extinct family of snakes that have primarily a Gondwanan distribution. Their fossil record extends from the mid-Cretaceous to the Pleistocene and their first record in Australia is in the Eocene Oakdale Sandstone Formation of Eastern Queensland. The Eocene specimens are very small as compared to later forms and have been attributed to the Cretaceous Argentinean genera *Patagoniophis* and *Alamitophis*. Several endemic early Tertiary madtsoiid genera are known from northern Australia particularly from the faunal assemblages of Riversleigh. However, the madtsoiid record from the early Tertiary of South Australia is nonexistent.

The Etadunna Formation, Lake Eyre Basin, is the oldest fossiliferous Tertiary formation in South Australia. The Etadunna Formation is a sequence of clays and sands, which represent lake and stream deposits laid down at the end of the Oligocene and beginning of the Miocene. The formation has been divided into five faunal zones (zones A-E, oldest to youngest) and nine members (1-9, oldest to youngest). The mammalian assemblages are well known and contain the first recorded occurrences of several living and extinct endemic species such as the platypus and koala, but the lower vertebrate record is poorly known. Due to the environment of deposition, whole or articulated specimens are very uncommon and much of the material is fragmentary.

Three snake caudal vertebrae were recovered from Theresa's Treasure (Treasure Local Fauna, Member 9, Zone E) of the Etadunna Formation. These vertebrae represent the first definitive Etadunna Formation snake material known that can be tied to a stratigraphic level. These vertebrae are referable to the Family Madtsoiidae based on the presence of pedicles and the lack of prezygapophyseal processes. They are equivalent in size to the Eocene specimens of Queensland and the smaller genera of Riversleigh. However, at this time there is not enough preserved material to make generic comparisons.

ADAPTIVE VALUE OF THE INTRAMANDIBULAR JOINT IN ARCHOSAURS: *IN VIVO* EXPERIMENTAL EVIDENCE FROM CROCODILIANS

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Mobility between the dentary and the post-dentary series of bones in the mandible has implications for the evolution of feeding in archosaurs. There has been much conjecture about the adaptive value of kinetic movements at the intramandibular joint and a wide range of functions hypotheses have been proposed. These include increasing gape through lateral expansion of the mandibular rami, more precise occlusion of the upper and lower tooth rows, and absorption of high bite forces.

We investigated strain patterns across the dentary-angular intramandibular joint in crocodilians as a first step to investigating the function of this joint in archosaurs. Strain gauges were placed on the dentary and angular of two species of crocodilians, *Caiman crocodilus* and *Alligator mississippiensis*. On the ventral side of the mandible during feeding, compressive strain magnitudes in the dentary were consistently higher than those in the angular bone. Additionally, strain orientation changed significantly across the joint. It is hypothesized that during jaw closing the mandible is loaded in torsion with some ventral bending in a parasagittal plane, causing compression on the ventral aspect of the mandible.

These results do not directly address whether movement occurs across the dentary-

angular joint, as has been proposed for some theropod dinosaurs. However, it appears that in some archosaurs, the intramandibular joint serves to re-orient or absorb some of the force passing through it. The relationship between the function of this joint and the ability to generate a high bite force is presently unclear. While a mobile intramandibular joint may have decreased stresses transmitted into the posterior portion of the mandible and the skull, it would also decrease muscle forces that travel rostrally through the joint to the bite point. Detailed investigation of intramandibular joint morphology in extant and extinct archosaurs would serve to better address the function of this structure.

THE DIVERSITY AND STRATIGRAPHIC DISTRIBUTION OF PRE-DINOSAURIAN COMMUNITIES FROM THE TRIASSIC MOENKOPI FORMATION, UTAH

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Recent discoveries in the Moenkopi Formation (Middle Triassic?) of central and southeastern Utah have revealed new terrestrial and subaqueous vertebrate track localities. These well-preserved tracks occur on multiple stratigraphic horizons and are the oldest and most laterally extensive track-bearing horizons documented in the Western U.S. Ichnogenera *Chirotherium*, *Rhynchosauroides*, and *Rotodactylus* are the dominant forms. Rare fish fin drag marks *Undichna* and fish skeletal remains have been identified in the Torrey Member and equivalent strata of the Moenkopi Formation.

Tracks are preserved either as positive relief "casts" filling impressions in the underlying mudstones or on plane bed surfaces as negative relief "impressions". Exposed traces occur on the undersides of resistant sandstone ledges where the mudstone has eroded away and in finer grained sediments such as mudstones and siltstones. The Torrey Member represents deposition on a broad, flat-lying coastal delta plain. Both nonmarine (fluvial) and marine (principally tidal) processes influenced deposition. Even-bedded mudstones, siltstones, claystones, and fine grained sandstones, containing abundant ripple marks and parallel laminations dominate lithologic types. Ichnites indicating swimming/floating behavior are associated with the walking trackways. The water depth was sufficiently shallow to permit the vertebrates to touch the substrate with manus and pedes when moving through the water.

Tracks form locally dense concentrations of toe scrape marks which sometimes occur with complete plantigrade manus and pes impressions. Well preserved, skin, claw, and pad, impressions are common. Occasional, well developed, tail-drag marks frequently occur in many of the trackway sequences. Fish fin drag marks and fish skeletal material are preserved with tetrapod swim tracks. In addition to vertebrate ichnites, fossil invertebrate traces *Arenicolites*, *Paleophycus,,* and *Fuersichnus* are abundant within the track-bearing horizons.

EVOLUTION OF THE PERCHING FOOT IN THEROPODS

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A grasping foot is a key feature of most living birds, essential for perching and other behaviors. At least once during theropod evolution, the hallux (digit I) reoriented to oppose digits II-IV, but little work has been done on the mechanism, timing, or selective pressures associated with this important novelty. In extant birds, I have found that the degree of torsion in metatarsal I correlates with hallucal orientation. By applying this morphological method to fossils, I have reconstructed the foot structure of extinct theropods, even from flattened specimens.

Metatarsal I shape varies little across the full phylogenetic range of non-avian theropods. Contrary to previous reports, torsion indicates that all maintained a primitive, anteromedially-directed hallux. Based on preserved appearance, the halluces of *Archaeopteryx* and many other Mesozoic birds have been interpreted as posteriorly directed. However, in *Archaeopteryx* the morphology of the first metatarsal is most consistent with it having been anteromedially, or at most medially, directed rather than fully reversed. More derived birds, particularly enantiornithines, possess intermediate metatarsal I morphologies comparable to those in extant birds with medially directed halluces. In contrast to the simple unreversed-reversed dichotomy found in most phylogenetic analyses, these findings support a more gradual evolution of the grasping foot, which did not reach its modern form until well after the origin of flight. Experimental recordings of hallucal motion, muscle activity, and force are providing insights into the role of the first toe in living species. A combined analysis integrating data from extinct and extant theropods will likely yield the most robust evolutionary scenario of this structural complex.

BODY SIZE, DENTAL MICROWEAR, AND BRONTOTHERE DIETS THROUGH THE EOCENE

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The Brontotheriidae, a perissodactyl clade that originated, radiated, and went extinct in the Eocene, evolved dramatic changes in body size. Because size imposes metabolic constraints on organisms, paleoecology is expected to vary with size. Brontothere paleodiets were examined with dental microwear scar topography (138 observations) with a binocular microscope under low magnification. The results were compared with microwear patterns of 63 modern ungulates (969 observations). *Lambdotherium*, from the early Eocene, had wear patterns indicating primarily folivorous diets with a smaller amount of frugivory in comparison to the early equid, *Hyracotherium*. Brontotheres through the middle to late Eocene of North America were leaf-dominated browsers as indicated by microwear similar to that of moose and giraffe. These include Bridgerian taxa (*Palaeosyops*, *Telmatherium*, and *Mesatirhinus*), Uintan taxa (*Dolichorhinus*, *Metarhinus*, *Metatelmatherium*, and *Protitanotherium*) and Chadronian taxa (*Menops*, *Brontops*, and *Megacerops*). There was no evidence for mixed feeding, bark/coarse stem eating, or fruit/seed eating. This interpretation differs from one based on the semilophodont morphology of brontothere teeth that predicts a significant fruit component. In North America, subtle changes in the frequency of microwear features were found through time that could relate to the gradual shift from tropical-like forests to drier woodland habitats. Although sample sizes are smaller for Asian brontotheres, their microwear patterns do not differ from similarly aged North American taxa. There was no evidence for niche partitioning among contemporaneous species. Nor was there any detectable co-variation of diet and crown height. Most notably, there was no evidence for dramatic dietary changes associated with body size evolution. With the exception of *Lambdotherium*, all brontotheres, ranging approximately from tapir size to elephant size, were leaf-dominated browsers. Dietary specialization is consistent with the hypothesis that climate change ultimately caused the extinction of this clade.

LATE TERTIARY VERTEBRATES AND SEDIMENTATION IN THE SAN JOSE DEL CABO BASIN, SOUTHERN BAJA, CALIFORNIA

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Continued field work in the San Jose del Cabo Basin of southern Baja California has yielded new information on both late Tertiary vertebrates as well as their containing sediments. This half-graben basin, also known as the Cabo Trough, measures roughly 65 km north-south by 20 km east-west. It is situated to the east of the Sierra la Victoria mountains and to the west of the Sierra la Trinidad mountain. Recently named and newly defined late Cenozoic formations in the Basin have been described as either marine or nonmarine. However, our investigations show that one and possibly two of these formations of Pliocene age record transgressive/regressive phases. Interfingering beds, primarily of sandstones and siltstones with some claystone lenses, include terrestrial vertebrates and marine invertebrates (mostly molluscs) with marine vertebrates (cetacean and shark) in alternating sequence. These beds vary from less than 1 m to more than 8 m in thickness. In some areas occasional terrestrial vertebrates were found mixed with abundant shallow water marine invertebrates. In other areas occasional marine invertebrates occurred with terrestrial vertebrates.

New terrestrial vertebrate discoveries were made in the central part of the San Jose del Cabo Basin at various localities. Preliminarily identified taxa include fish bones; reptile, *Geochelone* shells (large and small), limb bones and isolated scutes; bird, rare avian bones; and mammal, abundant *Hypolagus ?vetus* cranial and postcranial material, rodent bones, a partial premolar of *Felis*, a *Canis* axis vertebra, relatively abundant *Rhynchotherium* cf. *falconeri* cranial and postcranial material including upper and lower tusks with enamel bands and a juvenile lower jaw with dentition, limb bones of cf. *Camelops*, a molar of *?Hemiauchenia* and abundant *Equus* cf. *simplicidens* specimens including a skull and mandible, isolated teeth and postcranial bones. The *Equus* material examined indicates a primitive form, even for *Equus simplicidens*, and suggests an early Blancan age for the sediments from which its fossils have been recovered.

DVINOSAURIAN TEMNOSPONDYLS IN THE PERMIAN

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Dvinosauria are a clade of aquatic temnospondyls, which appear to have evolved by limited accumulative paedomorphosis. *Eugyrinus* from the Langsettian (early Pennsylvanian) of Lancashire is the earliest genus and is probably a stem-taxon. The two major subclades are the Trimerorhachidae and the Dvinosauroidea, which had differentiated by the late Middle Pennsylvanian, although most genera are Permian.

Trimerorhachidae are known only from the late Pennsylvanian and early Permian of North America and comprise the stem-forms *Lafonius* and *'T.' sandovalensis* and the terminal sister-taxa *Neldasaurus* and *Trimerorhachis* sens. strict. All retain distinct tympanic embayments. In the Texas red-beds, *Neldasaurus* characterises the Archer City Formation, while *Trimerorhachis insignis*, presumably an immigrant, replaces it in the Nocona and Petrolia Formations. Two diverging *Trimerorhachis* lineages characterise the later Waggoner Ranch to Choza Formations, namely a small-eyed lineage (*T. mesops*) and a large-eyed lineage (*T.* sp. nov.). No post-Artinskian members of this clade are known. Dvinosauroidea are found across Euramerica and comprise the Pennsylvanian stem-taxa *Erpetosaurus*, *Dawsonerpeton* and *Isodectes*, the early Permian stem-taxa *Isodectes* and *Acroplous* and the terminal families Dvinosauridae and Tupilakosauridae. All post-*Erpetosaurus* taxa have lost the tympanic embayment. *Slaugenhopia* from the San Angelo Formation of Texas is an early tupilakosaurid, demonstrating that the dvinosaurid-tupilakosaurid divergence had occurred by the late Lower Permian.

Dvinosauria occur in low diversity, usually with only one species in a given assemblage but occasionally two (Linton, Ohio; Speiser Shale, Kansas) or three (Arroyo Formation, Texas). They were absent from the upland intermontane lakes of Europe and appear to have required lowland water bodies with open water. Some may have been brackish-tolerant.

IDENTIFICATION OF NON-COLLAGENOUS STRUCTURAL PROTEINS IN *IGUANODON* BONE

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There have been numerous attempts to detect and identify indigenous organic components in fossil bone, including dinosaur bone. Mineralised tissues are more likely to preserve and retain their tissue specific extracellular matrix components over a long time period; this project has therefore focused on the search for bone specific proteins. Results from a pilot study on demineralised extracts of *Iguanodon* bone, from the Early Cretaceous (Barremian) in southern

England, demonstrate that electrophoretically defined non-collagenous protein products can be isolated and identified in dinosaur bone. The amino acid compositions and specific enzyme susceptibilities of the separated protein fractions indicate the presence of geologically ancient bone protein products—glycosaminoglycans—which control bone mineralisation. This is the first confirmatory evidence for the isolation of dinosaur bone proteins which mirror similar material in extant avian and mammalian species. The study extends earlier observations on dinosaur bone which employed histochemical and amino acid profiling. The absence of hydroxyproline and hydroxylysine confirm the absence of collagen and the absence of ornithine implies the absence of bacterial protein. We do not claim to have isolated intact proteins but that the crystallite environment of bone offers a valuable protection over time to allow the preservation and identification of protein and other potential products.

NEW INFORMATION ON THE DENTAL MORPHOLOGY OF *TROGOSUS* MATERIAL FROM THE BRIDGER FORMATION, UINTA COUNTY, WYOMING, AND ITS IMPLICATION TO THE EVOLUTIONARY HISTORY OF TILLODONTS

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Undescribed material of *Trogosus*, USNM 364762, from the lower Bridger Formation, southwest of Church Buttes, Uinta County, Green River Basin, Wyoming, beautifully preserves eleven upper teeth (I2, P3-M3, eleven lower teeth (i2, i3, c, p2-m3), and fragmentary postcranial material from a single individual. The tooth crowns of *Trogosus* are typically worn out because of its heavily grinding diet, and the cusp patterns of the taxon have been poorly understood. Well-preserved teeth in USNM 364762 reveal detailed cusp patterns and the derived dental condition in Tillodontia.

Trogosus is a common tillodont genus of the early Bridgerian of North America, and five valid *Trogosus* species are described from the Western Interior. USNM 364762 has two dental characters that are distinct from previously described *Trogosus hyracoides* from the same formation as well as from other primitive tillodont genera: the extremely diminutive parastyle on the P3 (not occluding against the p3 trigonid) and the talonid basin of the m3 is divided into two by a posthypocristid. The former character is present in *Trogosus latidens*, *Trogosus hillsii*, and the derived tillodont *Tillodon fodiens*, and the latter character is preserved in *Trogosus grangeri*. These indicate the primitive status of *Trogosus hyracoides* and the closer relationship of USNM 364762 with *T. grangeri*, *T. hillsii*, *T. latidens*, and *Tillodon fodiens*.

This study of USNM 364762 implies that the variations of cusp patterns in *Trogosus* are greater than previously suggested and is significant to help elucidate the evolutionary history of North American tillodonts.

THE PHYLOGENY AND FORTUNES OF DIAPSID REPTILES DURING THE PERMIAN

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Diapsid reptiles make their first appearance in the fossil record with the araeoscelidians *Petrolacosaurus kansensis* and *Spinoaequalis schultzei* from the Upper Carboniferous of central North America. During the Early Permian araeoscelidians are uncommon in terrestrial faunas compared with other basal amniotes; more crownward diapsids during this time are represented only by *Apsisaurus witteri*. Diapsids continue to be relatively rare until the close of the Paleozoic: araeoscelidians are completely absent from the Upper Permian record, whereas stem diapsids of Younginiformes and the gliding clade Weigeltisauridae are the most common Late Permian diapsids. Representatives of the former group are restricted to central Gondwana, whereas species of the latter are found in both Madagascar and Europe. The enigmatic aquatic reptile *Claudiosaurus germaini* from the Madagascan Upper Permian was described originally as a plesiosaur ancestor, but recent cladistic analyses identify this taxon as a stem diapsid more basal than Younginiformes. Except for the archosauromorph *Protorosaurus speneri*, crown-group diapsids are extremely rare during the Permian and most taxa make their appearance only towards the end of the period (late Tatarian). Other crown-group taxa include the lepidosauromorphs *Saurosternon baini*, *Paliguana whitei*, and *Palaeagama vielhaueri* from southern Africa and the archosauromorph *Archosaurus rossicus* from Eastern Europe.

We augment Paleozoic diapsid diversity with the description of a new genus and species from the Kazanian-Tatarian boundary of the Mezen River Basin, Eastern Europe. Cladistic analysis suggests that the new taxon is either a member of the crown group or a very close relative. The new diapsid importantly narrows the stratigraphic hiatus between the last appearance of araeoscelidians in the Lower Permian and the first appearance of more crownward diapsids of the Upper Permian.

HAMBACH—EUROPE´S MOST NORTHWEST OUTPOST OF CONTINENTAL MIOCENE VERTEBRATE FAUNAS

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The first vertebrate fauna from the Miocene Ville Series of the Lower Rhine Embayment in western Germany is represented by numerous bones, jaws, and teeth. The fossils were discovered in a channel-fill within the main lignite seam at the Hambach open cast mine, west of Cologne. The material documents chondrichthyans, teleosteans, amphibians, reptiles, and mammals which inhabited brackish-estuarine, lacustrine-fluviatile, and terrestrial environments.

This is the first fauna to provide an insight into the diversity of vertebrates which lived in the vast, partly forested peat swamps of the Tertiary Rhine delta. Based on the rich association of more than 70 mammalian taxa, including about 30 rodent species, this late Orleanian fauna can be correlated with the upper part of the Mammalian Neogene biozone MN5. That means an age of 16.0-15.2 Ma (Langhian or Reinbekian according to the stratigraphy of the NW German Tertiary Basin). Therefore the main lignite seam can be placed in the early middle Miocene.

Compared with other European localities of that age, Hambach 6C exhibits a very unusual faunal composition. For some mammalian taxa (*Lanthanotherium, Plesiosorex, Miopetaurista, Myoglis, Fahlbuschia, Karydomys, Anchitheriomys, Dorcatherium*), Hambach 6C is one of the richest sites. In addition this assemblage contains some very rare mammals (*Karydomys, Anchitheriomys, Orygotherium, Pliopithecus*). On the other hand, usually abundant taxa are completely missing (e.g. *Galerix*) or very rare (eomyids, ochotonids, cervids, bovids). The Hambach vertebrates are also of great palaeobiogeographic importance as they represent the northwesternmost outpost of terrestrial Miocene faunas in Europe.

A NEW OCCURRENCE OF THE REPTILE TRACKWAY *NOTALACERTA MISSOURIENSIS* FROM WESTERN INDIANA

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The discovery of a reptile trackway from the early Pennsylvanian in western Indiana has provided new insight into the distribution of primitive reptiles. The trackway was found along the banks of Big Pine Creek, Warren County, Indiana on the northeast margin of the Illinois Basin. Cox originally described *Collettosaurus indianaensis* from this locality. Recently, numerous other tracks have been recovered from this locality of several taxa of tetrapods suggesting a diverse ecosystem existed here. The tracks are found in thin interbedded shales and sandstones from the Mansfield Formation. It is believed that the new material comes from more than one stratigraphic horizon. Unfortunately none of the recently discovered material has been found in situ. Geology of the site reveals that this was probably a tidally influenced mud flat setting inhabited by a number of types of primitive tetrapods ranging from small to medium size. Also preserved on the slabs are desiccation cracks and rain drops. Our set of prints are similar to those of *Notalacerta missouriensis* from the Pennsylvanian of Missouri and Kentucky, yet the new trackway lacks the tail drag impression typical of *N. missouriensis*. The new tracks also have complete and rounded sole impressions while *N. missouriensis* typically lacks or has a triangular sole impression. However, aside from these extramorphological variations, the new tracks have similar proportions to *N. missouriensis* and show other similar characteristics such as lacertiod digits and digit four being the longest, suggesting the trackway should be assigned to *N. missouriensis*. This trackway represents the earliest evidence of reptiles in the Illinois Basin, and one of the earliest occurrences of reptiles in North America. The recovery of this trace provides insight into the early diversification and distribution of reptiles shortly after their appearance in the early Pennsylvanian. The new trackway implies that reptiles were present in the Illinois Basin during the early Pennsylvanian, suggesting that the distribution of primitive reptiles was much broader than previously believed.

NEW GIANT GOPHER TURTLE FROM NORTHEASTERN MEXICO AND THE MORAFKA´S PARADOX

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The recovery of a complete skeleton of a gopher turtle from the Pleistocene (Rancholabrean) deposits of Villagrán, Tamaulipas, brings important information about the biogeography of gopher turtles, particularly in relation to the separated distribution of *G. flavomarginatus* (in north central México) and *G. polyphemus* (in Florida).

The specimen is one of the few giant gopher turtles whose skull is known. It is very short resembling that of the early Pleistocene *G. canyonensis*, but differs in several cranial and shell characters. Plastron meristic variation of the new species, *G. berlandieri* and *G. laticuneus* (=*G. praeextans*) is discussed denoting problems in the assessment of species based on extremely variable shell characters. Lack of diagnostic features in shells of *G. edae*, *G. hexagonatus*, and *G. praecedens* suggests their status as *nomen vanum*. Cladistic strict consensus tree suggests the constitution of Gopherus as a monophyletic group where *G. mohavetus* falls within the outgroup questioning its status as a *Gopherus*. *G. berlandieri* and *G. agassizii* branched out paraphyletically after the basal Oligocene *G. praecedens*. *Gopherus sensu stricto* is monophyletic but with unknown relationships among its taxa; it includes the Miocene *G. brevisternus*, *G. pansus*, and *G. vagus*, the Plio-Pleistocene *G. canyonensis* and *G. donlaloi*, and the recent *G. polyphemus* and *G. flavomarginatus*.

Reanalysis of the biogeographic relationships based on the phylogeny suggests that the origin of *Gopherus sensu stricto* can be traced to the Miocene of the central plains; later extending southwardly during the Plio-Pleistocene from eastern Arizona to Florida and as south as Aguascalientes. The extinction of giant gopher turtles in Texas and eastern Mexico associated to the invasion of their distribution area by *G. berlandieri* is the better hypothesis to explain the recent broadly separated distribution of *G. polyphemus* and *G. flavomarginatus*.

NON-ALLOMETRIC VARIABILITY IN THE SKULL OF THE TEMNOSPONDYL AMPHIBIAN *WELLESAURUS PEABODYI*

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Wellesaurus peabodyi is a capitosauroid temnospondyl from the Wupatki Member (Upper Olenekian: Lower Triassic) of the Moenkopi Formation of northeastern Arizona. It is known from at least 30 skulls, which range in midline skull roof length from 164mm to 557mm, thus the collected sample represents a growth series. As expected, biometric and qualitative character analyses of the skulls revealed allometric (size/age-related) variation in the specimens. The study also uncovered cranial variability not related to the size/age of the skulls, including the following characters: sutural contact of either the supratemporal and postfrontal or the postorbital and postparietal; degree of inclusion of the jugal in the orbital rim; relative positions of the exoccipital and quadrate condyles; shape and long-axis orientation of the choana and parietal foramen; degree of sinuosity of skull roof sutures; antero-posterior position of the

widest point transversely across the interpterygoid vacuities; presence/absence and relative size of the beveled area around the anteromedial part of the otic notch; position of the jugal canal relative to the squamosal-quadratojugal suture; development of the lateral line system as either continuous grooves or a series of elongated pits; asymmetry of skull roof midline sutures; ventral sutural contact of the pterygoid and exoccipital; orientation of the anterior end of the lacrimal-maxilla suture; shape of the nostrils; and relative size and shape of the interpremaxilla foramen. The non-allometric variability may be attributed to sexual dimorphism, polymorphism, and geographic or stratigraphic or individual variation. Because the data did not clump into two or more groups of skulls or localities, the first four reasons are unlikely, leaving individual variation as the probable explanation. In any case, both allometric and non-allometric variability needs to be strongly considered when conducting a cladistic analysis of capitosauroids.

CAMEROS BASIN MEGASEQUENCE (SPAIN): AN OVERVIEW ON BODY AND ICHNOLOGICAL BIODIVERSITY FROM THE EUROPEAN CRETACEOUS

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The Cameros Basin is located at the north branch of Iberian Range, including part of three Spanish provinces: La Rioja, Burgos and Soria. The basin is wide geographically extended, about 8000 km^2 and the sediments are approximately about 9 km thick. Such large number of strata comprises a big span of time: from Tithonian (Upper Jurassic) up to Aptian (Lower Cretaceous). The deposits of Cameros Basin came from a continental environment, dominated by low energetic fluvial channels, shallow lakes and some dryness periods with playa-like episodes. A relatively scarce body fossil record dominated by invertebrates (gastropods and bivalves) and some vertebrate remains (holostean fishes, turtles, crocodiles, pterosaurs and dinosaurs) is in contrast with a remarkable abundant and wide extended ichno-record. More than 100 tracksites are actually been studied in this big area. This ichnological record is clearly dominated by dinosaurs but, during recent years, a big amount of new non-dinosaurian material has been discovered, showing an outstanding bio-diversity. The dinosaurian ichnofauna is mainly constituted by theropods (about 80%), with at least three principal footprint types. Most of the ornithopod dinosaurs (about 15%) from Cameros belong to iguanodontids (with two different morphotypes), another one belonging probably to a camptosaur-like dinosaur and some small trackways attributed to hypsilophodontids. Sauropod tracks are relatively scarce (5%), with two described morphotypes based on trackway pattern: wide-gauge and narrow gauge sauropods. Pterosaur tracks belonging to *Pteraichnus* ichnogenus are wide distributed all over Cameros Basin. One tracksite named Los Cayos (Cornago township, La Rioja province) has yielded abundant theropod tracks, some of them up to 50 cm in length. Five big exposures are located at Los Cayos area. The outcrop named Los Cayos C shows an impressive ichno-diversity with tracks of theropods, turtles, pterosaurs and diverse avian-like specimens, some of them in the same sedimentary level. The Cameros Basin shows a change in the dinosaur ichnofauna from Berriasian to Aptian. The oldest ichnofauna is more clearly dominated by theropods of middle size; both the record and the diversity of ornithopod and sauropod trackways clearly increase from Berriasian to Aptian. The Cameros ichno-record suggests a gregarious behavior within theropods, iguanodontids, and small hypsilophodontids. Some of the iguanodontid trackways show a quadrupedal locomotion pattern. Both the trackway pattern and the manus print shape have yielded interesting inferences on locomotion behavior and hand reconstruction. Biomechanical considerations stress on the quadrupedal optional condition for these dinosaurs. The current research on Cameros Basin should produce in the future new insights on this paleo-community from the European Cretaceous times.

NEW BATS IN THE NEOTROPICAL FAMILIES EMBALLONURIDAE AND MORMOOPIDAE FROM THE OLIGOCENE AND MIOCENE OF FLORIDA, AND THE BIOCHRONOLOGY OF FLORIDA WHITNEYAN, ARIKAREEAN, AND HEMINGFORDIAN FAUNAS

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Fossils representing the tropical bat families Emballonuridae and Mormoopidae are reported from the Oligocene and Miocene of peninsular Florida. Neither family was known previously from Tertiary deposits in North America, although emballonurids occur in the Eocene of Europe and the Miocene of Colombia. A new genus and species of large emballonurid occurs in the early Oligocene I-75 Local Fauna (LF) and the late Oligocene Brooksville 2 and Buda LFs. Another smaller species of emballonurid belonging to this same genus is also known from I-75 and Brooksville 2. The new genus exhibits several significant differences from extant emballonurids in the upper dentition and may represent a new subfamily. A second new genus of smaller emballonurid, from the early Miocene Thomas Farm LF, is similar to the living genus *Saccopteryx*. Another new genus and species from I-75 and Brooksville 2 shares derived characters of the dentition, humerus, and femur with the Mormoopidae. Although the Florida fossils are intermediate in certain characters between the two living mormoopid genera, *Mormoops* and *Pteronotus*, they are more similar to *Mormoops* in characters of the lower premolar dentition and humerus. I-75 (6 bats), Brooksville 2 (5 bats), and Thomas Farm (8 bats) have the richest Tertiary chiropteran faunas in North America. These faunas contain the earliest New World records of the Emballonuridae, Mormoopidae, Phyllostomidae, and Natalidae, confirming the presence of a tropical American chiropteran fauna in Florida during the Oligocene and early Miocene. Recent studies have established a well-constrained biochronology for Florida mammalian faunas from the Whitneyan, Arikareean, and Hemingfordian NALMA (early Oligocene-early Miocene; 31-16.5 Ma), many of which are paleokarst deposits containing bat fossils. The Florida bat faunas from these three NALMA are (oldest to youngest): I-75 (Whitneyan, 30-31 Ma); Brooksville 2 (late early Arikareean=Ar2, 26-28 Ma); White Springs and SB-1A/Live Oak (late Ar2, 24-25 Ma); Buda (latest Ar2, 23-24 Ma); Thomas Farm and Seaboard (late early Hemingfordian, 18-19 Ma); Brooks Sink (late Hemingfordian, 16.5-18 Ma).

DIET OF NON-FLYING MESSEL TETRAPODS: DIRECT VS. INDIRECT EVIDENCE

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Due to its extraordinary conditions for preservation, 22 out of 76 non-flying tetrapod species from the middle Eocene site of Messel reveal direct evidence of diet, mostly by gut contents. If this is compared to indirect evidence resulting from morphological analyses, three different pattern may occur: Direct evidence may corroborate, enhance or contradict the diet reconstruction by morphological analysis for a single taxon.

Examples are given for all three patterns, including a bird with a fish in its esophagus and a juvenile creodont which contains fragments of a very small reptile, presumably an iguanoid lizard. The extremely uncommon preservation of the creodont's skeleton with the ribs broken and the limbs curled around the body forces us to interpret it as a spit-ball (vomitous) of a snake. This single specimen, thus, documents both, prey and predator, of a juvenile creodont.

A semiquantitative comparison of direct vs. indirect evidence in non-flying tetrapods of Messel shows that gut contents of herbivores are over-represented while omnivores and insectivores are under-represented. For herbivores this is reasoned mainly by their digestion processes, while a statistical effect takes place for omnivores: at least two gut contents are necessary to declare a specific taxon to be omnivorous. Most insectivores, judged by morphology, are small reptiles from which very few gut contents are known. A comparison of preserved gut contents to taxon size shows that direct evidence of diet more probably comes from larger taxa.

BRACKETING DINOSAURIAN BODY MASS USING ELASTIC SIMILARITY APPROACH

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If and how body mass constrains limb bone dimensions is a long standing question. The elastic similarity hypothesis, proposed by McMahon, postulates that the resistance against elastic instability links limb bone dimensions to body mass. More precisely, it states that dimensions of limb bones scale by preserving similar levels of resistance against elastic instability in a given group of vertebrates that share similar postures. The hypothesis was initially accepted but later works showed that the predicted scaling patterns were not observed in nature. It is no longer accepted by recent workers.

Here I show that, contrary to the conventional wisdom, elastic similarity hypothesis is valid. The original model used an equation for heavy columns, where the instability of the column is caused by its own weight. This is inappropriate for limbs, which are loaded by the rest of the body. I therefore revised the model using a more appropriate mechanical equation, and tested it with empirical data. Humeral and femoral data of 94 mammalian species (34 families, 12 orders), based on individuals of known body mass, were used. The result shows that elastic similarity is approximately preserved among the species examined. Use of comparative methods did not affect the outcome.

If body mass constrains limb bone dimensions, then it should be possible to estimate the former from the latter. Numerous efforts have been made in the past to correlate body mass with bone dimensions, with various successes. However, these equations are strictly phenomenological and valid only within a given clade, and there is no reason why they should be applicable to other clades. The new equation provides a mechanical justification for body mass estimations from limb bone dimensions, and therefore facilitates cross-clade application when limb postures can be considered similar. Estimates can be given for bipeds as well as quadrupeds, with prediction intervals. Application to some dinosaurs revealed that the estimates are similar to those derived from existing equations, except in a clade with unusual limb proportions (*Brachiosaurus*).

LATE OLIGOCENE HYRACOIDS AND ARSINOITHERES FROM CHILGA, ETHIOPIA

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Fieldwork on Ethiopia's northwestern plateau at Chilga has yielded a mammalian fauna dating from the late Oligocene, at about 27-28 Ma. This fauna is significant as the most diverse and best-sampled fauna of mammalian herbivores from the early Tertiary of sub-Saharan Africa. It is intermediate in age between the well-known older Fayumian faunas of Egypt and other sites in North Africa and Arabia, and the younger Miocene faunas of East Africa. We report on two important mammalian orders of the Chilga fauna, Hyracoidea and Embrithopoda. Hyracoids are represented by at least four taxa: a new species of *Pachyhyrax*, a new species of *Megalohyrax*, a new genus perhaps related to *Pachyhyrax*, and possibly a species of *Bunohyrax*. All of these hyracoids show closer affinities with early Oligocene Fayumian hyracoids rather than those from the early Miocene of Kenya. Indeed, *Pachyhyrax* and *Megalohyrax* are the two most common large hyracoids from both Chilga and the youngest levels of the Fayum (quarries I and M, ca. 32 Ma). The most common mammal at Chilga is a new species of *Arsinoitherium*, and it differs from *A. zitteli* of the Fayum in its larger size and in proportions of the upper premolars; the Chilga arsinoithere is also larger than the large type specimen of the probably invalid species, *A. andrewsi*, from the Fayum. The Chilga arsinoithere is the youngest and largest known species of embrithopod. The Chilga fauna suggests that the typical Fayumian herbivores (consisting primarily of hyracoids, embrithopods, and proboscideans) were probably successfully distributed throughout Africa during the early Tertiary.

DIAPSID INTERRELATIONSHIPS AND THE INFLUENCE OF TAXON SELECTION

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In recent years, there was a significant progress in the understanding of diapsid phylogeny,

such as, e.g., the removal of the well-known Younginiformes from lepidosauromorphs, and their placement at the base of the diapsid clade. On the other hand, also some new and highly discussed problems arose, of which the most prominent example surely is the suggested diapsid affinity of turtles. The stability of several results, however, suffered from the problem that only a few taxa were entered in the respective analysis. For that reason, a new analysis of the interrelationships of basal diapsids was performed in the here presented study, with the main focus on taxa that were either rarely entered in the latest analyses (e.g. drepanosaurs or thalattosaurs) or where strongly differing opinions towards a phylogenetic placement exist (e.g. turtles, ichthyosaurs, sauropterygians). In total, 30 taxa and 182 informative characters were taken into consideration. The most important results are a positioning of thalattosaurs and ichthyosaurs outside the lepidosauromorph/archosauromorph dichotomy, a placement of turtles close to lepidosaurs, a grouping of kuehneosaurs with drepanosaurs outside saurians, and the paraphyly of prolacertiforms. Although the present result is relatively stable, it should be noted that the topology much more depends on the choice of taxa than on the number and definition of characters. This means that the removal of some taxa or clades has an effect on the position of other diapsids. For example, the lepidosauromorph nesting of kuehneosaurs is only present when drepanosaurs are deleted. Furthermore, the influence of a taxon may change when an additional taxon is entered in the analysis. Interestingly, however, this influence appears independent from the number of characters for which a taxon can be coded. With regard to these phenomena, it is postulated that in the case of large-scaled phylogenetic analyses, the stability of the results should not only be tested by using statistical methods, but also by evaluating the influence of a respective taxon on the general outcome of the analysis.

AN EXPANDED FAUNAL LIST, NIGHTINGALE SPRINGS, NEVADA.

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In 1956 J.R. Macdonald published the results of his work in west central Nevada at Nightingale Springs. Since 1989 paleontologists from the Sierra College Natural History Museum, Rocklin, California, have done extensive collecting in Macdonald's original area and environs, resulting in additions to Macdonald's list. These include peccary, cervoid, rhino and mouse, possibly *Copemys*. We have also added specimens of known species including tapir, and a juvenile *Aepycamelus* mandible. One of the most exciting finds was a nearly complete gompothere, now on display at Sierra College. Several different sized cats have been found, including one estimated to be larger than a modern African lion. Three different sized beavers, have been recognized also been identified plus several smaller fossils including birds.

A cyprinid that is the first reported finding of this fish in Nevada may indicate a link to the Snake River drainage. Other finds include coprolites; one of which contains bone fragments, indicating it was from a carnivorous mammal. Plants include water chestnut, a palm, oak leaves and flowers, along with many examples of petrified wood. All of these findings help give a better understanding of the environment and ecological communities present in the Miocene of west central Nevada.

EXCEPTIONAL SOFT-TISSUE PRESERVATION IN A MUMMIFIED ORNITHOPOD DINOSAUR FROM THE CAMPANIAN LOWER JUDITH RIVER FORMATION

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A newly-discovered *Brachylophosaurus canadensis* specimen, PCM115-H, informally named "Leonardo", is one of the best-preserved mummified dinosaur specimens ever discovered. The specimen is 90% complete, fully articulated, and the first reported subadult of this taxon.

The specimen displays extensive preservation of soft-tissue structures that suggests a unique combination of post-mortem dessication and subsequent rapid burial in channel sands, followed by geochemical reactions and diagenesis. Excavation of the specimen as a single 6.5 tonne block helped to preserve integrity of the extensive integument features which cover 80% of the body. These integument features required special preparation. Evidence of soft-tissue structures along a portion of the dorsal vertebrate suggest that a comb or frill was present. Pseudomorphic carbonate replacement of keratin features on the beak and both pes and manus provide data on appearance and function. Evidence of soft-tissue structure preservation in musculature of the lower neck and pectoral girdle are present. The shape and size of the musculature can provide new insights into the functioning of forelimbs and possible constraints on locomotion. An extensive area of fine-grained lignaceous material occurs within the ribcage, beneath integument layers, and extending through the pelvis area between the ischia and anterior chevrons. This is suggestive of stomach and lower digestive tract contents. Preliminary laboratory identification of the lignaceous material includes masticated coniferous cellulose material.

This specimen provides one of the most complete sets of morphological data for any dinosaur known.

AN EOCENE CATFISH (CLAROTEIDAE: *CHRYSICHTHYS*) FROM AN EAST AFRICAN CRATER LAKE

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Several specimens of a fossil catfish were collected from the Eocene Mahenge site of Tanzania. The specimens are identified as *Chrysichthys* (Claroteidae) based on several features, including the robust pectoral and dorsal spines and the presence of nasal barbels. However, they are considered to be a new species based on several unique characters (e.g. 20 principal caudal fin rays).

The fossil fishes collected from the lower levels of the Mahenge site are incomplete and show signs of taphonomic disturbance, unlike the relatively well-articulated fossil fishes collected from the upper levels. Despite extensive collecting at Mahenge, the catfishes have been found only in the lower levels. A possible reason for this distribution of the catfish fossils and the difference in articulation of the fishes among the fossiliferous layers is a change in oxygen levels of the water. Possibly, the lower levels represent an initially well-oxygenated lake bottom capable of supporting the bottom dwelling catfishes, and allowing scavenging or decomposition of the remains of dead fishes leading to less well-articulated fossils. In contrast, the upper levels may represent a time of a poorly oxygenated or anoxic lake bottom, during which the catfishes could not survive and bottom organisms were absent, hence there was no disturbance of fish remains. However, the palaeoenvironment at Mahenge may be more complex than this scenario. The lower level rocks are partially silicified and preserve diagenetic structures which may indicate geothermically disturbed beds. If geothermal activity took place after the catfishes were already established in the crater lake, the fish may have lost their bottom habitat because of increased temperatures or release of toxins into the lower water levels.

NEOGENE MAMMALIAN BIOSTRATIGRAPHY OF THAILAND

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The Japan-Thailand expedition surveyed Neogene basins in Thailand from 1996 to 2002. The Neogene sediments in Thailand have yielded plenty of vertebrate fossils including hominoids. Mammalian assemblage from Thailand is correlated with those of the Neogene mammalian fauna from the Siwaliks by previous works. We reexamined the lithostratigraphy, geochronology and vertebrate fauna of the following Neogene sites, Mae Soi, Li Basin, Pong Basin, Mae Moh, Chiang Muan, Had Pu Dai and Sop Mae Tham of Northern Thailand and Tha Chang, Nakhon Ratchasima of northeastern Thailand.

A primitive amebelodontid gomphothere (*Archaeobelodon*) and equids, for the first time from Southeast Asia, were discovered at Mae Soi 50km south west of Chiang Mai. We found hominoid cheek teeth (the first discovery from the southeast Asian Miocene), as well as *Propotamochoerus* and/or *Hippopotamodon* and three individuals of the primitive tetralophodont gomphothere from the Chiang Muan Lignite Mine 150 km east of Chiang Mai. The mammalian fauna from the Chiang Muan Formation suggests that this fauna is the end of middle Miocene in age. The Sop Mae Tham Fauna was the first Hipparionini record from the Neogene Southeast Asia. The Sop Mae Tham Fauna consists of tetralophodont gomphotheres, rhinocerotid, hipparionin equids, *Listriodon* and *Propotamochoerus* and/or *Hippopotamodon*, tragulids, Boselaphini and primitive bovids. This mammalian assemblage suggests that the Sop Mae Tham Fauna is early late Miocene in age. We found new Neogene mammalian faunas from a number of sand pits in Tha Chang, near Nakhon Ratchasima. The middle Miocene mammalian fauna consists of amebelodontid gomphothere and *Prodeinotherium*. The latest Miocene to early Pliocene fauna yields *Hipparion*, *Stegolophodon* and *Merycopotamus*. The early Pleistocene fauna yields advanced *Stegodon*.

It has been made clear that the previous mammalian biostratigraphic horizons of Thailand were mostly correlative with the early to middle Miocene, but the mammalian ages of some new faunas are equivalent to the late Miocene and Pliocene-Pleistocene.

USING X-RAY CT TO STUDY THE CRANIAL OSTEOLOGY OF THE RARE, BASAL GERRHOSAURID LIZARD, *ANGOLOSAURUS SKOOGI*

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Gerrhosauridae is a diverse group of scincomorphs found in Africa and Madagascar. Phylogenetic analyses suggest a close relationship between Scincidae, Cordylidae, and Gerrhosauridae, but such relationships among these groups are not resolved definitively. While Gerrhosauridae and Cordylidae are often treated as sister taxa, a recent phylogenetic analysis based on morphology suggested Gerrhosauridae may be more closely related to Scincidae. To resolve this discrepancy, more data on the distribution of characters closest to the basal condition of Gerrhosauridae are required.

Angolosaurus skoogi was hypothesized by Lang to be the basal member of Gerrhosauridae, although a recent molecular analysis nests *A. skoogi* within the *Gerrhosaurus* clade. Such discrepancy over the basal condition of this rare lizard, found only in the Namib Desert of southwest Angola and northwest Namibia, renders it a good candidate for detailed morphological study. While the number of *A. skoogi* specimens preserved is exceedingly low, resulting in minimal knowledge about its morphological characters, high resolution X-ray CT offers a means of attaining such information in great detail without damaging the few preserved specimens available. Such a detailed study of the skull and braincase of *A. skoogi* has greatly enhanced the search for new characters necessary to resolve existing ambiguity within the scincid, cordylid, and gerrhosaurid clades.

WERE ALL EXTINCT SLOTHS "GROUND SLOTHS?"

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Anatomic studies of the extinct sloth, *Hapalops*, one of the smaller, earlier genera of the family Megatheriidae, suggest that this animal could assume an upright body posture. Such an orientation would permit the sloth to stand bipedally, and the small body size of this genus might permit arboreal or semiarboreal habits. Features such as the size, position and orientation of the occipital condyles indicate that *Hapalops* individuals were able to flex the head on the neck to greater than 90 degrees. Great cranial flexure is required to reach forward to feed for an animal standing with a vertically or nearly vertically oriented vertebral column. Animals that also can stand with a horizontally oriented spine, the typical mammalian posture, therefore also require a great range of motion at the occipital-cervical joint, as in *Hapalops*. Recent

sloths are selective feeders, frequently reaching forward with a forefoot to draw flexible tree branches toward their mouths, using their elongated tongues to select and obtain preferred leaves. The elongate anterior facial region, deep mandible and pointed predental spout with a smooth U-shaped channel projecting to the anterior edge indicate a similarly elongate tongue ocurred in *Hapalops*. Although it is impossible to observe behavior directly for fossil species, inferring their habits from anatomical parallels with living species can improve the ability to estimate their capabilities and habits. In this case, anatomic similarities to Recent sloths suggests that *Hapalops* could assume the body posture necessary to feed from an arboreal or semiarboreal position, as do the smaller, living tree sloths.

NEW APPLICATIONS OF MODERN LAND SURVEYING TECHNIQUES FOR PRECISE LOCATION OF MIOCENE FOSSILS AT GRAY, TENNESSEE

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Modern land surveying techniques where utilized to record the location of fossils at the new Miocene site in Gray, Tennessee. The project includes mapping of the existing ground conditions of the site, establishment and location of the site's research grid, locating the stratigraphic position of each specimen collected, and recording the spatial orientation of each major element. This data can then be easily converted into a Geographic Information System (GIS) format for taphonomic and ecologic analyses.

Global Positioning System (GPS) was utilized for the establishment of the site's research grid, which included the horizontal and vertical control monuments. These monuments are located in the Tennessee State Plane Coordinate System, an easily reproducible datum. Utilization of this cartesian coordinate system allows for a seamless transfer of field data to a GIS format. The fossils where located by means of a modern land surveying total station and data collector, both capable of measuring to the nearest millimeter. This accuracy required the development of new field methods for locating pre-selected morphological landmarks on the fossils. The modern land surveying techniques employed here provide a fast, accurate and precise method of mapping fossil elements in three-dimensions. Furthermore, utilization of these techniques enables the relocation of features in the field quickly and accurately (particularly important where excavations of large specimens encompass multiple field seasons).

THE FIRST DISCOVERY OF A RHYNCHOSAUR FROM THE UPPER MOENKOPI FORMATION (MIDDLE TRIASSIC) OF NORTHERN ARIZONA

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A partial left rhynchosaur maxilla was discovered recently in the Holbrook Member (Early Anisian) of the Moenkopi Formation. The isolated maxilla represents the oldest rhynchosaur in North America. The Moenkopi rhynchosaur has a mixed suite of primitive and derived characteristics, including: one well-developed longitudinal groove that runs anterioposteriorly; one row of longitudinal teeth on the lateral crest; three rows of longitudinal teeth on the medial crest; three rows of longitudinal lingual teeth; one longitudinal tooth row on the medial crest that comes very close to the anterior end of the maxilla; v-shaped longitudinal groove. The lateral and medial crests are similar in size and area. It is probable that the Moenkopi rhynchosaur had only primitive conical teeth. Morphological comparisons with other rhynchosaurs suggest a close relationship to *Rhynchosaurus brodiei*; however, a phylogenetic analysis of rhynchosaurs using maxillary characters offered little resolution. Most Late Triassic rhynchosaurs, like the Moenkopi rhynchosaur, have a single longitudinal groove. Most Middle Triassic rhynchosaurs have a double groove, but some have a single groove, depending on the specimen. The Moenkopi rhynchosaur's phylogenetic placement, as well as its stratigraphic position so low within the Middle Triassic, test hypotheses about the evolution of rhynchosaur dental morphology.

GROWTH OF *ESOX TIEMANI* OF THE PALEOCENE SENTINEL BUTTE FORMATION OF NORTH DAKOTA WITH EVIDENCE TO ESTIMATE MEAN ANNUAL TEMPERATURE

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Scales and skeletons of *Esox tiemani* (Teleostei: Esocidae) were recovered from a lacustrine deposit in the Sentinel Butte Formation (Paleocene) near Almont, North Dakota in order to contrast the growth patterns between fossil and extant *Esox* and to estimate the mean annual temperature of the Paleocene Almont environment. Scales and vertebrae were aged by counting annuli and the data were then used to construct a Von Bertalanffy growth curve. The growth curve and total lengths of *E. tiemani* provided information for a comparative analysis between growth patterns of Late Paleocene and extant *Esox*. Growth and mean average temperature data for 29 populations of extant *Esox*, ranging in latitudes from the Northwest Territories, Canada to Tennessee, USA, were analyzed using linear regression. Examination of *E. tiemani* scales and skeletons showed that the Almont population had a longevity of at least nine years, attained greater than 80% of maximum size (asymptotic length) by age five, and reached a total length of at least 120 cm. Our results also show that *E. tiemani* had an accelerated growth rate like that of extant *Esox* in Tennessee compared to *Esox* in cooler climates, but overall had a similar growth pattern and total maximum lengths-at-age to living *E. lucius* and *E. masquinongy*. Using regression equation parameters and growth information from *E. tiemani* a mean annual temperature of approximately 15˚C was calculated for the late Paleocene Almont environment, making it comparable in temperature to that of North Carolina today. The Almont, North Dakotak mean annual temperature has cooled approximately 9.3˚C to the current mean of 5.7˚C. The analysis of mean annual temperature concurs with previous estimates based on fossil flora indicative of warm temperate climatic conditions.

COMPLETE OSTEOCALCIN SEQUENCES FROM 10,000 TO >53,000 YR BP *BISON* BONES.

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We present the first complete sequences for osteocalcin from ancient bison bones (10,000 to >53,000 yr BP). This was possible through careful purification and subsequent sequencing using matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS). The small quantities of bone (ca. 20 mg) that were required prevent significant destruction of precious fossil material. Our data are important because, like DNA, protein sequences contain fundamental genetic information that is the key to phylogenetic reconstruction. The demonstration of a 129 mass unit difference between modern cow and the fossil osteocalcin sequence emphasizes this point. The suggestion that proteins may be preserved in fossils longer than DNA and implies the possibility of extending genetic record farther back in time and extending the concept put forth by Paabo of genetic time-travel.

SKULL MORPHOLOGY OF *CANDIDODON ITAPECURUENSE* (CROCODYLOMORPHA, MESOEUCROCODYLIA) FROM THE CRETACEOUS OF BRAZIL

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Candidodon itapecuruense is a mesoeucrocodylian from the Parnaíba Basin, Brazil. It was found in fine-grained sandstones of Albian age (Itapecuru Formation) interpreted as fluvial deposits. Previously it was known from a single mandible and isolated molariform, premolariform and incisiform teeth. The present study describes the first complete skull of *Candidodon itapecuruense*.

The skull of this crocodyliform shows a short rostrum, of tubular shape. It is slightly compressed between the maxillar and premaxillar region. The external nares are anterior and subvertical. The orbits are lateral, three times the size of the temporal fenestrae. The antorbital fenestrae is small and oval-shaped. The skull surface is sculptured with small and irregular rugosities. The skull roof is rectangular shape, dorsally plain. The supratemporal fenestrae are oval and slightly laterally positioned. The quadrate is backward inclined. The pterygoids are big. The internal nares are oval-shaped, narrow and are located between the palatines and pterygoids. In the premaxilla are three conical pointed teeth with different sizes. In the maxilla there are two small pointed and spatulated teeth, and a hypertrophied caniniform tooth. After a small diastema, there are four molariform teeth that have a main spatulated cusp surrounded by small denticles on the crown´s base.

Candidodon itapecuruense has a specialized teeth pattern showing a possible omnivorous diet. Its lateral orbits, with anterior and verticalized external nares are evidences of terrestrial habits.

INDIRECT EVIDENCE OF SAIL PRESENCE FROM HEALED SPINOUS PROCESS FRACTURES IN SEVERAL *DIMETRODON* SPECIMENS

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Sailback forms are known from pelycosaurian-grade synapsids in seven genera distributed between two families. While the precise function of the sail remains disputed, most researchers agree in assuming the presence of soft tissue in the form of webbing between the elongate neural spines. A series of associated neural spines from the collections of the Field Museum of Natural History, as well as fragmentary material from the UCLA-VP Collections demonstrate definite signs of healed fractures. The fractures are well resolved, with minimal evidence of malalignment in the form of subluxation, torsion or lateral bending. The lack of deformation provides indirect evidence of the presence of a soft-tissue sail webbing that was strong enough to have provided a biological splint to neural spine fractures, thus retaining alignment during healing. A survey of pelycosaur specimens from collections of the Field Museum of Natural History, the Carnegie Museum of Natural History, University of California Los Angeles Vertebrate Paleontology, Museum der Natur (Gotha, Germany) and the American Museum of Natural History reveals that healed fractures of axial structures are the most common form of pathology in Late Paleozoic pelycosaurian-grade synapsids.

ROCKS, BONES, AND PLANTS: A PATTERN OF LATITUDINAL DEPENDENCE DEMONSTRATED BY THE DISTRIBUTION OF JURASSIC DINOSAURS.

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Extant plants and animals are adapted for life within a specific range of climatic conditions. These climate conditions influence the distribution of organisms by placing limits on the biotic and abiotic factors that a species encounters during its evolutionary history, causing adaptation to and subsequent dependence upon, the environments where these climates prevail. Climatic conditions also vary with latitude due to factors like insolation, landmass position, wind and precipitation patterns, and ocean currents. Therefore, latitudinal changes in climate profoundly effect species distributions. This large-scale phenomenon has also been found to be the case for fossil organisms, including trilobites, brachiopods, ammonites, mammals, and plants.

One group in which latitudinal climatic effects have not been sufficiently studied is the Dinosauria. During the Mesozoic, dinosaurs attained a global distribution that extended from pole to pole and across a wide variety of environments. Like all other organisms, dinosaurs

were likely adapted for living within specific climatic parameters. It should then be expected that dinosaur faunas will demonstrate a nonrandom spatial distribution which may shift over time. Distribution data from a comprehensive database of worldwide dinosaur fossil localities was plotted on stage-level paleogeographic maps for the Jurassic Period. This information was combined with data on paleofloral and climatically sensitive sediment distributions in order to determine relative climatic zones (biomes).

Preliminary results indicate that a peak in dinosaur diversity exists between 30-40? N paleolatitude. This peak remains relatively constant throughout the Jurassic, despite continental drift, leading us to believe that this represents a real historical pattern and is not the result of taphonomic bias. Interestingly enough, this peak is not concurrent with the peak in floral diversity, which may have important implications for dinosaur paleoecology. It is acknowledged that certain biases, such as amount of surficial rock exposure, may be confounding this pattern, and further work to correct for these factors is underway.

OVERVIEW OF EVIDENCE FOR SUPERORDINAL/ORDINAL EUTHERIAN TAXA AND TIMING OF THEIR DIVERSIFICATION

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Over the past decade, the Cretaceous eutherian record has dramatically expanded in quantity, quality, and geographic distribution. In addition to more fragmentary materials primarily from North America and Asia are nearly complete skeletons for taxa from the mid-Barremian of China and from the Campanian of Mongolia. We review the evidence for the current views on the phylogenetic relationships of the major Cretaceous eutherian lineages and the impact on the timing of superordinal/ordinal diversification. Some Cretaceous eutherians are stem taxa to crown group Placentalia; others have been alternatively viewed as either stem taxa (i.e., none of the modern superorders have Mesozoic representatives) or as having already attained membership in a particular superordinal group of placentals. Crown group membership of some Cretaceous forms is more in line with molecular clock estimates for a more remote time of diversification. Prime examples are the alliance of the Late Cretaceous Asian zhelestids with Ungulata and of the Late Cretaceous Asian zalambdalestids with Glires (rodents and lagomorphs). A second controversy, with wide geographic implications, concerns the relationships of the aukstribosphenids from the Australian early Aptian, which are viewed either as eutherians, possibly related to erinaceoids, or as members of a clade of tribosphenic mammals from the southern hemisphere unrelated to Eutheria.

A NEW SPECIMEN OF *POSTOSUCHUS* FROM THE LATE TRIASSIC NEWARK SUPERGROUP: DEEP RIVER BASIN, NORTH CAROLINA

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A new, associated partial skeleton of *Postosuchus* from North Carolina has clarified several issues regarding the osteology of this suchian. Some of the new elements recognized include the interclavicle, clavicles, phalanges of pedal digit V, and a unique manus different from that previously described for *Postosuchus*.

The interclavicle of the North Carolina specimen is mediolaterally expanded and dorsoventrally flattened. The outer, ventral surface is finely, longitudinally striated, and the shaft is slightly convex. One nearly complete clavicle is associated with the skeleton as well as a partial second clavicle. The clavicle shaft is ovate in cross-section and is slightly twisted proximal to the articulation with the interclavicle. The fifth metatarsal has three highly reduced phalanges. The phalanges on the fifth metatarsal were previously thought to be absent in *Postosuchus*. The manus differs from the paratype (TTUP 9002) hand of *Postosuchus kirkpatricki* in being shorter relative to the length of the ulna(approximately one-fifth the length of the ulna compared to the larger, putative manus of *Postosuchus kirkpatricki* (TTUP 9002), which is about half the length of the ulna). An unusual feature of the North Carolina manus is a deeply excavated groove on the proximal end of the medial surface of metacarpal I. A laterally projecting flange on the proximal end of metacarpal II articulates with this groove. The corresponding bones of *Postosuchus kirkpatricki* show only a slight flange and groove relationship. The North Carolina specimen is otherwise very similar to the holotype and paratype specimens of *Postosuchus kirkpatricki* in other features of the skull, post-cranial axial, and appendicular skeleton.

This new specimen extends the geographic range of *Postosuchus* from the western to eastern.

ADVANCES IN OUR UNDERSTANDING OF THE POLYGLYPHANODONTINE LIZARDS OF NORTH AMERICA

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The record of transversely-toothed lizards from the Cretaceous of North America has significantly improved in the last several years. Previously described taxa include *Polyglyphanodon sternbergi*, *Paraglyphanodon utahensis*, and *P. gazini*. Recently described taxa include *Dicothodon moorensis*, *Polyglyphanodon bajaensis*, and *Bicuspidon numerosus*. New specimens provide sufficient information to name a species of *Dicothodon* from the Turonian. The teeth of all of these lizards are morphologically complex and several features of crown structure shared amongst these taxa supports monophyly. These dental features include transverse orientation, V-shaped central blades, primary cusps with angular sides, semicircular accessory structures, asymmetry in the size of the accessory structures, and arrested tooth replacement. *Peneteius* (including additional speciments from the Campanian of Utah and Texas) shares many of these dental supporting its inclusion in Polyglyphanodontinae. These features of tooth structure are clearly distinct from the polyglyphanodontines from the Late Cretaceous of Asia, including the oblique-toothed *Cherminsaurus*, which is shown to be more similar to Asian polyglyphanodontines with polycuspate, leaf-shaped teeth. If related, the Asian and North American polyglyphanodontine taxa share a recent common ancestor that can be no younger than the Early Cretaceous.

With the exception of *Peneteius aquilonius* (Montana), all of the known polyglyphanodontine taxa from North America occur in southern latitudes closely matching the distribution of Lehman's "*Alamosaurus* fauna." This distribution reinforces the need for further investigation of the Mesozoic microvertebrate faunas of South America in addition to the relevant faunas of North America.

PULMONARY PNEUMATICITY IN NON-DINOSAURIAN ARCHOSAURS WITH COMMENTS ON *ERYTHROSUCHUS* AND DISTAL FORELIMB PNEUMATICITY IN PTEROSAURS

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Various archosaur taxa possess postcranial osteological features that have been interpreted as pneumatic. For example, certain saurischian dinosaurs and pterosaurs exhibit fossae and/or foramina leading into chambers within vertebrae. Researchers have inferred a causal relationship between this morphology and an air sac system similar to the one in living birds. Pneumatic bones of saurischian dinosaurs (exclusive of avian theropods) are limited to the axial skeleton while pterosaurs display pneumatic axial and appendicular elements, including distal forelimb bones. Additionally, recent work has suggested the presence of pneumatic fossae and foramina in vertebrae of the basal archosauriform *Erythrosuchus*, significantly expanding the distribution of postcranial pneumaticity throughout the archosaur clade.

In this project, extant archosaurian reference taxa were examined to determine osteological correlates of different soft tissue systems, to provide a key for identifying pneumatic postcranial bones in fossil specimens. Using this information, inferred pneumatic features were evaluated in a variety of fossil taxa including *Erythrosuchus* and various pterosaurian taxa.

Results of this study demonstrate that many soft tissues (e.g., musculature, adipose deposits) are related to vertebral fossae. However, only fossae and foramina leading into large internal chambers are consistently associated with pulmonary diverticula. Based on this criterion, purported pneumatic features identified in *Erythrosuchus* cannot confidently be associated with pneumatic invasion of bone. Additionally, features identified in distal forelimb segments of some pterosaurs (e.g., *Pteranodon*) are consistent with pneumatic morphology. The distribution of distal forelimb pneumaticity in extant birds is restricted to forms with an extensive subcutaneous diverticular network (e.g., pelicans). It is proposed that distal forelimb pneumaticity in pterosaurs likely resulted from a similar network.

INFERENCE OF PLESIOSAUR HUNTING STYLES FROM FLIPPER GEOMETRY: PARALLELS AMONG BIRDS, BATS, AND AIRPLANES.

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Previous work on plesiosaur hunting styles has focused on calculations of maximum swimming speed inferred from overall body shape. This study utilizes measurements of well-preserved plesiosaur flippers to compute the aspect ratio (AR) characterizing a variety of taxa. AR is a dimensionless number expressing the ratio of wing span squared over wing area, and is a measure of wing geometry. Short, wide wings have low AR, while long, thin wings have high AR. Variation in AR has a large effect on the magnitude of induced drag generated by a wing; wings of high AR are more efficient but less maneuverable than wings of low AR. The trade-off between efficiency and maneuverability is a well known factor in airplane design, and has influenced the evolution of birds and bats as well. Birds with high AR wings such as albatrosses generally cruise long distances at intermediate speeds, while birds with low AR wings such as the magpie are specialized for tight maneuvering. Birds that hunt on the wing, such as falcons, have intermediate AR. The range of AR variation in plesiosaur flippers is very similar to that seen in bats. High AR was probably the plesiomorphic condition for the clade, and is retained in plesiosauromorph taxa. Pliosauromorph taxa exhibit flippers of intermediate AR regardless of ancestry, while some cryptoclidids have flippers of low AR. When coupled with previous calculations of maximum swimming speed, plesiosauromorphs are inferred to have hunted by cruising long distances searching for small, dispersed food items. Pliosauromorphs are inferred to have actively hunted single, large food items 'on the wing'. The cryptoclidids are inferred to have been maneuverability specialists.

CONTINENTAL TETRAPOD ICHNOFAUNAL SUCCESSION AND TURNOVER IN THE NEWARK SUPERGROUP (?MIDDLE-UPPER TRIASSIC AND LOWER JURASSIC, EASTERN NORTH AMERICA) AND TEMPORALLY-EQUIVALENT STRATA IN MOROCCO

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Three distinct assemblages characterize the >34-million-year track record in the Newark Supergroup and coeval Moroccan strata. The oldest, Atlas-type (Deep River, Moroccan basins), is characterized by numerous *Apatopus*; unnamed, sometimes very large (>30 cm) ?bipedal tetradactyls; *Brachychirotherium*; ?*Chirotherium*; *Rhynchosauroides*; and far less common indeterminate tridactyls. Grallatorids appear to be absent. Conventionally considered Early-Late Carnian, the strata may extend into the Ladinian.

The Passaic-type assemblage (Dan River, Culpeper, Gettysburg, Newark, Fundy basins; Late Carnian to the Triassic-Jurassic boundary [TJB]) is the most diverse and long-ranging. Theropod prints increase in size and abundance: the small and quite rare *Grallator parallelum* occurs throughout, but by the end of the Triassic (202 Ma) both *Grallator* and the larger *Anchisauripus* are common. The ornithischian track *Atreipus* is abundant from the base (~228

Ma) to ~207 Ma but absent thereafter. Other common forms include *Rhynchosauroides*, *Brachychirotherium*, *Gwynnedichnium* and *Apatopus*; far rarer are *Procolophonichnium*, *Chirotherium* and a new dinosaurian genus. The latest Triassic has several batrachopids.

The youngest (Connecticut Valley-type) assemblage (Culpeper, Newark, Hartford, Deerfield, Fundy basins; basal Hettangian [202 Ma] to base of Sinemurian [~200 Ma]) is much less diverse, with only grallatorids, *Batrachopus* and *Rhynchosauroides* basally. *Eubrontes* is an abundant grallatorid, appearing within 10,000 years after the TJB. Above this, the assemblage remains quite stereotyped through the end of the Newarkian record. Grallatorids, *Anomoepus* and *Batrachopus* are abundant; *Rhynchosauroides* and *Amheghinichnus* are much rarer. In the northern basins, *Otozoum* is also present and can be common.

Ichnofaunal change is slow through the Late Triassic except at the TJB, where the turnover between Passaic and Connecticut Valley-type assemblages, characterized by a 20% increase in the maximum size of theropod tracks, occurs in <30,000 years. The transition between Atlas and Passaic-type assemblages also seems unusually rapid, but sampling is still too sparse to assess the pace of change.

ADVANCING OUR UNDERSTANDING OF BIOMOLECULAR PRESERVATION

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Recovering biomolecules from the vertebrate fossil record is time consuming, difficult, and results in a sacrifice of a finite resource. The key to success lies in the ability to identify samples with optimal preservation. Thus, one goal of our work is to establish a reliable screening to that identifies samples containing well-preserved biomolecules. We have developed immunological and mass spectrometric techniques (matrix-assisted laser desorption ionization mass spectrometry) that allow us to sequence proteins and their diagenetic products from small quantities of bone (ca. 20 mg). In addition, we are able to relate mineralogical characteristics (e.g. porosity, crystallinity) to diagenetic states of proteins and DNA. The possibility for exceptional preservation of bone proteins is demonstrated by our data. Our results show that a portion of the bone protein osteocalcin remains after samples are heated to 100 degrees centigrade for 200 hours and that osteocalcin can be sequenced from >53,000 yr BP bones. These data suggest that phylogenetically informative molecules can be retrieved from bone and emphasizes the importance of our efforts.

A CLADISTIC ANALYSIS OF MIDDLE CENOZOIC EQUIDAE

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The first major adaptive radiation of equids has its roots in the late Oligocene-early Miocene. It includes the small Miocene horse *Archaeohippus*, an evolutionary mosaic. Arguments regarding the phylogenetic position of *Archaeohippus* have been polarized, with some students emphasizing affinity with *Anchitherium* based on its low-crowned teeth and others with *Parahippus* based on derived pedal adaptations. A cladistic analysis was performed to test the hypothesis that the species of *Archaeohippus* form a monophyletic clade more closely related to the parahippines than to the clade of large browsing horses that includes *Anchitherium*.

A matrix of 21 taxa and 62 characters was compiled in MacClade 4.0 and analyzed in PAUP 4.04b4a for MacIntosh. A heuristic search produced 106 shortest trees 190 steps long, CI=0.45 and RI=0.59. Of these, 95 trees include a monophyletic *Archaeohippus*. *A. mourningi* and *A. ultimus* consistently form a small clade that is often joined with *A. blackbergi*. *A. penultimus* and a new species of *Archaeohippus* often form a clade. The sister taxon to the entire *Archaeohippus* clade is *Parahippus pawniensis*. In some trees the new taxon—which is the oldest, smallest, and most primitive *Archaeohippus*—is the sister taxon of the *Desmatippus/Parahippus* clade. When *Mesohippus bairdi* is designated as outgroup, the sister taxon to the *Archaeohippus/P. pawniensis* + *Desmatippus/Parahippus* clade is *Anchippus texanus*. Without an outgroup, *A. texanus* is the sister of this clade and an outgroup assemblage that includes a strongly supported clade of large browsers including *Anchitherium+Hypohippus+Megahippus* (but not *Kalibatippus praestans*). *Mesohippus stenolophus* and *Miohippus equinanus* are never nested within the *Archaeohippus/P. pawniensis* + *Desmatippus/Parahippus* clade.

Thus, the evidence suggests that the monophyletic *Archaeohippus* was derived from a primitive parahippine close to *P. pawniensis*.

PRIMITIVE AMERICAN BADGERS (MUSTELIDAE, TAXIDIINAE) FROM THE LATE CLARENDONIAN OF NEBRASKA

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Two localities in the Merritt Dam Member of the Ash Hollow Formation in north-central Nebraska have produced fossils of primitive taxidiine badgers. The specimens were curated into the Frick Collection at the AMNH in the 1950s and are here described, providing a significant contribution to our knowledge of taxidiine evolution and distribution. Given the published dates of 9.7 ± 1.2 Ma and 10.2 ± 0.7 Ma obtained from ashes in the Merritt Dam Member, these fossils are the oldest documented taxidiines.

An isolated right M1 and a partial right dentary with dp3-4 and m1-2 were recovered from the Eli Ash Pit in Cherry County. The M1 exhibits wear on its transverse cristae so it is not from the same individual as the dentary. Given its moderate development of lingual cingulae, the M1 is not triangular in form as in other taxidiines. The m1 paraconid and metaconid are positioned such that the trigonid is more sectorial than that of *Pliotaxidea* and *Taxidea*. The m1 talonid is comparable to that of other taxidiines, having a strong central hypoconid, entoconid, and accessory cusps.

The rostral right half of a skull with C and P3-M1 was recovered from the Alligator Slide locality in Brown County. The M1 bears transverse cristae and greatly expanded lingual cingulae. A constriction separates the buccal from the lingual portion of the tooth such that this tooth appears to be a transitional morphology between the Cherry County M1 and the M1 of *Taxidea*. The P4 does not exhibit the development of a medial shelf and hypocone observed in *Pliotaxidea* and *Taxidea*. This P4 morphology is shared with a previously described new taxidiine from the Chamita Formation in New Mexico, and supports a previous phylogenetic analysis that indicates the acquisition of a P4 medial shelf and hypocone by taxidiines is independent from that of meline badgers. The partial skull and m1 demonstrate that the Clarendonian taxidiines were smaller than Hemphillian *Pliotaxidea*, and that taxidiines have increased in body size in addition to dental complexity.

CANIDS FROM RANCHOLABREAN DEPOSITS OF SNAKE CREEK BURIAL CAVE, WHITE PINE COUNTY, NEVADA

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Snake Creek Burial Cave, Nevada is an important Quaternary mammalian deposit, however the canids of this cave have yet to be analyzed. Several hundred canid (Carnivora; Canidae) bones and teeth were recovered in 1989. Preliminary analyses of the material collected suggest that there are several species of fox, including *Urocyon cinereoargenteus* (gray fox) and likely members of the genus *Vulpes*. *Vulpes vulpes* (red fox) is no longer present in the Snake Range of Nevada. *U. cineroargenteus* is still present in the Great Basin, while *Vulpes macrotis* (kit fox) has moved further south and west into Arizona and California. There is still a controversy whether or not *Vulpes velox* (swift fox) is distinct from *V. macrotis* based on osteological characteristics. In western Rancholabrean localities, canids, especially foxes, are rarely recovered in large quantities, and are infrequently studied in great detail from any North American locality. Snake Creek Burial Cave provides an excellent source for such a detailed study of these smaller canids. I am examining the following taxa to determine which foxes inhabited the Great Basin during the Wisconsinan glaciation: *Alopex lagopus*, *Urocyon cinereoargenteus*, *Vulpes macrotis*, *Vulpes velox*, and *Vulpes vulpes*. Continued analysis and identification will reveal the total number of canid species contained within the fossil material collected.

DOES DIVERSITY OF EGGSHELLS MEAN DIVERSITY OF DINOSAURS?

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The homogeneity of eggshells belonging to the Megaloolithidae oofamily from Suterranya (Catalunya) is evaluated and compared with eggshells from other Catalan localities. The utility of eggshells as an indicator of nesting dinosaurs diversity in the Catalan Pyrenees is also discussed.

In addition to morphological characters, two metric variables have been used in this analysis: diameter of eggshell unit, and eggshell thickness. The metric values of eggshells from Suterranya were dispersed, and some values were more associated with eggshells from other localities. The t-tests show these differences were highly significant. The statistical analyses also exposed significant differences in eggshell thickness between the Suterranya eggshells and other Catalan localities and within these localities as well.

Thus, the eggshells from Suterranya exhibit significant heterogeneity, and a new oospecies of *Megaloolithus* is proposed for the anomalous Suterranya eggshell sample besides the well-represented *M. pseudomamillare*. Therefore, metric values and statistical analyses are a valid tool to differentiate oospecies, which could be attributed to different dinosaur species.

TRIASSIC PARK—FIRST YEAR RESULTS OF THE PALEONTOLOGICAL INVENTORY OF PETRIFIED FOREST NATIONAL PARK, ARIZONA

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Petrified Forest National Park (PFNP) in northeastern Arizona contains some of the premier exposures of Late Triassic sediments in the world. The vertebrate fauna of the park is dominated by pseudosuchian archosaurs including phytosaurs, aetosaurs, and rauisuchians. Metoposaurid amphibians are also very common while smaller terrestrial taxa such as dinosaurs and spenosuchians are less so. Also occurring are numerous small "problematic" taxa.

Vertebrate paleontology research over the last 80 years, under paleontologists including those from the University of California at Berkeley, the American Museum of Natural History, the Museum of Northern Arizona, and the Mesalands Dinosaur Museum in Tucumcari, New Mexico, has resulted in the documentation of over 260 sites. Unfortunately, a large amount of the locality data for these sites is either ambiguous or nonexistent, however, despite this drawback a paleontological inventory initiated by PFNP in the summer of 2001 has resulted in the relocation and documentation of over 82, or 30%, of these sites through April of 2002. Site documentation includes photographs, collected specimen information, stratigraphic and geologic information, as well as global positioning data. The purpose of this inventory is to create a working database for resource management decisions as well as for ongoing paleontological research and to establish protocol for future, periodic monitoring of vertebrate fossil sites.

Furthermore, as a result of the current inventory, 23 new vertebrate localities have been discovered with several important vertebrate specimens collected. Most notable is a relatively complete skeleton of the aetosaur *Stagonolepis wellesi*, this being only the second such specimen ever recovered from the American southwest.

A TEIID LIZARD IN THE EARLY TERTIARY OF NORTH AMERICA

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The substantial fossil record of the lizard family Teiidae is thus far confined to the Western Hemisphere and Mongolia. The record of the family in the Cretaceous of North America is widespread and diverse, but seemed to end abruptly at the end of that period. It was previously assumed that all of the characteristic Cretaceous teiid taxa were extirpated from North America in the Cretaceous/Tertiary boundary event. Teiids reappear in North America later in the Tertiary and are extant as the genera *Cnemidophorus* and *Ameiva*, presumably by diffusion from South American populations.

At least one taxon of teiid apparently did survive into the Tertiary of North America, as demonstrated by a specimen from the Bear Creek Local Fauna of Carbon County, Montana. The specimen was in the Princeton University collections and is now in repository at Yale University, catalogued as YPM-PU 17705. It is a dentary fragment with four teeth, which are characteristically isodont, tricuspate, and striated. Such a dentition is distinctive to the subfamily Chamopsiinae, specifically *Chamops segnis*. A prudent referral of the Bear Creek dentary is *Chamops* cf. *segnis*, based on the distinct lateral cusps with well-defined tips, the expanded pleurodont tooth bases, and the low tooth crowns.

Although no new specimens have been added to the Bear Creek Local Fauna for many years, restudy of existing material continues to produce unexpected finds. It now appears to represent a hypothetical environment for a surviving population of teiids, a paludal setting near a basin margin. This is yet another instance of an anachronistic taxon in a basin margin assemblage.

RIB ANGULATION, SCAPULAR POSITION, AND BODY PROFILES IN SAUROPOD DINOSAURS

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Ribs are one of the most ignored parts of the skeletons of fossil vertebrates. In dinosaurs generally and sauropods in particular, the neutral position of the dorsal ribs has a significant impact on calculations of body mass and of the positioning of the shoulder girdle. Rib articulation is reconstructed by analysis of the joint articular surfaces in sauropods, and of the normal neutral orientation and range of mobility of the ribs in extant archosaurs. A rib is raked when the distal end of the rib is posterior to the proximal head as viewed laterally relative to the long axis of the centrum. In dorsal view the rib may also be swept, such that the plane containing the rib's curvature is not perpendicular to the long axis of the centrum. The relative rake and sweep of the ribs of *Apatosaurus* and *Camarasaurus* are compared, and used as the basis for their ribcage reconstructions. A digital model of the sauropod ribcage is animated to examine the role of rake and sweep in the volumetric changes associated with lung ventilation. A flattened area on the lateral surface of dorsal ribs 2-5 in *Apatosaurus* indicates the likely position of attachment of the scapula to the trunk. If these contours indeed reflect the position of the scapula to the trunk, this would favor a subhorizontal orientation of the shoulder girdle, with the glenoid opening almost directly ventrally. The more nearly continuous curvature of the ribs in *Camarasaurus* precludes the use of similar landmarks to position the scapulae, but similarities in shape and medial curvature of the scapula suggests a shoulder girdle orientation similar to that in *Apatosaurus*. A reconstruction of the curvature of the dorsal column along with the dimensions of the ribcage and the position of the scapulocoracoid permits a geometrically constrained skeleton which can then form the basis of an estimation of body profile and derivative volume and mass estimates.

DATA FROM NEW DINOSAUR MATERIAL DISCOVERED IN THE CLOVERLY FORMATION OF CENTRAL MONTANA

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The newly discovered mid-section and partial premaxilla belonging to the skull of *Sauropelta edwardsi* (MOR 1073) reveal some new and interesting characters. These include substantial maxillary sinuses, a straight maxillary tooth row, considerably thickened bone in the parietal dome region, a raised ring-like dermal segment surrounding the orbital rim, and the presence of premaxillary teeth.

A microsite within the basal portion of Unit VII of the Cloverly Formation has produced evidence of a small theropod (MOR 1178) that may be new to the faunal assemblage thus far recognized from this Early Cretaceous unit. Its characters are a shallowly grooved neural platform running along the dorsal surface of the distal caudal vertebrae, small rectangular anterior serrations on an associated maxillary tooth fragment, a strong sagittal crest on the parietal fragment, a particularly robust metatarsal IV, and 2nd 3rd and 4th pes unguals which conform closely to the proportional ratios found on *Troodon formosus* (NMC#8539). The rostal/caudal cross-sectional thickness of the maxillary tooth fragment is 5.8 mm. The dorsal surface of the ectopterygoid possesses complex pneumatic depressions. The skeletal elements measure approximately 76 percent the size of the corresponding bones of *Deinonychus antirrhopus* (YPM 5205, 5211, AMNH 3015), though the forelimbs are closer to 89 percent. Thus the forelimbs on this new specimen would be appear to be unusually long. The coracoid, semilunate carpal, cervical vertebrae and pes unguals display some unique and interesting characters that differ from *Deinonychus antirrhopus*. The sagittal crest continues on to the frontal region on the dorsal surface of the skull. This would create a striking feature in a life reconstruction.

A HADROSAURINE DINOSAUR MUMMY FROM THE LANCE FORMATION (UPPER MAASTRICHTIAN), NIOBRARA COUNTY, WYOMING

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In 1995, a partial hadrosaurine dinosaur skeleton was discovered in the Lance Formation (uppermost Maastrichtian) of Niobrara County, Wyoming. This new fossil is comparable to but less complete than the 1908 and 1910 Sternberg mummies. The skeleton lay within a point bar sand, perpendicular to current with the tail nearest the channel.

The tail, pelvis and posterior torso are well articulated. More anterior portions of the carcass are progressively more disarticulated and the pectoral girdles, forelimbs, neck, and skull are missing. As currently prepared, three-dimensional skin impressions enclose portions of the tail. The new fossil shows a range of caudal scale morphologies. These dermal scales are sub-equal in size with the exception of several large scales located along the dorsal ridge of the tail.

Several skeletal pathologies are present on this fossil. They include punctured, fractured, and/or infected caudal neural spines, fused caudal vertebrae, and fractured ribs. These pathologies indicate that this particular individual survived multiple traumas. Possible scenarios to explain these injuries are trampling, disease, mating behavior, and survival of attack by one or more large predators.

RARE EARTH ELEMENT SIGNATURES OF FOSSIL VERTEBRATES COMPARED WITH LITHOSTRATIGRAPHIC SUBDIVISIONS OF THE UPPER CRETACEOUS PIERRE SHALE, CENTRAL SOUTH DAKOTA

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Rare earth element (REE) concentrations were measured in mosasaur bones collected from five members (Sharon Springs, Gregory, Crow Creek, DeGrey, and Verendrye) of the upper Cretaceous Pierre Shale at localities near the Missouri River in Brule, Buffalo, Hughes and Hyde counties, South Dakota. REE signatures in fossils from individual members are similar and may be distinctive over wide areas; fossils from the Verendrye Member have REE signatures that are consistent over 250 km2. However, fossils from each member of the Pierre Shale have different REE signatures. 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 members, fossil bones eroded from stratigraphic context can be assigned to a member based on REE signature comparisons. REE patterns can indicate microenvironments of deposition and, on a larger scale, reveal fossil provenience. Differences in REE signatures between members may be interpreted as resulting from differences in mixing of shallow coastal seawater and anoxic deep waters. If differences in mixing are interpreted as depth differences, the lower Sharon Springs was deposited in deep, anoxic water, with gradual shallowing through the upper Sharon Springs. The Gregory was deposited in shallow coastal water, and the overlying Crow Creek, DeGrey, and Verendrye Members in progressively deeper marine waters. These interpretations are generally consistent with those based on faunal diversity and lithological interpretation of the members. REE signatures in fossils from the Campanian Verendrye Member were also compared with those of similar fossils from the Maastrichtian Navesink and Hornerstown Formations of New Jersey. Comparison of the signatures suggests similar paleo-oceanographic conditions in the two areas.

PROBLEMS WITH SAUROPOD NECK POSTURE

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Neck posture in sauropods remains controversial. The anatomical argument for horizontal necks presumes that habitual posture follows a "neutral" cervical articulation with fully overlapping zygapophysis, and centra facets paralleling one another. Although an S-curve results from this method in theropods and some sauropods, the inverted U-curve restored in *Apatosaurus* is so strong that the head is well below ground level. Neutral neck posture consequently does not necessarily match normal posture in sauropods, or in giraffes whose cervicals articulate horizontally although the neck is often held near vertical. The neck base of *Brachiosaurus* is too poorly preserved to restore its posture, but the presence of well developed withers and stress analysis suggest it was carried erect. In multiple camarasaur, mamenchisaur and euhelopid specimens the neck base is kinked upwards even when the rest of the neck is not dorso-flexed. Cervicals remain functionally articulated when vertical in most sauropods, except diplodocids which had to rear up to hold the neck vertically.

The common claim that the sauropods' ultralong necks saved energy by working like a ground level vacuum cleaner has never been verified. Just 1 kg worth of browse powers a 50 tonne animal for 400 m, and walking 7 m requires only 20 g of browse. Such trivial energy savings do not compensate for the extra energy needed to grow and maintain long necks, or breathe through long trachea. Tall necks would have required overly large, very high pressure sauropod hearts, but such inefficiency is similar to the high cost of elevated metabolic rates, the energy expensive brains of humans, or massive flight muscles. Sauropod necks probably evolved to reach floral resources beyond the reach of shorter herbivores, and lack of grit wear on sauropod teeth confirms that they rarely low browsed.

THE POSTCRANIAL SKELETON OF TEMNOSPONDYL AMPHIBIANS.

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Study of the postcranial skeleton of the Temnospondyli is important for understanding both the lifestyle and phylogenetic relationships of the group. Generally the skulls of temnospondyls have been used for phylogenetic analysis, rather than the postcranial skeleton. The Temnospondyli currently are divided into two major groups, the heavily ossified and highly terrestrial Euskelia, and the poorly ossified and obligatorily aquatic Limnarchia, which includes the Stereospondyli. Recent study of the postcranial skeleton of basal members of the Stereospondyli has shown that some taxa may be highly terrestrial, and there is wide morphological variation in the degree of ossification of the adult postcranial skeleton between apparently closely related taxa. This indicates that the degree of ossification of the postcranial skeleton within the Temnospondyli is highly plastic, which, in turn, has implications for

assessment of the lifestyles of these animals.

Comparison of the postcranial skeleton of the Lepospondyli, Seymouriamorpha and basal amniotes with that of basal members of the Temnospondyli reveals striking similarities, and suggests a common origin for the fully terrestrial bauplan. The evolutionary transition between the paddle-like limbs of the early tetrapods (as evidenced by their L-shaped humeri, for example) and more terrestrial limbs with paddle shaped humeri and reduced dermal pectoral girdles (characteristic of the early Temnospondyli, Lepospondyli, Seymouriamorpha and basal amniotes) is a complicated evolutionary step, and it may be more parsimonious to suggest a common origin for these fully terrestrial taxa, rather than convergent evolution across the crown clades. To date, preliminary cladistic analysis (including both postcranial and cranial characters) supports this hypothesis, which disagrees with previous hypotheses concerning the phylogenetic relationships of early tetrapods in that *Greererpeton*, the Baphetidae and the Anthracosauria all form successive stem taxa to a clade containing the Seymouriamorpha, Lepospondyli, basal amniotes, and Temnospondyli.

MOSASAUR BONE HISTOLOGY

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The paleohistology of mosasaurs has not previously been studied in detail. The few works published focused only on ribs, and the sample size used (number of individuals) was relatively small. This is the first attempt at a detailed study of the histology of several skeletal elements of mosasaurs of different genera, using various individuals. This comparative study sheds light on diving habits, thermoregulatory mechanisms, and growth strategies of *Tylosaurus*, *Platecarpus*, and *Clidastes*. Genera like *Tylosaurus* show secondary osteons, possible transphyseal canals and other microstructures linked to rapid growth and an elevated thermal metabolism. *Platecarpus* and *Tylosaurus* show avascular necrotic bone, likely a result of decompression sickness. The data obtained for the different genera are compared and conclusions are drawn on mosasaur diving and growth. The possibility of *Dermochelys*-like thermoregulation in mosasaurs is considered.

THE REVEREND HENRY DUNCAN: FOSSIL FOOTPRINTS AND SAVINGS BANKS

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The Reverend Henry Duncan (1774-1846), clergyman, philosopher, writer, politician, archeologist, reformer, and the founder of savings banks, was indeed a "Man for All Seasons". In 1824, while Minister of the Church of Scotland at Ruthwell, Dumfriesshire, he was presented with a slab of red sandstone from the Corncockle Muir quarry in Annandale, exhibiting a set of footprints on it. The specimen had been collected by a Mr. Carruthers and proved of great interest to the Minister.

Although Duncan felt from the start that he was dealing with the tracks of an animal, he wrote to the Reverend William Buckland, Reader in Mineralogy and Geology at the University of Oxford to solicit his opinion on the origin of these curious markings. Buckland was at first skeptical but, after receiving casts of the markings from Duncan, he became convinced that they did in fact represent footprints, urging Duncan to study and publish on what he considered to be a very important paleontological find. He thought that the footprints were reptilian in nature, most likely representing either crocodile or turtle tracks. Buckland's experiments before a gathering of scientists demonstrated the close similarity of the fossil track to turtle footprints, which shared the character of having a broad trackway and short stride.

On January 7, 1828 Duncan described the Corncockle Muir footprints to the Royal Society of Edinburgh and quoted Buckland's findings. Duncan's paper was not published by the Society until 1831, but it aroused considerable interest-—"Footsteps before the Flood"!—and was reported in several newspapers. This was the first scientific report of a fossil track; although a schoolboy, Pliny Moody, had found fossil footprints in Connecticut in 1802, they were not scientifically described until 1836.

The Scottish tracks are still considered to be reptilian in origin, though now thought to be those of synapsid reptiles; the rocks containing them are now known to be of Permian date.

SPECIES COMPOSITION OF *APHELISCUS* FROM THE BIGHORN BASIN, WYOMING, WITH EVIDENCE OF ANAGENETIC EVOLUTION

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Apheliscus from the early Eocene of Wyoming remains a relatively rare and phylogenetically problematic mammalian taxon. It has variably been classified as a pentacodontine pantolestid, or as a hyopsodontid condylarth. The difficulty of classification arises not only from the extreme paucity of skeletal material attributable to the genus, but also from its unique dental morphology. As *Apheliscus* dental morphology changes very little through time, species recognition has been based on crown area, relative proportions of cheek teeth, and stratigraphic position. Several species have been recognized in the Clarks Fork Basin, but a comprehensive study of *Apheliscus* from a greater stratigraphic range in the southern Bighorn Basin has not been attempted recently. Based on crown areas and stratigraphic position, the following sequence of *Apheliscus* species is postulated for the southern Bighorn Basin: *Apheliscus chydaeus* (above Wa-0 and below Biohorizon A); *A. insidiosus* (from Biohorizon A through Biohorizon B); *Apheliscus* (sp. nov.?, above Biohorizon B). In contrast to the Clarks Fork Basin, there is little evidence of *A. wapitiensis* in the Bighorn Basin. The unnamed population above Biohorizon B exhibits a p4 area significantly larger than the expected range for *A. insidiosus*. The areas of p4 and m2 (the most frequently recovered teeth) indicate a gradual increase over time with no apparent cladogenic events. From *A. chydaeus* to *Apheliscus* sp. (above Biohorizon B), the hypocone generally diminishes on M1 and M2, but more data are needed from the upper Willwood Formation to confirm this trend. Lastly, m1 morphology (ratio of trigonid width to talonid width) fluctuates through time: the trigonid and talonid widths are nearly equal below Biohorizon A; the trigonid becomes narrower between A and B; the relative trigonid width increases again after Biohorizon B. The pattern of metric and morphologic change in Bighorn Basin *Apheliscus* is best interpreted as anagenetic, although more data are needed for the interval straddling Biohorizon A to completely assess the lineage.

IS *SCLEROMOCHLUS* A BASAL CROCODYLOMORPH?

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Recently the clade "Ornithodira" suffered one defection as the Pterosauria was shifted to the Prolacertiformes. Now another ornithodire appears to be leaving the fold. Long considered a sister taxon to the Pterosauria and the Dinosauromorpha, *Scleromochlus* is a Late Triassic obligate bipedal archosauriform known from a series of natural sandstone molds discovered near Elgin, Scotland. Striking differences divide *Scleromochlus* from the Dinosauromorpha. In the former the following crocodylomorph synapomorphies are present: 1) a low, wide skull; 2) a laterally expanded nasal; 3) a sharp ridge on the maxilla demarcating the antorbital fossa; 4) a broad-based quadratojugal; 5) a short neck of only six or seven vertebrae; 6) a long torso and extended "lumbar" region; 7) a low primitive deltopectoral crest; 8) a fibular flange; and 8) a calcaneal tuber or heel. Certain basal crocodylomorphs share the following characters with both *Scleromochlus* and dinosauromorphs: 1) a reduced manus; 2) a preacetabular process of the ilium; 3) a gently bowed femur; 4) a tibia at least as long as the femur; 5) appressed metatarsals; 6) a metatarsal III at least half the length of the tibia; and 7) a spike-like metatarsal V without phalanges. The following correlates with bipedality are not found among other crocodylomorphs but are present in *Scleromochlus*: 1) the incorporation of more than two vertebrae into the sacral series; and 2) subequal metatarsals. The *Scleromochlus*/crocodylomorph relationship probably went unnoticed for so long because the tell-tale carpals are not ossified, the tarsals have been difficult to identify, many digits are missing, and most of the quadrate/quadratojugal complex is unobservable. Other crocodylomorphs have been reconstructed as bipeds, but none perfected it as well as *Scleromochlus* did.

ANTIQUITY OF THE MISSISSIPPI-ALABAMA 'BLACK PRAIRIE': PALEOFAUNISTICS OF A LATE PLEISTOCENE VERTEBRATE FOSSIL ASSEMBLAGE FROM THE CENTRAL GULF COASTAL PLAIN

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Over the last 30+ years, portions of a very fragmentary late Pleistocene vertebrate assemblage have been reported from the Black Prairie Province of Mississippi and Alabama. The rare fossil material occurs in fluviatile deposits within a regolithic basal conglomerate overlying Cretaceous soft-sediment carbonates. Previous work on the assemblage has been sporadic with most treatments rather limited in scope. Most reports are simply faunal elements or, in a few instances, actually provide some systematic description. Only a small portion of this growing 'fauna' has benefited from formal, descriptive systematics and paleofaunistics. Because of its poor visibility in the literature, and except for references to the testudinine component, the fauna has gone largely unnoticed by occurrence-distribution data sets for the North American Quaternary.

The current study of this late Rancholabrean assemblage (1) systematically describes the most comprehensive collection recovered to date; (2) provides a simple NISP-based specimen analysis and discussion of taphonomic bias; (3) explores the degree to which the assemblage actually represents a true 'fauna'; (4) compares it to other similar late Quaternary fluviatile assemblages; and (5) uses paleosynecology, stable C-isotopes, and historical floristics to interpret the native (or 'pre-anthropogenic', late Quaternary) composition and structure of Black Prairie vegetation—a subject of considerable debate.

Among the new species additions are freshwater fishes, frogs, turtles, snakes, an anatid duck, and several large mammalian carnivores-altogether amounting to a 30% increase in species diversity with new extralimital and extinct additions. Chronologic proxies, including radiocarbon dates and regional geomorphic history, suggest a diachronous Sangamon(?)-Wisconsinan age for the assemblage. The terrestrial component consists of a typical inland riparian 'fauna' with contributions from two distinct riparian subenvironments. Black Prairie megafaunal composition differs in several respects with adjoining contemporaneous assemblages. Preliminary floristic studies suggest ancient prairie openings in the region.

TWO JUVENILE *PROSAUROLOPHUS* (HADROSAURINAE) SPECIMENS FROM MARINE SEDIMENTS: UNIQUE TAPHONOMY OR PALEOBIOLOGY?

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The current study reports 1) the first known record of two juvenile hadrosaurs belonging to the genus *Prosaurolophus* and 2) the spectacular preservation of both juveniles in the deep marine sediments of the Bearpaw Formation (Campanian) of southern Alberta. The first specimen, found near Manyberries, Alberta, is a semi-articulated juvenile preserving a partial skull and postcranium. The second specimen, found in the St. Mary's River Valley near Welling, Alberta, is a beautifully preserved, articulated juvenile. This specimen retains the skull, vertebral column and ribs in front of the sacrum, the forelimbs, some disarticulated elements including the ilium and a partial femur, a skin impression in the abdominal region and numerous tendons running down the vertebral column. Both juveniles are assigned to *Prosaurolophus* cf. *maximus* based on anatomy and geographic location.

Although it is intriguing to speculate that hadrosaurs may have been marine dinosaurs, there is no evidence to support such a claim. In fact, the isolated occurrence, completeness of the specimens, and distance from the paleoshoreline (which at the time was positioned west of the Rocky Mountain foothills) suggests a unique, instantaneous, taphonomic event rather

than paleobiology. The animals were probably swept out to sea after getting caught in the undertow of a near shore, fast flowing, river. Nevertheless, this scenario does suggest these juveniles were inhabiting a terrestrial environment in close proximity to the sea.

A NEW CROCODYLIFORM FROM THE LATE CRETACEOUS OF MONGOLIA

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Several crocodyliforms are currently known from Upper Cretaceous beds of Mongolia that possess a large number of characters showing the plesiomorphic condition for Crocodyliformes. Particularly, *Artzosuchus brachycephalus*, is a poorly known short-snouted crocodyliform proposed to be related either to 'protosuchians' or to 'notosuchians'.

Here we report on a new form recently recovered at Zos, a locality exposing levels of the Djadokhta Formation that underlies those exposed at Ukhaa Tolgod. The new specimen shares some derived similarities with *Artzosuchus*, although it is distinguished from it by the extension of the dentary beneath and above the mandibular fenestra, the location of the postorbital bar respect to the lateral surface of the jugal, and the extension of the posterolateral process of the squamosal.

A cladistic analysis including the new taxon and *Artzosuchus brachycephalus* was conducted in order to test their relationships among crocodyliforms. The taxon sampling scheme was emphasized in protosuchian and basal mesoeucrocodylian taxa (e.g., 'notosuchians'). Interestingly, the set of most parsimonious trees depicts the new taxon and *Artzosuchus brachycephalus* neither as protosuchids nor as notosuchids. These taxa, along with other Cretaceous forms from Central Asia (e.g., *Gobiosuchus*) are considered to be succesive sister groups of Mesoeucrocodylia, being more closely related to this clade than protosuchids (e.g., *Protosuchus*, *Hemiprotosuchus*).

A PALEONTOLOGICAL APPROACH TO THE PROBLEM OF COVARIANCE MATRIX EVOLUTION

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Morphological traits seldom evolve independently of other traits. Genetic correlation (pleiotropy) and developmental constraints, categories that are not mutually exclusive, can create covariance among traits so that change in one trait results coordinated change in another. A current question in evolutionary biology is whether the genetic covariances (G-matrix) among traits are conserved for long periods of evolutionary time, an assumption that is necessary to predict the evolutionary response to selection in multiple trait systems.

I looked at the evolution of the phenotypic covariance matrix (P-matrix), which is usually correlated with the G-matrix, of dental traits in viverravid carnivorans from the Bighorn Basin to determine the time scale over which the P-matrix changes. Four traits—length and width of the fourth lower premolar and first lower molar—were studied in six samples: *Didymictis proteus* from the Clarkforkian, *D. protenus* from the middle and upper Wasatchian, and *Viverravus acutus* from the lower, middle, and upper Wasatchian. Matrix evolution was studied using Common Principal Components Analysis, which determines whether matrices are equal, proportional, or share common variance components.

All six samples shared one common component, a size-related vector, with high probability. With a lower probability (p=0.0360), the samples had proportional P-matrices (shared all components, but with variances that differ by a constant). Samples whose phylogenetic divergence is on the order of 1 to 2 million years had equal P-matrices, but samples whose divergence is on the order of 5-10 million years shared only one or two common components. Over long time scales (5-10 my) the multivariate direction of evolution parallels the conserved common component to within a few degrees, but on shorter time scales (1-2 my) the vector of evolutionary change may be at an oblique angle of as much as 20 degrees. A limited number of variance components appear to be conserved over long time periods, but other covariance components come and go over shorter periods.

MORPHOLOGIC VARIATION IN PYCNODONTIFORM FISHES: TROPHIC AND PALAEOENVIRONMENTAL IMPLICATIONS

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New discoveries and a revision of known material reveal that morphologic variation in pycnodontiform fishes is unexpectedly diversified. About body shape, not all of the pycnodonts are the typical rounded fish with elongated dorsal and anal fins, specialist for manoeuvering. However, the observed morphologic variation affects mainly the dentition, clearly heterodontous in all pycnodonts. Although the vomer and prearticular always bear molariform teeth, the shape of these bones do vary. The height/length ratio of the jaws is variable; their morphology ranges from high and short to elongated, even prognathous. This indicates that the forces applied to the tip of the jaws probably varied considerably. Furthermore, the morphology of the non-durophagous dentition on premaxilla and dentary presents a relatively high degree of diversity. It ranges from large, hooked-shaped rasping teeth to small, conical ones. Even the widely present prehensile teeth of the Pycnodontoidea vary from stout and strong to thin and delicate. Branchial teeth are also polymorphous, from minute and slender to strong and hook-shaped.

Therefore, the morphologic variation in the dentition of pycnodonts suggests different possible strategies to foraging in these fishes, allowing us to hypothesize that the durophagous diet of these fishes may have been pretty diversified. Preys may range from small to large, from "softer" to very hard. They could probably feed on variable sources, from coral and rudist reefs to a large array of decapods, isopods, bivalves, ostracodes, peracarids, even detritus in the sediments. And there are also possible exceptions to durophagy.

This very preliminary approach to mechanistic models for predicting dietary composition in pycnodontiform fishes suggests that their potential diet was broader than previously thought. This potential trophic diversity confirms that pycnodonts are not necessary linked to coral or any other particular kind of reefs, not even to marine environments, as already concluded by some previous isotopic studies. Pycnodontiform fishes can consequently be very misleading if used as unequivocal palaeoenvironmental indicators.

ONTOGENY AND THE EVOLUTION OF CARPAL ELEMENTS IN MARSUPIAL MAMMALS

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The goals of our study are to document 1) adult variation and 2) the pattern of mesenchymal tissue condensation and the formation of centers of chondrification and ossification in the hands of a wide range of marsupials. Here we present a first report based on the study of histological sections of ontogenetic series of *Caluromys philan*der, *Monodelphis domestica*, and *Dasyurus viverrinus*, as well as early stages of a variety of australidelphians, including *Dromiciops.* A long distolateral process of the scaphoid is probably plesiomorphic for Dasyuridae, but it is much reduced in at least some species of *Dasyurus*. No prepollex was found in the hand of pouch young and adult *Dromiciops* examined. Considering development, there is no support for the hypothesis that the prepollex and the pisiform represent sesamoid bones, no differences in mode and timing of ossification with other carpals were recorded. Some of the features that are variable and that may provide phylogenetic signal include the presence or absence of prepollex, size of the lunate (including total reduction), shape of the magnum, processes of the scaphoid and contact between magnum and lunate. During development of the carpals, there is almost no recapitulation of tetrapod or mammalian evolution, and loss of embryonic precursors characterizes the evolutionary loss of elements (e.g., prepollex). Marsupials are almost unique among amniotes in that the earliest onset of ossification of at least one element among carpals and among tarsals is almost simultaneous.

ANDEAN LINEAGE OF PLEISTOCENE *MEGATHERIUM*: GEOGRAPHICAL IMPLICATIONS

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The subfamily Megatheriinae was extremely diverse from the late Miocene (Montehermosan) to late Pleistocene (Lujanian) in South America. Megatherium americanum is known from meridional areas of South America while *Eremotherium laurillardi* is distributed throughout the tropical and subtropical areas of North and South America. The large *M. americanum* is the only well known species of its genus.

Several Pleistocene *Megatherium* species have been discovered in the Andes: *M. medinae* (Chile), *M. sundti (*Bolivia), *M. tarijense* (Bolivia and Peru), and *M. elenense* (Ecuador and Peru). Two new species of *Megatherium* (*M*. sp. nov. 1 and *M*. sp. nov. 2) from Peru are being currently described. All the Andean taxa share the following characters: (1) reduction of total body size (from 20 to 60%); (2) raised, prominent, and posteriorly extended occipital condyles; (3) reduced deltopectoral crest of the humerus; (4) short rostrum; (5) relatively flat femur; and (6) enlargement of the surface of the ectal facet of the astragalus.

Megatheriinae are usually considered bipedal and/or quadrupedal. In these Andean megatheriines the morphology of the humerus and the position of the occipital condyles suggest a predominantly quadrupedal locomotion, which may be related to the Andean relief. Metacarpals IV and V are sub-equal in size and longer than the others, bear dorsodistal tuberosities, and are tightly articulating. This peculiar morphology reflects lateral contact of the hand with the ground during locomotion. While walking, digits four and five contact the ground at an angle between 30 to 45 . Furthermore several carpal/metacarpal facets (Mc III/Mc IV, Mc IV/Mc V, and magnum/Mc III) are parallel. This particular arrangement produces a highly stable structure.

These Megatheriinae may have evolved endemically in the Andean region. Preliminary phylogenetic analysis confirms the existence of a distinct Andean lineage of *Megatherium* that can be clearly separated from the clade containing [*M. altiplanicum* + *M. americanum*].

QUANTIFIED APPROACH FOR PREDICTING TRACEMAKER SIZE: APPLICATIONS IN TETRAPOD ICHNOLOGY USING CARBONIFEROUS TEMNOSPONDYL TRACKWAYS FROM THE UNION CHAPEL MINE SITE, ALABAMA

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Beginning in 2000, members from the Birmingham Paleontological Society in collaboration with researchers from the Geological Survey of Alabama and Emory University collected and documented more than 1,200 ichnofossil specimens from the Union Chapel Mine (UCM) site in northwestern Alabama. Amphibian tracks (*Cincosaurus cobbi*) represent the majority of ichnofossils from this site; tetradactyl manus and pentadactyl pes tracks point toward a temnospondyl tracemaker. Given the quantity and quality of specimens from the UCM site, we were able to devise a statistical model to predict tracemaker sizes based on single ichnological variables. For 94 specimens, we recorded the three most behaviorally invariant measurements that most closely reflect size of the tracemaker: pes width, manus width, and glenoacetabular distance. Other measurements (e.g., trackway width)were taken but not used for body-size predictions because variations in tracemaker behavior (e.g., sideward movements) could have caused measurements unrepresentative of size. Descriptive statistics and size-frequency distributions were plotted for manus, pes, and glenoacetabular distance, and then natural-log transformed to meet assumptions of normality. A correlation matrix showed a high correlation among the three size parameters ($0.848<r<0.902$) and multiple-regression analysis produced a linear equation of best-fit. This equation allows for the prediction of tracemaker

trunk size (an approximation of body size) based on any of other two measurements (manus or pes width). We tested the predictive values in this equation, and determined that they were significant (P<.0001). The model requires an assumption of only one ichnospecies and species of tracemaker, a non-asymptotic temnospondyl growth rate, and one individual tracemaker per measured specimen. Nevertheless, we suggest that this statistical model holds broad implications for tetrapod neo- and paleoichnology. The high correlations of manus and pes width with glenoacetabular distance should be tested on other Carboniferous trackways, as well as other fossil (and modern) trackways.

THE PANGEAN ICHNITES *OTOZOUM* AND *PSEUDOTETRASAUROPUS*: AN EXAMPLE OF RELATIONSHIPS AMONG AND BETWEEN TETRAPOD ICHNOTAXA AND SKELETAL TAXA

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Otozoum was originally described for material from the Portland Fm. (Lower Jurassic, Massachusetts). It consisted of a single species (*O. moodii*), though 6 more species were subsequently added; these have all been either removed into other genera or synonymized with *moodii. Otozoum* is pentadactyl, but functionally tetradactyl; the 'ichnophalangeal formula' (defined here as the number of pads per digit, including those underlying the claw-tip and the [interpreted] metatarsal-phalangeal [mtp] joint) is 3-4-5-6-1. Assuming the arthral condition (that pads underlie the inter-phalangeal joints), the maker would have had a phalangeal formula of 2-3-4-5-?. Digit III is longest, and I>V; II-IV are usually in contact along their length. The foot exhibits the primitive dinosaurian condition; there are no skeletal synapomorphies. It is generally interpreted as a prosauropod print; the present interpretation of the manus (tetradactyl impression, digit I held off the ground) supports this hypothesis.

Nine species of *Pseudotetrasauropus* were described from the Molteno Fm. (Upper Triassic, Lesotho); based on the resemblance to *Otozoum*, it was suggested that it too was a prosauropod track. *Pseudotetrasauropus* has also been found in the Upper Triassic of the southest United States, Wales, and France; it has been assumed that these tracks provide ichnological evidence for prosauropods in these strata. A skeletally-significant difference between the genera is the presence of only 5 pads (i.e. 4 phalanges) on digit IV of *Pseudotetrasauropus*. If this accurately reflects the osteology, this genus can not have been made by a dinosaur.This example serves to demonstrate that care must be taken when documenting footprints: not all 'big 4-toed tracks' are alike. *Pseudotetrasauropus* is not *Otozoum*, and can not be used as evidence for prosauropods! It also shows that superficially-similar tracks may have been made by animals that are less closely related to each other than the makers of tracks which are unlike each other: the makers of *Otozoum* and *Grallator* (a small, tridactyl, probable-theropod track) are more closely related to each other than are the makers of *Otozoum* and *Pseudotetrasauropus*.

A RE-EXAMINATION OF THE PLIO-PLEISTOCENE CAMELIDS FROM ANZA-BORREGO DESERT STATE PARK, CALIFORNIA

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Several genera of camelids are recognized to have lived in North America during the Pliocene and Pleistocene. These genera are broken down into two separate monophyletic clades or tribes: the Lamini and the Camelini. Recognized genera for the tribe Lamini include: *Hemiauchenia*, *Blancocamelus*, *Camelops*, and *Palaeolama*. Recognized genera for the tribe Camelini include: *Procamelus*, *Megatylopus*, *Megacamelus*, *Gigantocamelus* and *Titanotylopus*. In addition, Whistler and Webb reported on a new stenomyline camel from the Blancan of southern California. Although most camelid genera can be distinguished by characters of the dentition, skull, and mandibles, certain features of the distal limbs may also be used for identification. Some previous workers have established that measurements of metapodials may be used in bivaviate plots to group certain genera. The shape and relative size of the suspensory ligament scars, on the anterior surface of the proximal phalanges, can also be used for generic determination.

Numerous (1079) specimens of camelids have been collected from the Pliocene and Pleistocene terrestrial sediments in Anza-Borrego Desert State Park (ABDSP). This material, as appears in the specimen database, has been identified to either *Hemiauchenia*, *Camelops*, *Titanotylopus* or Camelidae indeterminate. Although most material collected in ABDSP consists of partial and isolated elements, the uniqueness of camelid postcrania has enabled generic level identification for some specimens. A re-examination of the camelid material indicates that, in addition to *Hemiauchenia*, *Camelops* and *Titanotylopus*; *Blancocamelus*, *Gigantocamelus* and *Paleolama* may have lived in ABDSP. This study has not only increased the geographic range of these later genera, but has improved camelid diversity in ABDSP and allowed for new insight into the paleoecology of the region.

INTERRELATIONSHIPS OF TREMATOCHAMPSID CROCODYLIFORMS

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Recent study of new material of the trematochampsid crocodyliform *Trematochampsa oblita*, from the Late Cretaceous of Madagascar, has provided additional data for a cladistic analysis of the family Trematochampsidae, an enigmatic group of metasuchian crocodyliforms known from the Cretaceous of Gondwana and the Tertiary of Europe. Among the questions addressed were: (1) Is the family Trematochampsidae monophyletic? (2) How do trematochampsids relate to other crocodyliform groups that have been hypothesized to be closely related, notably peirosaurids? and (3) Is the genus *Trematochampsa* monophyletic with respect to other trematochampsids?

For the cladistic analysis, PAUP*4.0 was employed, using a variety of search algorithms on a data matrix that included thirty unordered characters and thirteen total taxa, including two outgroups (*Araripesuchus patagonicus* and *Notosuchus terrestris*), two peirosaurids (*Peirosaurus tormini* and *Lomasuchus palpebrosus*), and the nine named trematochampsid species. Strict and Adams consensus trees were obtained with the data set, one set of consensus trees including, and the other excluding, the two peirosaurids. A monophyletic Trematochampsidae was recovered in both options, and the peirosaurids, when included, fall within Trematochampsidae. The genus *Trematochampsa* itself, however, was found to be paraphyletic, with *Trematochampsa oblita* closer to the European taxa on the consensus trees that do not include the peirosaurids. The two European Tertiary trematochampsids, *Bergisuchus dietrichbergi* and *Iberosuchus macrodon*, were found to be sister taxa and to occupy a relatively crownward position in the clade.

DINOSAUR EVOLUTION IN THE JURASSIC: A SOUTH AMERICAN PERSPECTIVE

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The Jurassic witnessed the major radiation of dinosaurs, but little is still known about the pattern of this radiation. This is especially true for the Southern Hemisphere. In South America, the Cañadón Asfalto Formation of Argentina is the only Jurassic rock unit that has yielded a diverse dinosaur fauna. So far, only saurischian dinosaurs have been reported. The Formation comprises two sedimentary sequences: a lower one, of most probably Callovian age, and an upper one, of probably Kimmeridgian to Tithonian age.

The lower sequence has yielded both sauropod and theropod remains. Sauropods are represented by the non-neosauropodan eusauropod genera *Volkheimeria* and *Patagosaurus* and an undescribed taxon originally included in *Patagosaurus*. The phylogenetic relationships of these taxa is consistent with the view that no faunal differentiation between the Northern and Southern Hemisphere had taken place by that time.

Theropods show a high diversity in the lower sequence, although their remains are generally less common than those of sauropods. Most remains represent basal tetanurans, including *Piatnitzkysaurus* and an undescribed species, but a fragmentary skull of a probable neoceratosaur has also been found. A further, small theropod taxon of uncertain affinities is represented by several vertebrae.

The fauna from the lower sequence is thus part of a rather uniform Middle Jurassic global fauna dominated by non-neosauropodan sauropods and basal tetanurans. However, if confirmed, the presence of a neoceratosaur is noteworthy, since this represents the oldest occurrence of this predominantly Gondwanan group.

Only few dinosaur remains have been reported from the upper sequence so far. The only described taxon is the basal titanosauriform sauropod *Tehuelchesaurus*. Newly found specimens include the remains of at least two further sauropod taxa, a probable brachiosaurid and an unidentified sauropod. Although caution is needed because of the sparse evidence, the fauna from the upper sequence might already show closer similarity with other Gondwanan than with Laurasian faunas.

THE RELATIONSHIP BETWEEN CLIMATE CHANGE, HISTORIC HUMAN IMPACT, AND SMALL MAMMALS IN PATAGONIA, ARGENTINA

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Estancia Nahuel Huapi Locality #1 is located northeast of San Carlos de Bariloche in Patagonia, Argentina. At the base of a limestone overhang is a debris deposit containing the remains of thousands of vertebrates, collected primarily by owls, which spans the last 1000 years.

Teeth from the deposit have been used to reconstruct the composition of the late Holocene rodent community. This study focuses on seven species of rodents with varied microhabitat preferences: *Euneomys chinchilloides, Loxodontomys micropus, Reithrodon auritus, Chelemys macronyx, Phyllotis xanthopygus, Ctenomys sociabilis, and Octodon bridgesi*. We tested whether the relative abundances of these species correlate with historic climate change, and whether the relative abundances of mesic/xeric indicator species indicate change in the small mammal community due to historic overgrazing or changes in fire frequency. We also compared our data to other zooarchaeological assemblages from this region.

PALEOPATHOLOGY OF AMNIOTE SPECIMENS FROM THE LATE PALEOZOIC AND MESOZOIC OF NORTH AMERICA: COMPARISON OF GROSS MORPHOLOGICAL AND HISTOLOGICAL ANALYSES

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Four different samples of paleopathological elements are analyzed and summarized from three widely divergent taxonomic groups. Healed fractures in the axial skeleton from the Early Permian pelycosaurian-grade synapsids *Dimetrodon* and *Sphenacodon* are compared with axial pathologies in an ornithischian dinosaur, the hadrosaur *Edmontosaurus* from the Upper Cretaceous Hell Creek Formation, and a variety of pathologies in a saurischian dinosaur, the Late Cretaceous *Tyrannosaurus rex* specimen better known as "Sue." To date, the majority of paleopathological studies have focused on gross morphological examination of external structure and sectioned materials. However, histological examination is a necessary tool for investigating the biology of disease response in extinct organisms. This is combined with a conservative approach to differential diagnosis that does not attempt to choose a single causal factor for pathologies, but rather attempts to make a broader, but more biological realistic and confident assessment of the potential range of causes or pathogens. This dual approach is applied to all four specimens discussed here. Despite the fact that the basal synapsids *Dimetrodon* and *Sphenacodon* are phylogenetically closer to mammals, the pattern of disease response in dinosaurs is more similar to that in extant mammals than is that observed in the pelycosaurs.

SYNAPSID FAUNA OF THE UPPER PENNSYLVANIAN ROCK LAKE SHALE NEAR GARNETT, KANSAS, AND THE DIVERSITY PATTERN OF EARLY AMNIOTES

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Stream channel infills near Garnett, Kansas preserve the most abundant and diverse assemblage of amniotes known from the Carboniferous. In addition to the diapsid reptile *Petrolacosaurus kansensis* and the synapsids *Haptodus garnettensis*, *Xyrospondylus ecordi*, and *Ianthasaurus hardestii*, at least three additional synapsid taxa can be recognized, including a new eupelycosaur genus that is represented by a partial skull and an isolated maxilla. This new form possesses only three premaxillary and about nineteen maxillary teeth, and the individual teeth are generally conical in outline, with only a slight recurvature near the tip. No distinct caniniform tooth is present on the maxilla, and only a modest caniniform region is exhibited along the anterior one-third of the bone. The available evidence suggests that this form is near the base of the clade of edaphosaurids and sphenacodontians. Phylogenetic evidence and occurrence data from Garnett and other Pennsylvanian localities indicate that the early history of amniotes is characterized by: 1) a basal dichotomy into synapsids and reptiles; and 2) an uneven rate of diversification, with synapsids diversifying rapidly and quickly developing a dominant role in the terrestrial ecosystems of the late Paleozoic.

EXCEPTIONAL OSTEOCYTE SIZES IN *TRICERATOPS* AND *TYRANNOSAURUS*

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Bone cells in rapidly growing woven bone tend have a globular shape and large diameter in transverse section, whereas the cells in slow forming lamellar bone tend to have a more elongate shape and small thickness along the minor axis. We have found globular cells in woven bone of a young *Triceratops* that are larger than any we have seen in woven mammalian bone tissue. There is considerable variation in the sizes of bone cells in mammalian secondary osteons; cells in the outer lamellae are larger than those in the central region, reflecting rates of deposition that begin high and then decrease. In osteons of both *Tyrannosaurus* and *Tarbosaurus*, we have found similar patterns, but the osteons in both taxa differ from those in mammals in greater maximum size of the outer osteonal osteocytes. The larger range in size of the osteocytes in the dinosaur taxa and the exceptional maximum sizes suggest a mechanism for stretching the range of bone deposition rates in juvenile tissue and in secondary osteons by elevating the peak rates.

RESULTS OF PURPOSELY PRESERVING PLASTIC DEFORMATION IN AN ARMATURED MOUNT OF THE SKULL OF *PENTACERATOPS STERNBERGII*

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The specimen was on a ten-year loan for exhibit to the New Mexico Museum of Natural History and Science. There the disarticulated elements where loosely assembled on a urethane foam support which was covered with gunnite to simulate beach sand in the museum's Cretaceous Seacoast Exhibit. At the expiration of the loan, the decision was made to mold the skull elements and assemble the casts on an armature in an elevated and more three dimensional way.

It was soon obvious that deformation was so advanced that it was impossible to correct, even by means of breaking and re-setting the alignment of cast elements. So, we decided to make a virtue of this condition. The resulting armature is 90% external. The elements are articulated as closely as possible following the full extent of the distortion. And, the major cracks, breaks, and open sutures are left clear and unfilled. This last criterion was more a necessity than a design decision since adjoining edges often failed to share the same plane. The result successfully conveys the conditions imposed on the original bone by the surrounding rock.

EARLY MIOCENE (HEMINGFORDIAN) APPEARANCE OF SOD GRASSLANDS AND ARID, SUMMER-DRY CLIMATE IN CENTRAL OREGON

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The oldest known paleosols in Oregon with crumb structure and abundant fine root traces of sod grasslands are in un-named valley-fill deposits of Rose and Bone Creeks, south of Kimberly. Mammal fossils, including *Mylagaulodon*, *Parahippus* and *Daphaenodon*, indicate an early Hemingfordian age (early Miocene, 18 Ma). These beds disconformably overlie the Arikareean (late Oligocene-early Miocene) Kimberly Member of the upper John Day Formation, and are in turn disconformably overlain by un-named lignites associated with the Columbia River Basalt Group, which is radiometrically dated at 16 Ma. Shallow calcic horizons and thick silcretes in the Hemingfordian paleosols are evidence of arid paleoclimate for these early Miocene sod grasslands. These early grassland paleosols differ profoundly from paleosols of bunch grasslands in the underlying John Day Formation, which have weak soil structure and sparse fine root traces. Furthermore, the Hemingfordian paleosols have little calcite within rhizoconcretions, nodules mainly siliceous, and soda unusually abundant. This degree of salinization and silicification is found in late Neogene paleosols of Oregon, as well as in modern soils of the Great Basin west and south of Salt Lake City. These paleosols may represent summer-dry climate in eastern Oregon. In contrast, paleosols in the upper John Day Formation have abundant large calcareous nodules like Cenozoic paleosols of the Great Plains, and probably formed in a dry climate with summer-wet cirulation from the Gulf Coast. Great Basin grasslands now dominated by wheatgrass (*Agropyron spicatum*) are quite distinct from Great Plains dry grassland with blue grama (*Bouteloua gracilis*). Crumb-textured calcareous paleosols of the Harrison Formation of Nebraska are evidence of sod grasslands as old as 20 Ma (late Arikareean, early Miocene), and probably also were distinct communities from coeval sod grasslands of Oregon. In both Oregon and Nebraska, early and middle Miocene sod grasslands were restricted to regions receiving less than 400 mm mean annual rainfall.

IMPRESSIONS: LATE TERTIARY MAMMALIAN FOOTPRINTS IN VARIOUS SUBSTRATES

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Fossil footprints can be used to determine the ductility of the substrate on which the animal trod. This preliminary study investigates footprints from three body mass morphologies (equine, cameline, and elephantine) with different foot structures (digitigrade, semi-plantigrade, and plantigrade) preserved in substrates that range from fluvial (braided stream), mud flow (matrix-suspended volcanic clasts), to siltstone and lacustrine limestone. The depositional environments under study are all associated with lacustrine margins or basin-filling fluvial deposits. The mammalian foot morphologies were selected because they are commonly preserved in the late Tertiary–Quaternary record and for their recognizable foot structures. During the study, the rock type containing the fossil prints is identified and measurements are taken of the area of the imprint, the height of the associated compression ring, and the depth of the track. A simple formula using these measurements yields a coefficient which can be used for comparing substrates at the time the track was emplaced. A high coefficient implies porous substrates, high water content, or ductility. A low coefficient implies a firm, possibly dewatered, substrate. This information will be useful for reconstructing paleoenvironments, paleohabitats, and relative behavior between ichnotaxa.

FLIPPING YOUR FOSSIL WILL FLIP YOUR TREE: CASES OF MISSING INFORMATION IN LEPIDOSAUR PHYLOGENY

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The importance of missing data is a current controversy in phylogenetic systematics, particularly when dealing with fossils. Here are presented two cases on lepidosaur phylogeny in which missing data does affect considerably phylogenetic results, differing from new analysis produced with a "more complete" data set.

Complete gracile fossils imbedded in flat stone are usually beautifully preserved but with the disadvantage that only one view is usually exposed. In the case of tetrapods, particularly in reptiles, the specimens are visible either dorsally or ventrally. This prevents the observation of many features that could solve problems in phylogeny. Even the allocation of specimens to any taxonomic group is uncertain, particularly for those taxa which recent representatives does not exist and that skeletal features in the hidden side cannot be predicted from the observed morphology. The addition of previously unknown information to cladistic data matrices may bring radically different results, that can even change the position of the fossil taxa from the crown to the base of the tree. The problem is illustrated with described examples in which either new specimens have been recovered or have been further prepared to almost complete the missing information of previous analysis.

This examples warn paleoherpetologist to resume conclusions drawn from only partially known taxa although the preservation of the fossils is exceptional. That is the case for sphenodontians and lizards such as *Eichstaettisaurus, Ardeosaurus*, *Tepexisaurus*, *Huehuecuatzpalli*, *Sapheosaurus*, and *Homoeosaurus*, among others.

CHONDRICHTHYANS FROM THE TERESINA FORMATION (PERMIAN) IN SOUTHERN BRAZIL

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Isolated teeth, scales and fragmentary fin-spines of Upper Permian chondrichthyans from the Paraná Basin occur in bone beds in hummocky deposits (tempestites) of the Teresina Formation in the municipality of São Gabriel, State of Rio Grande do Sul. This material is partly ascribed to a new genus and species of Xenacanthiformes. The presence of *Xenacanthus* sp. is doubtful in the Teresina Formation; *X. santosi* Würdig-Maciel is renamed. Also, a shark previously described from the Teresina Formation in the municipality of Dom Pedrito, 100 km due south, is taxonomically revised and ascribed to *Protacrodus milleri* (Würdig-Maciel). Dermal scales and pharyngeal denticles of insertae sedis sharks, together with remains of an eugeneodontid shark are reported for the first time for the Paraná Basin. The fin spines are badly fragmented and do not allow generic definition, but they show affinities with Sphenacanthiformes.

The majority of these remains are distinct from all those previously described in the literature, which suggests endemism of the South American palaeoichthyofauna at least at the species level. There is geological and geochemical evidence which indicate that this fauna lived in an environment highly influenced by fresh water. The fossil material yielded by the tempestites may represent a certain time-averaging assemblage. However, due to stratigraphic, taphonomic and palaeontological reasons, reworking is assumed to have been restricted to deposits originated within the Upper Permian. Surprisingly, besides abundant actinopterygian scales and teeth (Osteichthyes), there are also acanthodian scales (Acanthodii) associated with these shark remains and they represent the world' youngest record of this latter group.

THE ORIGIN OF SNAKES—CONSIDERING UNORTHODOX HYPOTHESES

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The origin of snakes, or rather the analysis of their sister–group relationships within squamates, is a long-standing problem in (paleo-)herpetology that has so far defied a satisfactory solution. Several theories have been proposed over the last 150 years, ranging from fossil marine or fossil/extant terrestrial varanoids, to fossorial amphisbaenians, dibamids, or scincomorphs, and also to gekkotans as potential candidates for snake sister-groups. Each one of these hypotheses can be supported with some shared derived characters, but each one of them also encounters a large degree of character conflict, and no consensus on snake origins has emerged. The most recent hypothesis of a snake-mosasaur relationship is imprecise when it

comes to the assessment of snake relationships. Are snakes the sister-group of varanoids as a whole, to the coniasaurs plus mosasauroids, just to mosasauroids, nested inside mosasauroids, or some other arrangement? Also, conflict exists between molecular-vs. morphology-based analyses and between paleontological vs. non-paleontological studies.

As was once proposed by David Hull: if we fail to find order in nature, it may be because nature is not ordered, or it may be that we are looking for order in the wrong way. We therefore propose to break out of the historical constraints of preferred hypotheses of snake relationships and to consider unorthodox alternatives with the idea that they may allow us to approach the problem from a different perspective. In this context, we review the characters that have been most controversial in previous competing hypotheses and also assess these hypotheses for levels of homoplasy and for congruence or incongruence with other sources of data. We also show that the typical character sets used for cladistic analyses have consistently ignored characters from those anatomical systems that are likely to contain signal for non-traditional hypotheses. The prevailing focus on the easy-to-collect, overutilized, and limited set of osteological characters may be part of the problem in this debate.

PROBABILITY PLOTS, POPULATIONS AND PALEOBIOLOGY: WHAT TO DO WITH LAGERSTÄTTEN

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We demonstrate the use of a probability plotting a technique adapted from reliability engineering to analyze population samples of three dinosaurs and three extant outgroups. This analytical tool yields morphological, ontogenetic, and "demographic" information. It is fast, simple, intuitive, sensitive, and commercial software or hand calculations may be used. Error correction is obvious and easy. Its power is to distinguish morphological groupings arising from any cause. Pre- and post-metamorphic stages, mixtures of similar species and other randomly mixed distributions are easy resolved.

For this study, agamid lizards, alligators, and cassowaries are used as proof-of-principle examples and outgroups for comparison to our analyses of dinosaurs. With adequate sample size, the technique accurately (~2%) extracts size information on yearly age groups, sexual dimorphism, and growth asymptotes in these extant taxa.

Application of this technique to populations of the dinosaurs *Allosaurus fragilis*, *Coelophysis bauri*, and *Maiasaura peeblesorum* quantifies the relative proportions of robust/gracile/juvenile morphs for each based on measurements of various skull and limb elements. From this data we extrapolate growth curves and sexual dimorphism indices. All three dinosaurs show a growth pattern similar to the ratite bird outgroup and dissimilar to the alligator and lizard. The pattern is characterized by rapid growth in all very young animals. The gracile morphs continue on the same trajectory as they grow slowly toward their asymptote. At some point the robust morphology onsets, accelerates away from the juvenile-gracile curve, and the robust morphs grow toward their asymptote. In every case all juveniles are gracile, and the robust morphs produce a significantly wider statistical distribution than the gracile animals. In all three dinosaurs the robust morph is greater than 1.2x the gracile morph, a ratio that often indicates male robust morphs in modern amniote populations. This method is applicable to any natural population (death assemblage) of fossil organisms and provides a ready test of many paleobiological hypotheses.

JURASSIC DINOSAUR TRACKSITE OF CABO MONDEGO (PORTUGAL): A GEOSITE OF THE WORLD GEOLOGICAL HERITAGE.

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The oldest known dinosaur tracks in Portugal are located in the Upper Jurassic deposits of Cabo Mondego area (central Portugal). This tracksite recorded in Oxfordian carbonate sediments (Vale Verde beds), is one of the first references in the world on dinosaur footprints. The lower level was found in 1884 at Pedra da Nau beach, 2 km north of Buarcos (Figueira da Foz) by the Director of the Cabo Mondego coal mine. J. Gomes (Natural History Museum of Lisbon University) studied the occurrence and they decided to remove the tracks to the Natural History Museum of Lisbon University where they can be observed. The tracks preserved as natural casts are very distinctive in revealing an elongate heel and hallux impressions. In 1951 three new levels with about 50 dinosaur footprints were found and the specimens are deposited at the Portuguese Geological Survey Museum. Recent work assigned them to the ichnogenus *Eutynichnium lusitanicum* and *Megalosauripus* sp.. Until now at least 9 dinosaur track levels in the Pedra da Nau beach are known and their systematic study and palaoenvironmental implications are on the way. The dinosaur tracks of Cabo Mondego section are historically relevant but the whole outcrop is particularly interesting from the scientific and pedagogic point of view, due to an unusual continuity of the sedimentary record (more than 900m thick) ranging from Late Liassic (hemipelagites of middle Toarcian–Callovian) to Tithonian (fluvio-deltaic sedimentation). An important and diversified content on fossil assemblages is recorded along a shoreline of about 5 Km long, showing unusual conditions for geological observation. In 1996 the GSSP for the Bajocian stage was established in this section, the first Jurassic stage boundary to be defined by the International Union of Geological Sciences (IUGS). The palaeontological and stratigraphical relevance of Cabo Mondego section are being demonstrated since 1849, when D. Sharpe published the first geological map of the region. The outcrop is an endless source of geological information on Jurassic, representing a geosite of global significance of the World Geological Heritage.

PALEOENVIRONMENTAL AND TAPHONOMIC PERSPECTIVES ON THE LATE CRETACEOUS WORLD OF THE ABELISAURID THEROPOD *MAJUNGATHOLUS ATOPUS*

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Majungatholus atopus was a "domed" theropod that occupied a prominent niche in the Late Cretaceous ecosystem archived by the Maevarano Formation of northwestern Madagascar. It apparently shared its domain with relatively few dinosaurs, including a bizarre small-bodied theropod with procumbent dentition (*Masiakasaurus knopfleri*) and two titanosaurs (*Rapetosaurus krausei* and the as yet unnamed "Malagasy taxon B"). Recent discoveries of exceptionally preserved skeletal material coupled with ongoing analyses of the sedimentology and taphonomy of the Maevarano Formation and associated units provide an excellent opportunity to reconstruct the Late Cretaceous world of this relatively large-bodied carnivore.

Although arguably well adapted for life on the expansive floodplains of the Mahajanga Basin, *Majungatholus* apparently frequented the broad and sandy channel belts that drained Madagascar's central highlands, where it presumably hunted and/or scavenged. These shallow rivers were populated by a variety of aquatic and semi-aquatic taxa, including fish, frogs, turtles, and a plethora of large and small crocodilians. These taxa were likely adapted for seasonal fluctuations in water availability because the fluvial sediments that entomb their remains indicate a variable and flood-prone discharge regime, and associated paleosols suggest that the ambient climate was semiarid. These same sediments yield taphonomic clues suggestive of localized and perhaps seasonal pulses of mortality. *Majungatholus* may have capitalized on the hardship of other animals (including members of its own species) during environmentally stressful periods, and supplemented its diet by preying upon weakened animals. There is certainly good indication from a wealth of tooth-marked bone derived from the carcass of a subadult conspecific that it fed with considerable rabidity upon the well-muscled axial skeleton in a fashion similar to that of many modern carnivores.

CHARACTERIZATION AND SPATIO-TEMPORAL DIVERSITY OF FOSSIL RUMINANT COMMUNITIES IN THE MIOCENE OF GERMANY AND THE INTERPRETATION OF HABITAT CONDITIONS

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Seven lower and middle Miocene ruminant communities from neighbouring habitats of the upper Freshwater Molasse (southern Bavaria) and the Franconian Jura (southeast Bavaria) representing a 5-million-year time interval were studied. The species lists comprise mostly familiar and poorly ecologically characterized Central European species, some new records for the region, and some entirely newly recognized representatives.

Body mass estimation, tooth mesowear analysis, and $\delta^{13}C$ enamel signature were used to interprete mainly dietary adaptations. The proportional species compositions of the different communities show an ecological spatio-temporal diversity. It indicates contemporaneous, but ecologically different habitats in the neighbouring Molasse Basin and Franconian Jura. A more detailed reconstruction of ecosystem development in the Molasse Basin has been presented for 2-million-year time interval within the total 5-million-year time span.

ARE THERE JUVENILE SPECIMENS OF THE AQUATIC SPHENODONTID *PLEUROSAURUS*, AND IF SO, WHAT CAN THEY TELL US ABOUT GROWTH IN THIS GROUP ?

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Acrosaurus frischmanni, from the Jurassic Solnhofen Formation of Germany, was initially recognised as a distinct sphenodontid genus. Due to its relatively small size and similarity to the aquatic sphenodontid *Pleurosaurus* it has been considered a putative juvenile of *P. goldfussi*. This was formalised by the identification of a number of juvenile characteristics. However, the characters previously used to assign *Acrosaurus* to a distinct genus remain unexplained. This study of all the available specimens reveals that osteological characters can no longer be used to distinguish separate taxa and the juvenile status of acrosaurs is confirmed. Nevertheless, the nature of the integument remains mysterious. The more complex, keeled scales visible in the holotype of *Acrosaurus* are not visible in any adult pleurosaur and this decrease in scale complexity during ontogeny is contrary to the increase in complexity that occurs in many living lizard genera.

Assuming acrosaurs to be juveniles, various estimates of age/growth stage reveal them to be pre-hatchlings or newly hatched. This, combined with observations on their degree of ossification, demonstrates that pleurosaurs hatched at a similar stage of development to the living Sphenodon and hence may have had a similarly long incubation period and lifespan.

Combining morphological data from acrosaurs and adult pleurosaurs in bivariate plots allows investigation of likely growth patterns within the group and examination of the hypothesis that *Pleurosaurus ginsburgi* may have arisen from *Pleurosaurus goldfussi* via paedomorphosis.

These plots reveal that body form in pleurosaurs changes significantly between juveniles and adults, notably the relative length of the humerus and tail compared with the trunk. This is not unexpected when you consider allometric growth. Interestingly the acrosaur ratios are almost identical to those of the Lower Jurassic *Palaeopleurosaurus*. Establishment of the taxonomic positions of all pleurosaur genera is necessary before the growth from acrosaur to pleurosaur can be compared with the morphological changes occurring along a putative evolutionary path from *Palaeopleurosaurus* to *Pleurosaurus*.

ANATOMY OF DATA-BASED DIAGNOSIS: BONE SURFACE DISRUPTION AND DISEASE ORIGINS

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Pathologic *Camarasaurus* vertebrae stimulated the search for etiology and an opportunity to

clarify the data-based diagnostic approach.

Recognition of pathology is a process of distinguishing normal and abnormal pathologic physiology and taphonomy. The response of bone to injury (natural or iatrogenic) is often new bone formation, if the animal sufficiently survives the incident and the causative agent does not alter healing. Ingrowth of bone edges after trephenation (<20 cases) illustrates the natural history of penetrating injury. Infectious agents produce a different appearance. Humans with tuberculosis (<200 cases) reproducibly illustrate zones of peri-articular bone and subchondral bone resorption; those with fungal disease (12 cases) manifest spheroid expansile lesions. Rheumatoid arthritis (>30 cases) presents as fronts of resorption with minimal bone response. Spondyloarthropathy (<800 cases) attacks articular surfaces, especially of vertebral facet joints.

An articulated caudal segment (20 vertebrae) of *Camarasaurus* (National Museum of Ancient Life, Lehi, Ut) was analyzed according to data-based criteria. Bilateral facet joint remodeled erosions were present on the articular surfaces of 4 consecutive vertebrae.

The only valid diagnostic considerations were taphonomy, tumor, infection and spondyloarthropathy. Presence of remodeling indicates biologic response, thereby falsifyng a taphonomic hypothesis. While infection and tumor can affect any joint, involvement of more than a single facet joint has never been reported. The diagnosis of spondyloarthropathy is thus substantiated.

This case documents the earliest (Jurassic) recognition of spondyloarthropathy, antedating previous Paleocene evidence.

A NEW SPECIMEN OF *EURYLAMBDA* AND ITS BEARING ON CUSP HOMOLOGIES AND RELATIONSHIPS AMONG BASAL MAMMALIAFORMES

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We report on a second specimen of *Eurylambda aequicrurius* from the type locality of Quarry 9, Como Bluff, Wyoming in the Upper Jurassic Morrison Fm. The specimen, a probable left M1, is complete and preserves the parastylar region unknown in the type. Comparison of the new tooth and the type suggests that the type is in fact an M2 instead of an M1 as originally suggested.

Eurylambda shows similarities with triconodonts on the one hand and with more derived members of the stem-group Theria such as spalacotheriids and cladotheres on the other. It is proposed here that the most mesial of the three main cusps of the crown of *Eurylambda* (traditionally interpreted as the stylocone) is homologous with the cusp B of triconodontids and amphilestids. In turn this cusp is also likely to be homologous with cusp 'B' of *Peralestes* and the zhangheotheriids. If this proposal is accepted, cusp B would be lost in most, if not all, cladotheres while the parastyle, and likely the parastylar hook, would be a derived feature of the post-tinodontid mammals. This hypothesis of homology also highlights the close dental similarities shared by triconodonts and basal symmetrodonts, where the ancestral pattern of cusps in line is not yet profundly modified. Our interprtation of cusp homologies implies a complex sequence of events for the acquisition of the upper molar morphology of therians, with the loss of a major cusp (B) and the development of a neomorphic parastylar cusp and hook.

ORGANIZATION AND ORIGIN OF THE MAMMALIAN OLFACTORY SYSTEM

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The mammalian olfactory system is unique in the breadth of its discriminatory power. Moreover, 1000 genes encode odorant receptors in the mammalian nose, making this the largest gene family in the entire genome. Each gene encodes a different type of odorant receptor, and the individual receptor-types are distributed in topographically distinct patterns in the olfactory epithelium of the nose. Their discriminatory power is multiplied by increased surface area provided by elaborate scrolling of the bony ethmoid turbinals. This rigid framework also enhances discrimination by facilitating the detection of spatial and temporal information as odorant molecules travel within the nasal cavity. Each odorant receptor transmits signals to a single glomerulus in the olfactory bulb, hence the topographic distribution of odorant receptors over the ethmoid turbinals is mapped in the spatial organization of neurons in the olfactory bulb.

Ossified turbinals occur only in mammals, although there is ample evidence of unossified turbinals among their extinct relatives. Because bone is fundamentally structural, turbinal ossification likely arose in response to tighter scrolling, increased surface area, and an increase in the number of olfactory odorant receptors in mammals compared to their closest extinct relatives. An X-ray CT study of the nose in *Monodelphis* further indicates that the bony lamina transversalis and first ethmoturbinal are fundamental organizers of the nose, serving to separate respiratory spaces and turbinals from olfactory spaces and turbinals. Phylogenetic analyses of mammals and their closest extinct relatives indicate that ossified turbinals are a mammalian apomorphy that appeared in concert with an inflated neocortex and inflated olfactory bulbs. The ossified ethmoid turbinal complex may thus be viewed as the skeleton of the olfactory system, arising in the last common ancestor of extant mammalian species, as an integral component of its distinctive forebrain.

NEW SPECIMENS AND NEW INTERPRETATIONS OF THE HAGERMAN INSECTIVORANS

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The Hagerman faunas from Glenns Ferry Formation (southwest Idaho) contain six described species of insectivorans. Previously published accounts of these taxa described the specimens in the UMMP collection. Here I report more recently collected specimens housed at the Hagerman Fossil Beds National Monument and Idaho Museum of Natural History. The sole talpid taxon, *Scapanus hagermanensis*, was originally described from a partial dentary containing a heavily worn p4 and partial m1, a partial ulna, and two partial humeri. To this list I add a radius and a complete lower right molar. These new elements contribute to the original description of *S. hagermanensis*, and support the original assertion that it is closely related to the extant *S. orarius* and *S. townsendii*. Further, the stratigraphic range of *Scapanus* in the Hagerman Glenns Ferry section is extended by 76 feet.

Among shrews, the genus *Sorex* is represented by four species, but none of them previously reported from more than two specimens. Of the two larger species, *S. hagermanensis* was described from a single dentary stratigraphically low in the Hagerman sequences, while *S. powersi* was described from one dentary high in the section and one low in the section. Two much smaller species, *S. meltoni* and *Sorex* cf. *S. rexroadensis* were reported by dentaries very high in the section. Recently discovered specimens represent one or both of the small species from localities much lower (>250 ft) in the section, where previously only large forms of *Sorex* were known.

The most abundant insectivoran by two orders of magnitude is *Paracryptotis gidleyi*. This ubiquity in the Hagerman deposits permits examination of incremental change. There is no significant directional change in the length and widths of lower molars, although some oscillation in the dimensions does occur. The lower molars do show two trends toward anteroposterior elongation. The two clines (one high in the section and one low) are separated by a 50 foot stratigraphic gap lacking recovered specimens of *P. gidleyi*.

MULTIVARIATE STATISTICAL ANALYSIS OF *DIMETRODON* SPECIES USING DORSAL VERTEBRAE DIMENSIONS

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Dimetrodon species have been identified based on morphological characters, stratigraphic horizon, overall size, and bone dimensions. In the absence of morphological differences the orthometric linear unit (OLU) was developed to differentiate species. The OLU is the ratio of the length of various load-bearing bones vs. half the transverse width of the dorsal vertebrae centra to the 2/3 power. Log-log plots were later used for graphical analysis. In these previous studies, measurement averages of species were used, but variation within a species was not considered.

Variation within a species is considered here by using measurement averages of individual specimens instead of measurement averages of species. Natural logarithms of the dimensions of *Dimetrodon* dorsal vertebrae are analyzed using Hotelling's T^2 multivariate statistic. Four species (*D. macrospondylus*, *D. loomisi*, *D. dollovianus*, and *D. giganhomogenes* ["type B" of Romer]) are analyzed because they are differentiated on the basis of OLU, size, and stratigraphic horizon, with no significant morphological differences.

Results indicate the differences of the dorsal vertebrae dimensions of the four species are not statistically significant at a 0.90 confidence level. The dorsal vertebrae dimensions of the four species are significantly different than another "type B" species, *D. natalis*, which is morphologically distinct, with slender, elongate postcranial elements.

The conclusions are: 1) Hotelling's T^2 multivariate statistic can be used to differentiate *Dimetrodon* species using dimensions of bones; 2) variation within a species must be considered when differentiating *Dimetrodon* species based on the dimensions of bones; 3) some *Dimetrodon* species without morphological differences may in fact be the same species, even though they occur in different stratigraphic horizons, and appear to have different OLU's.

VARIATION IN TOOTH SHAPE IN CARNIVOROUS REPTILES: THE INTERPLAY OF GEOMETRIC DESCRIPTORS AND SHAPE VARIATION WITH BIOMECHANICS AND PHYLOGENY

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Tooth shape among the different lines of carnivorous reptiles is often functionally homologous or convergent. Heterodonty in carnivorous reptiles, despite a relative lack of attention in the literature, is more common than previously recognized. A model for crocodiles has divided the jaws into incisor, canine and molar regions. We build upon this model and our own previous work on theropod dinosaurs by analyzing tooth shape variation in fossil groups (e.g., theropod dinosaurs and marine reptiles) based on detailed analyses of extant crocodiles and varanid lizards. We analyze variation of tooth shape within a single tooth position, distributed within a tooth row, between upper and lower jaws, and in relation to general anterior skull shape. Tooth shape is defined using geometric morphometric methods. Theoretical and empirical morphospaces are constructed to visualize and interpret the results. The observed heterodonty in carnivorous reptiles is primarily manifested as subtle shifts in tooth shape from mesial to distal positions in the jaw. This tooth shape variation is related to jaw position (mesial-distal, upper-lower), jaw shape, tooth orientation, and the height of the tooth row. Causative factors contributing to this variation can include the presence of cranial kinesis, and diverse modes of tooth replacement and development. The force exerted at each tooth position can vary considerably along the jaw, and tooth shape variation, in part, reflects this force differential. Phylogenetic and tooth development factors, and the nature of the prey and the mode of its consumption are contributing constraints and influences on the observed patterns as well. Developing a greater understanding of heterodonty in these groups will improve the identification of isolated teeth.

DETERMINING TOOTH POSITION IN THE JAW OF TYRANNOSAURID DINOSAURS—BITING OFF MORE THAN YOU CAN CHEW?

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Differences in the size and shape of dinosaurian teeth can often be used to help identify the

type of dinosaur to which they belonged. Characteristically, the crowns of tyrannosaurid teeth are nearly conical in shape and slightly laterally compressed, with round to ovoid cross-sections. However, the feasibility of quantifiably distinguishing alveolar position, bone of origin, ontogenetic stage, and taxon of origin for tyrannosaurid teeth is unexamined. Quantifiable distinctions would be extremely useful for the identification of isolated teeth.

Isolated tyrannosaur teeth and teeth in jaws (including teeth from *Gorgosaurus*, *Daspletosaurus*, *Albertosaurus*, and *Tyrannosaurus*) were examined comparatively and morphometrically. Qualitatively, five main tooth types are identifiable: premaxillary, anterior maxillary, posterior maxillary, anterior dentary, and posterior dentary. The four premaxillary teeth are small, and characteristically D-shaped in cross-section. There are two anterior maxillary teeth and two anterior dentary teeth, which are slightly larger than the premaxillary teeth, but are more rounded in cross-section. The posterior maxillary and dentary teeth are generally larger, and more laterally compressed. The number of posterior maxillary and posterior dentary teeth ranges from 13-14 and 13-15, respectively.

A principal component analysis (PCA) revealed that most of the shape variance in the analyzed data set was not associated with size (principal component I). An ordination of the PCA scores revealed substantial taxonomic overlap, with some minor separation of the large maxillary teeth of *Tyrannosaurus rex*. Ordination also revealed relatively little separation of bone of origin (i.e. premaxilla, maxilla, or dentary). Alveolar position is difficult to predict, possibly as a result of the pattern of tooth replacement. Therefore, it is very difficult to quantifiably separate the teeth of tyrannosaurids by taxon, bone of origin, or alveolar position.

NEW PALEOGENE SELACHIAN ASSEMBLAGE FROM NEARSHORE MARINE DEPOSITS IN MADAGASCAR

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The pre-Late Pleistocene Cenozoic fossil record of Madagascar is restricted to only a few localities, all of which represent deep marine environments. In the summer of 2001, a new Paleogene site was discovered in northwestern Madagascar near the town of Ampazony. These outcrops overlie marine Eocene sediments and consist of alternating mudstones and sandstones. The fauna comprises invertebrates, osteichthyans, chondrichthyans, and tetrapods. The sedimentology of Ampazony, as well as the presence of crocodylians and turtles and the absence of typical deep-marine fossils, suggests that this site was deposited under nearshore marine or estuarine conditions.

Although most remains are fragmentary, the diverse selachian fauna is of considerable biogeographic utility. Sharks include *Galeocerdo*, *Carcharhinus*, and *Rhizoprionodon* (Carcharhinidae) as well as *Nebrius* (Ginglymostomatidae), all of which are currently known only from the Cenozoic. The presence of taxa restricted to the Cenozoic, as well as the absence of typical Late Cretaceous taxa such as *Squalicorax*, *Cretolamna*, *Rhombodus*, and *Parapalaeobates* strongly suggests that this assemblage is Cenozoic in age. From a biogeographic perspective, the teeth of *Nebrius* and *Galeocerdo* are of particular interest because they appear to be more morphologically similar to congeners from the Eocene of the Middle East, Indo-Pakistan and Europe, rather than to those from Africa or the Americas.

The selachian fossils from Ampazony form part of the first Cenozoic nearshore marine assemblage reported from Madagascar. As such, this assemblage has the potential to fill a critical gap in our knowledge of the evolutionary history of several Malagasy clades. Ongoing fieldwork will continue to explore this important locality in the hope of procuring additional vertebrate fossils.

COMPARATIVE PATTERNS OF POSTCRANIAL ONTOGENY IN THERIAN MAMMALS: AN ANALYSIS OF RELATIVE TIMING OF OSSIFICATION EVENTS

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This study is a comparison of ontogenetic sequences among taxa in a phylogenetic framework with the aims of studying evolutionary changes in developmental timing and exploring the use of sequence data in phylogenetic analysis. Studies of this kind on the postcranial skeleton of mammals have been mostly anecdotical or restricted to a few taxa or areas of the postcranium. Data on the relative sequence of ossification of postcranial elements representing all areas of the body for eight therian mammals (*Myotis lucifugus, Homo sapiens, Rattus norvegicus, Mus musculus, Mesocricetus auratus, Cavia porcellus, Didelphis albiventris* and *Sminthopsis macroura*) and three outgroups (*Chelydra serpentina, Alligator mississippiensis* and *Lacerta vivipara*) were taken from the literature. For each species a matrix was constructed in which the relative timing of the onset of ossification in 24 elements was summarized. This resulted in 276 event pairs (characters) for each species. Thirty-three (33.3)% of the characters examined are uniform across all taxa, 16.3% are variable but uninformative in the phylogeny, and 50.4% potentially deliver diagnostic features for clades of two or more taxa. In all species examined the clavicle is the first bone to appear. Placentalia is not unequivocally diagnosed by the state of any event pair, while Marsupialia has the largest amount of autapomorphies with 18. The acceleration in the timing of ossification of the scapula in relation to the hindlimb in marsupials is most probably causally correlated to movements after birth and during early phases of pre-weaning life. Marsupials are almost unique among amniotes in that the earliest onset of ossification of at least one element among carpals and among tarsals is simultaneous. Three parsimony analyses, each one with a different reptilian taxon as outgroup, were performed using event pairs as characters. Results were in all cases incongruent with the phylogeny of the studied taxa.

DISCOVERY OF CONTINENTAL MAMMALS AND OTHER VERTEBRATES OF BIOGEOGRAPHIC SIGNIFICANCE IN THE EARLY MIOCENE OF VENEZUELA

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Since our knowledge of Cenozoic vertebrate paleontology of South America originates mostly from localities in the southern cone, findings in the northern portions of the continent are highly significant. Here we report the discovery of a diversity of vertebrates from the Castillo Formation of early Miocene age, in localities in the vicinity of Carora, Estado Lara, an arid region about 90 km south from the Caribbean Coast of Venezuela. Most taxa represent first or oldest ocurrences of a group in Northern South America. The sequence studied contains marine, near-shore, deltaic and continental deposits. Findings include 1) at least 10 species of elasmobranchs; 2) several catfish skulls and isolated teeth with close affinities to *Colossoma*; 3) the oldest and only second shell remains of a trionychid turtle from South America and the skull of a podocnemidid; 4) a complete skull with associated postcrania of a new and oldest gavialoid crocodylian currently known from South America; and 5) cranial and postcranial remains of a cetacean. Continental mammals are represented by isolated postcranials of a new astrapothere and isolated dental and postcranial remains of a mylodontid sloth. Our discovery of freshwater taxa in the lower Miocene of Castillo Formation provides further support to the hypothesis that a tributary of the paleo-Orinoco was present in northwestern Venezuela in what is today the desert area of the Falcón-Lara Basin.

MECHANICS OF STEGOSAUR TAILS AS WEAPONS: A MATHEMATICAL ANALYSIS

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Although the occurrence of spikes on stegosaur tails seems to be an obvious indication of a defensive function for the tail in this group, the mechanics of this defensive device are not necessarily obvious. Technical questions include: What were the degrees of freedom for tail movement? How far could the tail swing? How fast could the tail tip move? How much momentum could be imparted to the spikes? And finally, what was the maximum striking impulse that the spikes could deliver, and to what extent could the bones as well as soft tissues of predators be penetrated?

To answer these questions, the tail bones and spikes of a well-preserved *Stegosaurus stenops* skeleton at DMNH were measured, along with maximum articulation angles for those bones. Degrees of freedom of tail movement were established, and muscle cross sections and mass were inferred from bone sections. A mathematical model of tail movement was developed from these data. The tail was modeled as a set of rigid, linked rods (rod lengths being determined by dorsal plate lengths). The rods were connected by springs, with muscle action represented by spring action. Data from modern muscle-force studies were used to replicate *S. stenops* muscle strength. The tail's motion and functionality as a weapon were derived.

Significant results include: tail movement was constrained by the dorsal plates; movement was mostly restricted to lateral; maximum angle of tail movement was about 13° from the body's medial line; strike speed of a tail spike exceeded 8 m/s (29 km/hr); striking impulse exceeded 110 kg-m/s; and striking force exceeded 340 newtons. Pressure on target tissue at a spike tip would have exceeded 10^8 pascals (1000 atmospheres), more than sufficient to penetrate and possibly lodge within bones of predators such as *Allosaurus fragilis*.

Consistent with this possibility, a punctured *A. fragilis* caudal has been found. Also, a broken and diseased *S. stenops* tail spike at DMNH may have been injured as a result of breaking off within a predator's body.

A NEW, TRANSITIONAL LATE OLIGOCENE PROBOSCIDEAN ASSEMBLAGE FROM CHILGA, ETHIOPIA

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Recent fieldwork at Chilga, northwest Ethiopia produced a Fayumian-type mammal fauna dated radiometrically and by paleomagnetic reversal stratigraphy to 27-28 Ma, composed primarily of archaic African endemics and lacking Eurasian taxa characteristic of early Miocene Afro-Arabian faunas. Included in the Chilga fauna is a large proboscidean assemblage dominated by primitive elephantiforms reminiscent of late Eocene-early Oligocene palaeomastodonts, but with larger cheek teeth and considerably longer symphyses and tusks. Also present are several more derived species resembling elephantoid proboscideans, and the oldest known deinotheres, previously not documented from before the early Miocene. The deinotheres are quite primitive in having only incipient third loph(id)s in dp4, m1, and M1, and weak expression of the ectoloph in dP2, and probably represent a new subfamily. Molars of the more derived elephantiforms are larger than those of palaeomastodonts but smaller than those of Miocene elephantoids. They are also intermediate morphologically, retaining a small number of loph(id)s and other aspects of palaeomastodont occlusal organization, while exhibiting more advanced features such as zygodont crests and crescentoids, typical of mammutids, in some, and accessory central conules and pretrite trefoil wear figures throughout the crown, similar to gomphotheres, in others. The size, morphology, and age of the new assemblage indicates an autochthonous African beginning for the extensive radiation of elephantoids and deinotheres that followed in the Miocene. Considered as a whole, the Chilga fauna helps constrain the dating of the Eurasian immigration event, and suggests that the origination of elephantoids and deinotheres predated and was not initially influenced by that occurrence.

THEROPOD DINOSAUR DIVERSITY IN THE LATEST CRETACEOUS (MAASTRICHTIAN) OF NORTH AMERICA

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Did theropod dinosaur diversity in northern North America decrease during the final ten million years of the Late Cretaceous prior to the K/T extinctions? This study addresses this by comparing Campanian and Maastrichtian theropod diversity based on extensive collections of theropod teeth in museums (Tyrrell, UC Berkeley, and Pioneer Trails). Teeth were recovered by surface collection and screening microfossil sites from the Judith River Group of Alberta (Campanian; n = 1700) and the Lance and Hell Creek Formations of Montana, Wyoming, and North Dakota (Maastrichtian; n = 530).

Taxonomy of Maastrichtian theropod teeth is poorly developed compared to the Campanian. This taxonomic study included descriptions and photographs and measurements and bivariate plots to quantify tooth morphotypes. Taxa (excluding tyrannosaurids) include: *Richardoestesia isosceles* (32%), *R. isosceles* Morph 1 (20%), *Richardoestesia* sp. (3%), *Saurornitholestes* sp. and dromaeosaurid indet. (23%), *Troodon sp.* (13%), troodontid indet. (0.7%), and aves (8%). One result was solving *"Paronychodon"*, a common, but enigmatic Maastrichtian theropod. Based on similarity to *R. isosceles*, in both morphology and relative abundance, Maastrichtian *"Paronychodon"* is now considered a morphotype of *R. isosceles*. This theropod, with straight to slightly recurved teeth, may have been a fish-eater, convergent with spinosaurids from Africa, Europe, and South America.

North American Campanian and Maastrichtian theropod assemblages differ in 1) taxonomic composition, 2) relative abundance, and 3) diversity. 1) *Dromaeosaurus albertensis* and *Saurornitholestes langstoni*, common in Campanian, are absent from Maastrichtian and two new unnamed dromaeosaurids are present. 2) *R. isosceles*, uncommon in Campanian, is most abundant in Maastrichtian (52%). 3) Diversity is lower in Maastrichtian due to fewer dromaeosaurid species. Further work will test this apparant decline by increasing the Maastrichtian sample sizes and testing the taxonomic hypotheses.

DINOSAUR TRACKSITES IN PORTUGAL: SCIENTIFIC AND EDUCATIONAL VALUE OF ICHNOHERITAGE.

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Dinosaur footprints are known from at least twenty sites in the Mesozoic of Portugal (Middle Jurassic through Late Cretaceous). Several sites reveal tracks in many stratigraphic levels and yield good data. The majority of the well preserved tracks have been assigned to Theropoda and Sauropoda and a few of them to Ornithopoda. Important discoveries in the last ten years include: the longest and most complete sauropod trackway segments known anywhere and some of the largest known terrestrial trackmakers ever lived; a trackway of the smallest sauropod reported in Europe; several examples of wide and narrow-gauge sauropod trackways; Late Jurassic sauropod manus and pes prints both with digit impressions; sauropod manus impressions with a claw mark at digit I in a posterior-medial orientation suggesting an anatomical structure unknown in the body fossil record; a ratio of 1/2 for the manus/pes area which is very different from the known ratios in other sauropod tracks and corroborates the existence of a distinct ichnotaxon; complete sauropod trackways and only manus impressions sequences in the same tracklevel suggesting tafonomic causes and not a swimming behaviour as the origin of these incomplete trackways; good evidence for a herd of at least seven small sauropods representing the best known example of herding amongst juvenile sauropods; the first convincing example of sauropod herd behaviour reported from a European tracksite; two examples of Late Jurassic trackways revealing alternated long and short steps indicative of irregular or limping behaviour; the largest theropod footprints known. All these data on sauropod provide valuable information to characterise sauropod manus and pes morphology, locomotion and behaviour. Beside the significant scientific contribution of the dinosaur tracksites in Portugal some of them, today Natural Monuments, offer very good conditions to be outdoor geological/paleontological museums. The contribution of these sites to public education is the key to the success of geoconservation strategies in order to protect and to value the ichnoheritage.

THEFT AND VANDALISM OF VERTEBRATE TRACKSITES: CHALLENGES OF IN SITU MANAGEMENT AND PROTECTION

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The growth observed within the science of vertebrate ichnology has been accompanied by a near explosion in the discovery and documentation of new track localities worldwide. The descriptions and interpretations of vertebrate tracks have infiltrated scientific journals and popular publications. A number of vertebrate tracksites have been developed for public education.

The growing popularity of fossil vertebrate tracks is paralleled by the increasing documentation of their theft or vandalism. At least two dozen vertebrate tracksites were documented, from around the world, during a preliminary survey conducted during 2001. These cases range from tracks damaged by poor casting techniques to the theft of a trackslab from Grand Canyon National Park. A recent vandalism of a well known dinosaur track site by Boy Scouts received considerable media attention. Vertebrate tracks also become more visible on the commercial fossil market.

The management and protection of in situ fossil vertebrate tracksites has become challenging. Human impacts to vertebrate ichnofossils include incidents of unintentional damage/destruction, intentional vandalism, casual theft, and systematic theft. Sound management and protection strategies employed for fossil vertebrate tracksites include: tracksite inventories, site mapping, photodocumentation, track replication, specimen collection, site stabilization, burial, site closure, construction of protective barriers/fencing, and a variety of site monitoring strategies.

TRACKING FOSSIL VERTEBRATES IN CANADA

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In 1841, William Logan displayed fossil footprints from the Nova Scotia Carboniferous to the Geological Society of London. Since, at that time, it was believed that there were no land vertebrates in the Paleozoic, they attracted controversy and distrust. Discouraged, Logan dropped their study. However, it was taken up by J.W. Dawson, G.F. Matthew and others, who demonstrated an abundant amphibian-reptile ichnofauna from these rocks, the study of which has been resumed in recent decades.

Canadian dinosaur footprints were first reported from the Cretaceous of the Peace River Canyon, British Columbia, in 1923 and first described by C.M. Sternberg in 1932. They were neglected till the late 1960s, when the imminent flooding of the Canyon following dam construction stimulated "rescue" expeditions. Since that time, dinosaur footprints have been found at numerous localities in British Columbia and Alberta, including a first record of sauropod tracks. These researchers have furnished new information concerning growth rates and herd behaviour in hadrosaurs, the hunting tactics of coelurosaurs and carnosaurs and the environmental relationships of ankylosaurs. Middle Cretaceous bird footprints have been found in abundance; footprints of smaller reptiles and of small mammals being also reported.

Vertebrate tracks from the Paleocene of Alberta were first recorded in 1928, and later described (1932), by L.S. Russell. Subsequently, reptile footprints were discovered in the Triassic of New Brunwick (1978) and subsequently on Prince Edward Island. Recently (2001) a rich assemblage of Quaternary mammal tracks has been discovered on the margins of the St. Mary River reservoir in southern Alberta. These Canadian discoveries are contributing greatly to our knowledge of the life of the past.

RESTUDY OF *BISHANOPLIOSAURUS YOUNGI* DONG 1980, A FRESHWATER PLESIOSAURIAN FROM THE JURASSIC OF CHONGQING

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The holotype and only specimen of *Bishanopliosaurus youngi* Dong 1980 was described from the Jurassic Dongyuemiao Member of the Ziliujing Formation of Chongqing City, China. It is an incomplete postcranial skeleton of a young individual, but so far the most complete plesiosaurian fossil known from the Asian Jurassic. In the light of increasing information now available for various taxa of the Plesiosauria, we have re-examined the diagnostic features of *B. youngi*. In our revised diagnosis, the bifurcated sacral rib, compressed neural spine, narrow coracoid, and humerus with a peculiar projection are diagnostic features of the taxon; however, possible intraspecific and/or ontogenetic variations of the last three characters remain unknown. *B. youngi* is a valid taxon, but its phylogenetic relationship with other plesiosaurs remains uncertain mainly because of the poor preservation of the only specimen; at least 77% of taxonomic characters used in a recently published data matrix are unavailable from this specimen. This species, however, has a unique combination of characters not seen in any other taxa, i.e., diagnostic features listed above.

Paleontological studies of Dongyuemiao fauna and flora indicate that the sediments are of subtropical freshwater origin. The vast majority of plesiosaurian fossils comes from offshore marine sediments, but there is a growing number of reports of plesiosaurian fossils from inshore and freshwater sediments in England, Canada, South Africa, and Australia, in addition to China. Most specimens of freshwater plesiosaurs are very fragmentary, but many show rhomaleosaurid affinity. Wide geographic and temporal distributions of those fossils suggest that the presence of plesiosaurians in freshwater environments was not uncommon throughout most of their history.

UPDATE ON THE MIOCENE OF FORT POLK, WESTERN LOUISIANA

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Catastrophes have generally not been involved in the Fort Polk Miocene record, but at TVOR SE Site, a storm seems to have played a major role. Large camelid bones, rodent and insectivore teeth, cetacean vertebrae, and deep sea foraminifera are physically mixed in less than a meter vertically, suggesting that materials from land and sea, both shallow and deep open ocean, were dumped together with little sorting. The site contains fossils from a greater range of ages than the other sites. A hurricane could have brought waves to rework the nearshore, both marine and terrestrial, and heavy rain to erode soils in both river terrace dryer highlands and wet coastal lowlands. If wild fire had denuded the land, effects would be magnified and the presence of charcoal in the clays explained. Cretaceous foraminifera from older beds outside the local area, found for the first time in the Fort Polk sites, could have been added by a river in flood.

Supportive of terrestrial input from a greater variety of habitats is that TVOR SE is the most geomyoid-rich site and has approximately twice as many cricetid rodents as heteromyids. Previously, the site with the highest percentage of possibly burrowing geomyoids (Discovery Site) was also the lowest in cricetids and relatively high in heteromyids. High percentages of geomyoids and low percentages of cricetids which tend to prefer wooded areas had been interpreted to indicate a relatively more open and possibly drier situation at Discovery Site. The site has recently yielded two almost complete tortoise shells (*Geochelone*). Questions being addressed by continuing work at Fort Polk include taphonomy at all sites and a disparity of ages produced by mammal paleontology (Cold Spring equivalent early Late Barstovian) and magnetostratigraphy on one hand and paleopalynology and study of foraminifera, which agree in making the sites significantly younger, on the other.

PALEOENVIRONMENTAL CONTROLS ON MODES OF EXTRAORDINARY VERTEBRATE FOSSIL PRESERVATION, UPPER CRETACEOUS HELL CREEK FORMATION, NORTHEAST MONTANA

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Deciphering relations between depositional environment and both penecontemporaneous and eodiagenetic chemical and physical processes provides a powerful tool for understanding and predicting the occurrence of extraordinary preservation in the vertebrate fossil record. The Upper Cretaceous (Maestrichtian) Hell Creek Formation of northeast Montana contains at least two major modes of extraordinary preservation of vertebrate fossils recording distinct paleoenvironmental settings.

The Wankel *Tyrannosaurus rex* (MOR-555), one of the most complete *T. rex* skeletons ever found, contains abundant extraordinarily preserved bone with endogeneous molecular components including heme, red blood cell-like structures, and fragmentary collagen. Deposited in a low-gradient, shallow (<2 m deep) sandy meandering channel, the skeleton is articulated to associated, suggesting minor re-working by currents and rapid burial in sand. Well-preserved portions of the skeleton containing biomolecular components were entombed penecontemporaneously prior to significant burial in concretionary zones of calcite precipitated under the influence of microbial activity and high pH conditions. Subsequent early diagenetic conditions included acidic low pH pore waters that partially corroded bone in unentombed portions of the skeleton, and dissolved many labile carbonate components of the channel sand including carbonate framework grains and channel-dwelling molluscs.

Dinosaur eggshell fossils, extremely rare in the Hell Creek Formation, are present in some sandy lacustrine mudstones. These deposits record flood-induced, channel-sourced muddy sediment gravity flows (turbidity and fluid debris flow) in floodplain lakes that transported channel-dwelling molluscs and eggshell fragments into anoxic lacustrine bottom waters. The low acidity (high pH) of this oxygen-depleted environment facilitated extraordinary preservation of calcareous invertebrate shells, including preservation of shell ligament and periostracum, and dinosaur eggshell fragments. This preservation provides important information concerning molluscan channel faunas and eggshell morphologies during Maestrichtian time.

THE ORIGIN OF LISSAMPHIBIANS

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The origin of the Lissamphibia is the subject of continuing debate, and there is no current consensus. Albeit often considered a different problem, the intrarelationships of crown-lissamphibians have a strong influence on the identification of phylogenetic polarity for the lissamphibian stem, as cladistic reanalyses indicate. Regarding crown-group relationships, there is a majority view that salamanders and anurans are sister groups (Batrachia hypothesis), supported by morphological and molecular studies. In this concept, osteological evidence does play a more important role than has been traditionally acknowledged, as many soft-anatomical characters have proved to be ambiguous. Both albanerpetontids and the stem-groups of the three extant clades contribute significantly by adding information that sometimes reverses phylogenetic polarity, such as the stegokrotaphic skull of *Eocaecilia*. The two major hypotheses of lissamphibian origin (temnospondyl versus lepospondyl) rely on different character-sets, and true total evidence has not been reached yet. Most importantly, these theories involve diametrically opposite interpretations of the primitive salamander condition. The coding of many characters is made difficult by the divergent morphology of the two families of primitive urodeles: sirenids and hynobiids. While sirenids suggest that salamanders and caecilians have retained primitive states of many characters, hynobiids agree with the anuran condition as plesiomorphic. Further, sirenids clearly favor lysorophian characters be viewed as synapomorphies, while hynobiids support the temnospondyl concept instead. We conclude that future cladistic analyses will have to deal with (i) a thorough reanalysis of salamander ancestry, (ii) total evidence including albanerpetontids, (iii) the consideration of ontogenetic changes in morphology in the coding of many character-states, and (iv) the inclusion of additional character sources, such as ossification patterns among extant and fossil taxa. Our analysis of evolutionary scenarios interpreting the two alternatives favors the temnospondyl concept.

THE LATE PLEISTOCENE PALEOECOLOGY OF TWO EXTINCT TAXA: JEFFERSON'S GROUND SLOTH (*MEGALONYX JEFFERSONII*) AND ELK-MOOSE (*CERVALCES SCOTTI*)

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New records of *Megalonyx jeffersonii* and *Cervalces scotti* are reported from Lang Farm, a terminal Pleistocene bog deposit in north central Illinois. Four radiocarbon dates on *Megalonyx* cortical bone from the site (ranging from ~11,400 to 11,700 ^{14}C yr B.P.) and two dates (ranging from ~11,200 to 11,400 ^{14}C yr B.P.) on *Cervalces* cranial fragments represent some of the latest dates for these genera. The dates fall within the Bølling/Allerød warm period. Pollen data from northern Illinois indicate that forest dominated by spruce (*Picea*), fir (*Abies*), and deciduous trees covered the landscape at this time. Spruce was less abundant than prior to 12,500 ^{14}C yr B.P., and deciduous trees were probably more abundant than conifers. Important deciduous taxa included black ash (*Fraxinus nigra*), balsam poplar (*Populus balsamifera*), ironwood (*Ostrya* or *Carpinus*), oak (*Quercus*), and some elm (*Ulmus*). Black ash, which was especially abundant, and fir indicate wet climate and heavy winter precipitation. This may have been the preferred habitat for *Cervalces* because of its narrow geographic range. However, this habitat type was only one of many occupied by *Megalonyx* as indicated by its broad distribution.

MECHANISM OF PRESERVATION OF ENDOGENEOUS MOLECULAR COMPONENTS IN A *TYRANNOSAURUS REX* SKELETON

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Understanding factors controlling preservation of endogenous biomolecules in dinosaur fossils requires investigating the diagenetic history of the encompassing rock unit, since it provides the best proxy record of chemical, physical, and biological conditions affecting molecular diagenesis. This study focused on sandstone containing a *Tyrannosaurus rex* (MOR-555) recovered from the Upper Cretaceous (Maestrichtian) Hell Creek Formation in northeastern Montana. Previous chemical and biomolecular analyses of this specimen showed portions of well-preserved bone to contain heme compounds, blood cell-like structures, collagen fragments, and DNA unattributable to a definitive source, establishing it as an example of extraordinary preservation.

Field investigation of the medium-grained channel sandstone containing the *T. rex* skeleton reveals large (up to 3 m) zones of hard, concretionary calcite cement surrounded by friable clay- and hematite-cemented zones. Portions of the skeleton enclosed in calcite cemented sandstone exhibit exemplary preservation at meso- and microscopic scales; portions surrounded by hematite- or clay-cemented sandstone are less well preserved.

Petrographic analysis of calcite-cemented sandstone reveals floating and tangential grain contacts, and unfolded and exploded micas indicative of cementation before compaction. Pristine labile grains indicate calcite precipitation before development of acidic and oxidizing conditions. In contrast, clay- and hematite-cemented zones contain long and concavo-convex contacts, and folded micas suggesting free grain rotation during compaction before cementation. Dissolved labile framework grains, feldspar alteration to clay, and euhedral hematite crystal growth suggest subsequent eodiagenetic development of acidic and oxidizing conditions.

Biomolecular preservation was facilitated by penecontemporaneous precipitation of calcite cement around portions of the skeleton driven by: 1) fungi as evidenced by spherulitic fabric and isopachous fibrous calcite grain rims, and 2) cyanobacteria as evidenced by microstromatolitic fabric and calcified cyanobacterial sheaths.

PICRODONTIDS (MAMMALIA; PLESIADAPIFORMES) FROM THE PALEOCENE OF ALBERTA, CANADA

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The Picrodontidae are an enigmatic family of diminutive, peculiarly adapted plesiadapiforms from the early Tertiary of North America. At the time of their first appearance, picrodontids are highly modified, and are dentally among the most specialized of all therians. Picrodontids are known from numerous Torrejonian and Tiffanian localities in the Western Interior of North America; despite this extensive temporal and geographic range, meaningful inferences regarding phylogenetic relationships and paleobiology of the family have been hampered by limited anatomical evidence. We report the discovery of exceptionally well-preserved picrodontid specimens from the Paleocene Paskapoo Formation of Alberta, Canada, from a temporal range spanning the late Torrejonian to late Tiffanian. Significant among these specimens are two incomplete maxillae from the Torrejonian Who Nose? locality in Calgary; together these specimens preserve C through M3, as well as a considerable portion of the maxilla and anterior part of the zygoma. Numerous nearly complete dentaries are reported both from Who Nose? and the late Tiffanian DW-2 locality near Red Deer. Preliminary analysis suggests the material from Who Nose? represents a new taxon, with dental features near those of *Draconodus* Tomida, whereas the DW-2 material is more readily referable to *Picrodus* Douglass. Comparisons of the specimens at hand support previous systematic hypotheses indicating a close phylogenetic relationship with paromomyids.

LATE PLEISTOCENE DISTRIBUTION OF *BISON* IN THE MOJAVE DESERT, SOUTHERN CALIFORNIA AND NEVADA

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Review of extinct *Bison* from the Mojave Desert demonstrates that the genus is more rare from the region than previously reported. Examination of museum collections confirms the presence of *Bison antiquus* only from the Las Vegas Valley, China Lake, Lake Manix (high in the section) and Dove Spring Wash. Additionally, a magnum of a very large *Bison* is present from Twentynine Palms. Other published records of *Bison* from the Mojave are problematic. Examination of fossils assigned to *Bison* sp. cf. *B. antiquus* from older (~290 kya) sediments at Lake Manix reveals that these fossils are actually *Camelops*. Fossils previously assigned to *Bison* sp. from the Piute Valley are indeterminate large bovid (*possibly* bison) and large *Equus*. A reported occurrence of *Bison* from the Pinto Basin is erroneous.

The reported presence of *Bison* sp. cf. *B. antiquus* at Lake Manix ~290 kya was one of the earliest records of bison from North America south of the glacial ice. Elsewhere, *Bison* has often been considered to have arrived south of the ice *circa* 150 kya–120 kya. However, radiometric dates for confirmed occurrences of the taxon in the Mojave Desert range from >40 kya–15 kya in the Las Vegas Valley, to ~35 kya–19 kya at Lake Manix, ~19 kya–11 kya at China Lake, and ~16 kya at Dove Spring Wash. Fossils of bison are not infrequent at these sites, although sample sizes are small. The observed date range accords well with the age of coastal and inland southern California records (e.g., Rancho La Brea, Diamond Valley Lake), which are also relatively young. Older dates for fossils of *Bison* in the region are not in evidence, although fossils from Twentynine Palms remain to be dated. The observed distribution

and age of *Bison* in the Mojave Desert and the southwest suggests that the taxon may have had a more restricted temporal range than previously thought. This has important implications for biostratigraphy, for regional paleoecological reconstructions, and for correct interpretations of megafaunal representation and diversity at the end of the Pleistocene.

TAPHONOMY OF FLAMINGO FOOTPRINTS ON SALINE, ALKALINE MUDFLATS AT LAKE BOGORIA, KENYA RIFT VALLEY

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The taphonomy of modern footprints around several lakes in the Kenya Rift is being examined to better understand the factors that preserve and destroy footprints of vertebrates. A detailed study is being made of flamingo footprints around the margins of Lake Bogoria, a saline (90g/l TDS), alkaline (pH: 10.5) lake that is home to more than a million lesser flamingoes. The flamingoes trample the lake marginal sediments daily and roost on the mudflats at night.

Six test plots were constructed on the deltaic sands, silts, and muds of the Sandai Plain at the north end of the lake at different distances from the shoreline. In the late afternoon, the predominant north winds that funnel along the Rift Valley reverse direction, blowing saline waters across the lake marginal sediments. Observations were made over eight consecutive days and changes in footprint morphology monitored in conjunction with sedimentological examination of the host sediments.

Preliminary results show that many factors influence the formation and taphonomy of the bird footprints. The most important factors appear to be sediment texture, frequency of inundation, and salinity of the pore fluids. Muddy sediments retain print morphology longer than silts and sands, but the print morphology is degraded rapidly upon wetting. Crystallization of efflorescent salts changes the print morphology and size, while salt dissolution (e.g., during rain showers) can lead to collapse of print walls. Print preservation may be favoured during periods of low lake level when calcite or zeolites cement the sediments.

A parallel series of laboratory experiments is being undertaken to quantify the variables that appear to influence the morphology of the footprints. These variables include sediment texture, air temperature, the rate of drying of the substrate, and salinity of the pore fluids. Systematic studies of the footprint taphonomy may eventually explain why bird footprint preservation has been rarely reported, despite their abundance in East Africa.

LATE MIOCENE (LATE BARSTOVIAN TO EARLY HEMPHILLIAN) MAMMALIAN FAUNA FROM CENTRAL WYOMING AND IMPLICATIONS FOR THE TIMING OF POST-LARAMIDE TECTONICS

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Miocene strata are scarce in Wyoming and poorly dated. The late Miocene Moonstone Fm., which defines much of the Granite Mtns. graben in central Wyoming, provides an opportunity in which mammalian biochronology and U-Pb geochronology can be used to date post-Laramide tectonism. The crest of the Sweetwater Arch, formed during the Laramide orogeny, began to subside as an east-west oriented syncline early in the Miocene during deposition of the Split Rock Fm. Downwarp continued into the mid and late Miocene and allowed saline lakes to form among the sandy, fine-grained strata, paleosols, and air-fall tuffs of the Moonstone Fm. These strata yield the diagnostic mammals *Plionictis ogygia*, *Copemys pisinnus*, *Phelosaccomys hibbardi*, *Pronotolagus albus*, and *Goniodontomys disjunctus*, indicating late Barstovian to early Hemphillian ages. The biostratigraphic age of the fauna is supported by two U-Pb zircon radiometric dates of 11.3 ± 0.1 and 8.4 ± 0.1 Ma from different tuffs. After early Hemphillian time, conglomerates appear in the Moonstone Fm., derived from nearby mountains and heralding onset of normal faulting. The Granite Mtns. graben, within the core of the much larger Sweetwater arch, formed a block 100 miles long that dropped thousands of feet adjacent to original southern edges of the Sweetwater arch. Differential downdropping of the Granite Mtns. graben led to tectonic origin of the modern Seminoe and Ferris Mtns. to the south. Other evidence supporting timing of normal faulting involves presence of the Black Shale Member (BSM) in the Moonstone Fm. at levels that predate input of conglomerates from nearby mountains. The BSM contains pristine but detrital pollen and dinoflagellates transported northward along a shallow stream gradient in the late Clarendonian. These grains probably were derived from Upper Cretaceous strata of the Hanna Basin, indicating that the intervening Seminoe Mtns. were covered at the time. Using information derived from mammalian fossils and U-Pb geochronology, it is clear that the first evidence of graben development, topographic origin, and erosion of the Seminoe Mtns. postdates early Hemphillian.

REPRODUCTIVE MODE AND ITS EFFECT ON ONTOGENY AND EVOLUTION IN THERIAN MAMMALS: HAVE MARSUPIALS BEEN CONSTRAINED?

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The two groups of therian mammals, marsupials and placentals, can be distinguished by their mode of reproduction. While placental development occurs primarily in utero, marsupials give birth extremely early to neonates that must immediately crawl, using only their highly developed forelimbs, to the teat where they attach and complete their development. The extremely large and fused shoulder girdle of the marsupial neonate provides the skeletal support and muscle attachment areas necessary for the crawl. Traditionally, marsupial's unique mode of reproduction has been assumed to be constraining their evolution relative to placentals. The fossil record documents that throughout their evolutionary histories, placentals have been more numerically and morphologically diverse than marsupials.

I am testing the marsupial constraint hypothesis by comparing ontogenetic, adult and evolutionary morphological disparity in marsupials and placentals. By synthesizing different types of data, I can interpret how the importance of characters to the crawl has influenced their ontogenetic variation, and how their ontogenetic variation in turn has influenced their evolution. If marsupials are constrained, characters critical to the crawl (most notably certain shoulder girdle characters) should be less variable over ontogenetic and evolutionary time.

As predicted by the marsupial constraint hypothesis, marsupials are less disparate than placentals in every aspect of adult girdle and limb morphology. Ontogenetic results are also consistent with the hypothesis. Shoulder girdle characters critical to the crawl are significantly less variable through ontogeny in marsupials than in placentals. However, I found that ontogenetic and evolutionary variability are not necessarily positively related. In fact, in many cases the opposite pattern holds, and characters that are less ontogenetically variable, such as those critical to the crawl to the teat, are more evolutionarily disparate, a result in direct conflict with the constraint hypothesis. While marsupial's unique reproductive mode is influencing their ontogeny, it does not appear to be constraining their evolution.

MORPHOMETRIC ANALYSIS AND FUNCTIONAL IMPLICATIONS OF ARCHAEOCETE VERTEBRAL MORPHOLOGY

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Cetacean vertebral morphology is intricately related to mobility and swimming style. However, vertebral morphology and the degree of variability and complexity are difficult to quantify using traditional methods due to the large number of variables. Geometric morphometrics retains as much information as possible during analysis, preserving the geometry of the shapes being examined. Geometry is often subtle but can be very important in functional morphology, indicating neutral resting posture or the angle of lever arms for muscle attachment. Using geometric morphometrics, three vertebral views were analyzed together to create a tridimensional analysis for entire vertebral columns of a number of cetacean species. The inter-column trajectories were compared between specimens and taxa to determine interspecific variability and the relationship of morphology to swimming style. Extant taxa were used to define distinct swimming styles that could be distinguished using this method. Archaeocete vertebral columns were analyzed to determine whether the swimming styles of these transitional whales were the same as those used by modern aquatic or semi-aquatic mammals, or if archaeocetes used unique forms of locomotion not exhibited by extant taxa.

THE Y2K QUARRY, A NEW DIVERSE LATEST TIFFANIAN (LATE PALEOCENE) MAMMALIAN ASSEMBLAGE FROM THE FORT UNION FORMATION IN THE NORTHERN BIGHORN BASIN, WYOMING.

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The Y2K quarry was discovered by University of Michigan workers in the summer of 2000. Quarrying and screen washing began in the summer of 2001, during which time 98 mammalian jaws and jaw fragments, and 265 isolated teeth were collected. Fossils are abundantly concentrated in a thin (2-12 cm) siltstone layer along with snail shells and carbonized plant remains. Fragments of single jaws and bones are often found separated by a decimeter or more, suggesting post-depositional disturbance. No articulated remains have been recovered.

A total of 25 species have been identified, preserving a body size range from ~ 4 g (*Plagioctenodon*) to ~ 16 kg (*Claenodon*), based on M/1 dimensions, but the body size of most species is below 400 g. The most abundantly represented species is the multituberculate *Ectypodus powelli*, followed by the plesiadapiformes *Phenacolemur pagei*, *Plesiadapis fodinatus*, and *Carpolestes dubius*. Proteutherians include *Palaeoryctes* n. sp., *Prodiacodon*, *Palaeictops*, and an indeterminate apatemyid. Lipotyphlans include cf. *Leptacodon*, *Diacocherus*, and *Litolestes*. Other taxa include *Ignacius*, *Micromomys* n. sp., a new metacheiromyid palaeanodont, and at least three additional multituberculates.

Previous diversity analysis using rarefaction to correct for sample size indicated a significant increase in mammalian diversity from the late Tiffanian to the middle Clarkforkian. The Y2K Quarry lies in the upper part of the *Plesiadapis simonsi* Zone, between two larger quarry assemblages, Princeton Quarry (late Tiffanian), and Holly's Microsite (middle Clarkforkian). A preliminary rarefied diversity estimate for Y2K plots between that of Princeton Quarry and Holly's Microsite, and is consistent with an increase in diversity from the late Tiffanian to the middle Clarkforkian. Estimated diversity for Y2K is, however, within 95% confidence limits of both the other quarries due to small sample size. Rank abundance plots show a relatively even distribution of species at Y2K, comparable to that of Princeton Quarry and Holly's Microsite.

ENCEPHALIC SOFT-TISSUE EVOLUTION IN ARCHOSAUROMORPHA

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The encephalic space of extant archosaurs contains a complex system of interdependent soft-tissue structures that effect and are effected by the brain and the bony skull. Several of these structures were reconstructed in various fossil archosauromorphs, using the extant phylogenetic bracket approach, to further our understanding of archosauromorph brain and braincase evolution. This project was complicated by the highly derived head anatomies of the extant archosaur clades Aves and Crocodylia. Strikingly, numerous endocranial soft-tissue structures, including vasculature, pass the similarity test of homology in birds and crocodilians. Osteological correlates for several soft tissues, including the rostral semicircular canal and the auricular fossa, are more prominent in juvenile crocodilians than in adults and the juvenile braincase closely resembles the braincases of several basal avesuchians (e.g., aetosaurs and sphenosuchids). In birds, expansion and rotation of the brain has twisted the bones that accommodate it and re-oriented numerous non-neural soft-tissues, including encephalic vessels. However, after taking avian brain rotation into account, the avian braincase is very similar to basal ornithodiran braincases. Surprisingly, most of the dural venous sinuses, many encephalic arteries, various brain regions, the endolymphatic sac, and several other soft tissues shared by birds and crocodilians have clear osteological correlates that are identifiable in extinct archosaurs. Thus, many endocranial soft tissues pass the congruence test for homology.

Reconstructing encephalic soft-tissue evolution has great potential for furthering our understanding of archosauromorph biology and head evolution.

UPPER PERMIAN TETRAPODA FOOTPRINTS FROM THE IRATI AND RIO DO RASTO FORMATIONS, PARANA BASIN, BRAZIL

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Permian tetrapod footprints are rare in South America. Ichnological studies in the sediments from Parana Basin (southern Brazil) provide new and important information about Upper Permian tetrapod assemblages.

Ichnofossils attributed to Mesosauridae were recorded at Irati Formation (Sakmarian-Kazanian), at Guapirama (Parana, Brazil). The footprints are preserved as convex hyporelief, they are ectaxonic and formed by two to four parallel or divergent and curved marks. They are recognized as drag or scratch marks, produced by swimming mesosaurs. This is the first occurrence of tetrapod ichnofossils from the Irati Formation, and the first Mesosauridae footprint record. They provide a direct evidence of aquatic activity (swimming) of these reptiles.

An important Upper Permian (Tatarian) ichnocoenosis (Morro Pelado Member, Rio do Rasto Formation), was recorded at Sao Jeronimo da Serra, (Parana, Brazil). The footprints are preserved as convex hyporelief; the lacertoid footprints are pentadactyl, ectaxonic, plantigrade or semi-plantigrade, with the fourth digit prevalent, and were attributed to *Rhynchosauroides* Maidwell, 1911 (Lepidosauria). The theromorphoid footprints are pentadactyl, plantigrades with rounded outline, short digits with small interdigital divergence like those of *Dicynodontipus* (Rühle von Lilienstern, 1944) and were attributed to cynodonts. These ichnofossils can be correlated with those of "Arenarie di Val Gardena" Formation (Upper Permian) of Italy, while the fauna of this site can be correlated with the Cystecephalus Biozone (Upper Permian) of South Africa. The specimens are lodged at Museu de Ciencias Naturais, Universidade Federal do Parana (Curitiba, Parana, Brazil).

Before these findings, Brazilian Upper Permian ichnofossils of terrestrial tetrapods were unknown. These records supplement the knowledge about Permian vertebrate fauna, enlarge the fossiliferous sites and the list of Permian vertebrates of Parana Basin.

TAXON SAMPLING ARTIFACTS AND THE PHYLOGENETIC POSITION OF AVIALAE

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Inappropriate taxon sampling can reduce the accuracy of a cladogram. Taxon sampling artifacts fall into three categories: BABILON (*B*ranch *A*ttraction *B*y *I*ngroup *L*imitation or *O*utgroup *N*omination), BAAL (*B*ranch *A*ttraction *A*fter *L*umping), and PHAMIN (*PH*yletic *A*ttraction due to *M*issing *IN*termediates). BABILON occurs when an OTU is forced into a larger taxon by limitation of all other ingroups to members of the latter taxon, or is forced out of a taxon by nomination of that taxon as the outgroup. BAAL occurs when an analysis includes spurious OTUs (i.e. OTUs that are paraphyletic or polyphyletic relative to other ingroups, or are chimeras of data taken from different taxa). PHAMIN occurs when too few intermediate OTUs are included to subdivide long branches, enabling large evolutionary distances between OTUs to obscure character polarity shifts.

Taxon sampling artifacts have kept the three major bird-origin hypotheses (the dinosaurian-origin hypothesis, the crocodylomorph-origin hypothesis, and the basal archosauromorph-origin hypothesis) from being cladistically tested. In all published phylogenetic studies that include both dinosaurian and avialan ingroups, no non-dinosaurian, non-avialan ingroups are included. This artificially forces Avialae into Dinosauria by BABILON. In published studies that include both crocodylomorphan and avialan ingroups, dinosaurian and/or basal archosauromorph taxa are excluded. No published study includes both avialan taxa and *Megalancosaurus*, *Cosesaurus*, or *Longisquama* as ingroups.

Here, a new phylogenetic analysis of bird origins is presented, in which taxon sampling artifacts are avoided. BABILON is avoided by inclusion of *Megalancosaurus*, *Cosesaurus*, *Longisquama*, and several other taxa of basal archosauromorphs, crocodylomorphs, dinosaurs, and birds, as ingroups. PHAMIN is avoided by inclusion of many potential intermediate taxa as ingroups. BAAL is avoided by use of species-level OTUs only. This analysis is the first to test the three avialan-origin hypotheses.

ABELISAURID THEROPODS FROM AFRICA: PHYLOGENETIC AND BIOGEOGRAPHIC IMPLICATIONS

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Exploration of Lower and Upper Cretaceous outcrops in Niger has resulted in the discovery of abelisaurid fossils that impact on our understanding of dinosaurian biogeography during the Cretaceous.

The first abelisaurid, discovered in the Tiouraren Formation (Neocomian) in association with the sauropod *Jobaria*, constitutes the oldest material known for this clade. It includes an articulated presacral series from an individual that would have measured approximately three meters in length. Abelisaurid features include hypertrophied epipophyses, a strong interzygapophyseal lamina, and paired pneumatic openings on the centra. The second abelisaurid, discovered in the Echkar Formation (Cenomanian), includes a well preserved, hornless cranium that shows an unusual series of pits on the dorsal skull roof.

The new material is studied in the light of a phylogenetic analysis and clearly draws into question recent biogeographic scenarios that enlist the supposed absence of African abelisaurids to suggest the early separation and isolation of Africa from other Gondwanan landmasses.

THE BADGER ROOM FAUNA FROM PORCUPINE CAVE, SOUTH PARK, COLORADO: STRUCTURAL SIMILARITY BETWEEN MIDDLE PLEISTOCENE AND MODERN MAMMAL COMMUNITIES

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The Badger Room Locality from Porcupine Cave, South Park, Colorado, has produced more than 2500 identifiable fossil specimens, including gastropods, an amphibian, at least 4 bird species, and 46 species of mammal from 17 different mammal families. Arvicoline rodent taxa establish the age of the unstratified, homogeneous deposits as older than 850 Ka and most likely 850-950 Ka (Middle Pleistocene, Early Irvingtonian). Based on a detailed examination of 1500 specimens for physical and biological modification, we conclude that the primary taphonomic agents responsible for bone accumulation were carnivores (specifically canids and mustelids) and woodrats. Autecological reconstructions and comparative synecological analyses indicate that the Badger Room mammal assemblage represents a high fidelity sample of local steppe, tundra, and wetland ecosystems. In spite of high taxonomic turnover (half of the Badger Room species, and a total of 13 genera, are not known from the South Park region today) the structure of the ancient herbivore and carnivore fauna (in terms of taxonomic richness and body size structure) closely matches that of open habitat Rocky Mountain communities prior to European colonization. The diversity of omnivores has apparently increased (or omnivores were selectively undersampled in the Badger Room assemblage). In documenting these deep time patterns of community structure in Rocky Mountain ecosystems, we emphasize the important contribution that paleontology can make to neoecology and conservation biology.

ICHTHYODECTID FISH AND PROTOSTEGID TURTLE BITTEN BY THE LATE CRETACEOUS LAMNIFORM SHARK, *CRETOXYRHINA MANTELLI*

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Cretoxyrhina mantelli (Agassiz) is a Late Cretaceous lamniform shark that attained 6 m in total length (TL) and may have resembled the modern great white shark, *Carcharodon carcharias* (Linnaeus). Ichthyodectid fish bones and presumed plesiosaur gastroliths as putative gastric residues as well as mosasaur bones with embedded *Cretoxyrhina* teeth (including one specimen with post-bite bone healing) have suggested that the shark was predaceous. Here, we report a specimen of *Xiphactinus audax* Leidy (Teleostei: Ichthyodectiformes) and a specimen of *Protostega gigas* Cope (Chelonia: Protostegidae), which have one or more embedded *Cretoxyrhina* teeth. The *Xiphactinus* (ESU 1047: a nearly complete skull with the six anteriormost vertebrae) is from the Niobrara Chalk (early Santonian) of Kansas and is housed in Emporia State Univ., Emporia, Kansas. A *Cretoxyrhina* tooth is embedded in the third vertebra. Both animals were estimated to be about 3 m TL. The *Protostega* (FMNH P27452: a partial skeleton) is from the Mooreville Chalk (latest Santonian/earliest Campanian) of Alabama and is housed in the Field Mus. of Nat. Hist., Chicago, Illinois. Five *Cretoxyrhina* tooth fragments are lodged in the left humerus, and tooth marks presumably made by the same shark are present on the exterior surface of the left hyoplastron. The turtle had a carapace length of about 0.8 m, whereas the size of the shark is uncertain. Whether *Cretoxyrhina* attacked or scavenged these animals cannot be ascertained from these specimens. Nevertheless, these specimens are paleoecologically important, because they suggest the coexistence of *Cretoxyrhina* with both *Xiphactinus* and *Protostega*, and because they further support the idea that *Cretoxyrhina* frequently fed on large vertebrates in the Late Cretaceous seas of North America.

SEDIMENTOLOGY AND PALEOENVIRONMENT OF THE HORTON BLUFF FORMATION (LOWER MISSISSIPPIAN), NOVA SCOTIA, CANADA

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In the Lower Mississippian Horton Bluff Formation of Nova Scotia, Canada, lacustrine sediments occur. Fine grained shaly sediments predominant. Horton Bluff Formation represents quiet, basin deposits, far enough from active waters so that small amount of sand was deposited. Variable vertebrate fossils occur in the middle-upper member of the Horton Bluff Formation. The correlation between the nature of sediments and the type of fossils supports particular paleoenvironment. 108 specimens (including specimens from Mutton Cove) from Horton Bluff and Blue Beach were examined and classified to five types of sediments based on the color of sediments, grain size, sedimentary structures, and minerals. Numerical interpretation of vertebrate fossils which were preserved in these deposits suggests their particular habitats. Four distinct habitats were recognized: floodplain fluvial, shallow-water lacustrine, and deep-water lacustrine and broad general environment.

ON POSSIBLE RELICTS OF THE PALEOZOIC ARCHEGOSAUROIDS (AMPHIBIA, TEMNOSPONDYLI) IN THE TRIASSIC OF EURAMERICA

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Among the Early Triassic temnospondyls, the trematosaurids form the one of the predominant groups distinctive for their wedge-shaped skulls with laterally placed orbits. Their aberrant long-snouted members are usually united into the subfamily Lonchorhynchinae, whose monophyly and close relationships with typical trematosaurids have never been evidenced. It was long suggested that, unlike generalized trematosaurids which are the capitosauroid derivatives, at least some "lonchorhynchines" (such as *Aphaneramma* from Spitsbergen) might have originated from the long-snouted Permian archegosauroids typified by European *Platyoposaurus*. This view is indirectly corroborated by that some highly specialized "lonchorhynchines" have appeared as early as the Induan (*Gonioglyptus* in India, *Halobatrachus*

in Pakistan) while the development of the typical trematosaurid structural pattern proceeded gradually during the Early Olenekian, as documented by the morphological row *Benthosuchus–Thoosuchus–Angusaurus–Trematosaurus*. A new light on this problem is shed by a fragmentary find of "lonchorhynchine" in the basal Vetlugian (Induan) of the Ural Basin in Russia. It bears close resemblance to North American *Cosgriffius* (Olenekian-Anisian boundary) in such derived characters as (1) strong development of the premaxillary teeth and (2) lack of contribition from the maxillae to prechoanal elongation of snout, which are combined with (3) primitive pattern of the vomers that extend for most of length of the premaxillary tooth row. This justifies uniting both forms as the cosgriffiids. All characters listed distinguish cosgriffiids from *Aphaneramma*, and (1,3) from typical trematosaurids, with (3) being hardly consistent with common benthosuchid ancestry of all the so called trematosaurids. On the other hand, the characters (1,3) are shared by cosgriffiids with Paleozoic platyoposaurines, although the pattern of prechoanal elongation is different in these groups. Hence, it seems very likely that a part or most of Triassic "lonchorhynchines" are the archegosauroid survivors.

PYROTHERIUM OF SALLA (LATE OLIGOCENE, BOLIVIA) AND THE PEDAL MORPHOLOGY OF PYROTHERES

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Pyrotheres are enigmatic, extinct herbivores of South America of which only the Deseadan (Late Oligocene) *Pyrotherium* is reasonably well known. All other genera are represented by just fragmentary dental remains. Postcranial material is only known from *Pyrotherium* and this limited knowledge was acquired over 90 years ago.

Specimens of *Pyrotherium* have been collected from Salla, Bolivia (Deseadan) since the 1960s and have been regarded as belonging to *P. romeroi*. However, the results of this study indicate that the pyrothere of Salla is a distinct species, diagnosable by its relatively longer and narrower premaxilla, retention of a diminutive I3, and its smaller size (linear measures but two-thirds those of *P. romeroi*).

The recovery of the previously unknown pyrothere calcaneum from Salla presents opportunities for improved interpretations of the pyrothere pes. Ameghino had described the astragalus, but made several errors of interpretation, for which he begged his reader's forgiveness, noting the "strange nature of the bone." The calcaneum is equally peculiar. Its robust and flattened state immediately suggests the graviportal and plantigrade nature of the beast. The astragular facets grade into one another. Curiously, the ectal facet is strongly *concave*. A well developed fibular facet is present, but the cuboid facet is exceedingly reduced.

Thus, the pes of *Pyrotherium* may be characterized as being graviportal and plantigrade, having well developed cuboastragular and fibular-calcaneal contact. Calcaneal-cuboid contact is quite diminished and the astragular-cancaneal contact is distinguished by the reversed form of the ectal articulation. This unusual suite of tarsal characters of *Pyrotherium* is remarkably similar to that seen in *Arsinoitherium*. Whether this is due to phylogeny or to their nearly unique mode of locomotion (graviportal and plantigrade) remains to be seen.

NEW THERAPSIDS FROM THE PERMIAN OF SOUTH AFRICA: IMPLICATIONS FOR EARLY THERAPSID EVOLUTION

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The Beaufort Group of South Africa is internationally renowned for its abundance of Permo-Triassic therapsid fossils. Within Permian strata, the majority of localities reside near the middle of the basin and correspond to the *Tropidostoma*, *Cistecephalus*, and *Dicynodon* Assemblage Zones. Recent collecting efforts have been directed at the basin's periphery, especially the rocks immediately overlying the subaqueously deposited Ecca Group. This has led to the recognition of a new vertebrate biozone, the *Eodicynodon* Assemblage Zone, and a host of new therapsid taxa from the overlying *Tapinocephalus* Assemblage Zone.

Known from all but the lowest biozone, biarmosuchians are the most primitive therapsid clade. Unfortunately, they have until now been poorly understood due to a lack of well preserved material. In the past several years, five new taxa and additional, well preserved specimens of *Hipposaurus* and *Lemurosaurus* have been discovered. Surprisingly, four of the five new taxa belong to the Burnetiamorpha, which previously had been known from just two specimens (*Burnetia* from South Africa and *Proburnetia* from Russia). Burnetiamorphs are characterized by bizarre cranial morphology including numerous bony outgrowths.

Cladistic analysis supports a basal position for *Biarmosuchus* and *Hipposaurus* among biarmosuchians. *Lycaenodon*, "*Rubidgina*," and *Ictidorhinus* are unresolved, but are consistently placed between the former taxa and a derived subclade of burnetiamorphs. *Lemurosaurus* is recognized as the most primitive burnetiamorph, followed by a new taxon from the *Tropidostoma* Assemblage Zone. Three new taxa fall within the clade bounded by *Burnetia* and *Proburnetia*, the Burnetiidae proper. These new fossils from South Africa document previously unknown biarmosuchian diversity in the Beaufort Group and shed light on the morphology and phylogenetic relationships of early therapsids.

NEW VERTEBRATE FINDINGS IN THE LOWER CRETACEOUS OF PIETRAROJA (SOUTHERN ITALY).

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The Lower Cretaceous site of Pietraroja, in southern Italy, is well known for the findings of exceptionally preserved vertebrates, including at least two crocodiles and a theropod dinosaur. In the spring of 2001 new excavations were undertaken in the area, and new fossil finds came to light. Aside from representatives of the wel known fish fauna, interesting new findings that may be attributed to archosaurs have been excavated. Moreover, a new model for the palaeoecology and palaeogeography of the area has been created thanks to the new findings and data from the new excavation. Most of the tetrapods found there seem to be primitve respect to similarly-aged faunas around the world, but this may be due either to geographic insulation, or to the juvenile age of most of the animals, not excluding the combination of both factors. The final result is an interesting mixing of faunal characters, coupled with an exceptional preservation that makes Pietraroja one of the most important site in southern Europe.

DIVERSIFICATION OF THE MAJOR LINEAGES OF BATS: NEW PERSPECTIVES ON AN OLD RADIATION

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The order Chiroptera includes over one-fifth of all extant mammal species (>1090 species). These taxa, along with their extinct relatives, are presently placed in 22 families. Although virtually all workers agree that these families are monophyletic, there is little consensus concerning higher-level relationships. Clades strongly supported by morphological data (e.g., Microchiroptera, Rhinolophoidea) have been resoundingly refuted in recent molecular studies. Whatever the outcome of future combined-data and dense-sampling analyses, it seems clear many traditional groupings are likely to be non-monophyletic. Surprisingly, our understanding of the timing and pace of the initial chiropteran radiation remains largely unaffected by these major shifts in hypothesized phylogenetic relationships. Regardless of whether one uses trees based on morphology or molecular data, it seems clear that many of the major lineages of bats were distinct by the end of the Eocene. The earliest known bat fossils date from the ?late Paleocene/early Eocene of North America, and by the middle Eocene there were bats nearly every continent. Over 25 genera of bats are recognized from Eocene deposits around the world. Fossils referable to several extant families (Rhinolophidae, Hipposideridae, Megadermatidae, Nycteridae, Emballonuridae, and Molossidae) are known from middle-upper Eocene deposits, and reconstruction of ghost lineages (regardless of the phylogeny used) leads to the conclusion that many or most extant lineages were present by the end of the Eocene. It therefore appears that much of chiropteran diversity originated in a burst of speciation in the Eocene. Several factors likely contributed to this radiation, including the evolution of powered flight and echolocation. If Microchiroptera is diphyletic (as now seems likely), both flight and echolocation probably evolved in the chiropteran lineage prior to the beginning of diversification of the bat clade.

ENVIRONMENTAL RECONSTRUCTION OF THE 111 RANCH (BLANCAN) BEDS IN SOUTHEASTERN ARIZONA USING ISOTOPIC ANALYSIS, TAPHONOMIC OBSERVATIONS AND CENOGRAM ANALYSIS

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Paleoenvironmental reconstruction of the 111 Ranch was attempted using several different methods. The 111 Ranch fossils have previously not been analyzed using stable isotopes, so carbon isotopic analyses were performed on several proboscidean fossils from the fossil beds in southeastern Arizona. The carbon isotopic values range from -12 per mil to -17 per mil (corrected for large herbivores), and fall into the range of pervious isotopic analyses of similar proboscideans. the results of the analyses suggest that the proboscideans were consuming C4 plants suggesting a warm climate. This isotopic data is consistent with evidence of a worldwide increase of C4 plants after 8 Ma.

Taphonomic and sedimentologic evidence suggests the presence of flowing water, and the presence of fragmented and isolated bones suggest a well-drained, arid environment. Most bones were likely to have been transported some distance before fossilization, although a few show evidence suggesting rapid burial. The presence of *Neochoerus, Glyptotherium, Tapir, Kinosternon,* and *Castor* suggest the steady presence of water.

Cenogram analysis is a graphical method for inferring vegetation and climate based on body size of primary consumers. A preliminary cenogram analysis of the 111 Ranch fauna was done using all known primary consumers and was then compared to similar data of extant communities. This data suggests the environment was similar to a tropical savannah.

Stable isotopic data, taxonomic data and taphonomic observations obtained in this study suggests that the environment of the 111 Ranch was relatively warm and water was present most of the time. Preliminary cenogram data seems to agree with the previous data. This study opens the door for further isotopic, taphonomic and sedimentologic studies on the 111 Ranch fauna and beds.

AN EXPLORATORY SURVEY OF VERTEBRATE PALEONTOLOGICAL RESOURCES IN WISCONSIN CAVES

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In the fall of 2001, the University of Wisconsin Geology Museum initiated a survey to assess and inventory vertebrate paleontological resources in Wisconsin caves. The primary goals of this initiative are to identify bone-bearing cave deposits that warrant further investigation and possibly conservation. So far, samples of cave matrix have been collected from thirteen localities in the non-glaciated, southwestern corner of the state. Vertebrate material was recovered from each site, and several major bone accumulations were discovered. In general, bones from fishes, frogs, toads, snakes, birds, and mammals are abundant within the caves, wheras the bones of salamanders and turtles are less common. Due to an absence of arctic and northern boreal species, it appears that all samples collected are Holocene in age. Small mammalian carnivores were the primary agents of bone accumulation in nearly all of the caves surveyed. This is not surprising given that most of these caves have small, horizontal entrances and constricted passages.

Deposits such as those identified in this survey are essential for determining the distri-

bution of Wisconsin amphibians prior to Euro-American settlement in this region. Knowledge of such past distributions would facilitate a better understanding of the dramatic amphibian range reductions and population declines that have taken place in Wisconsin during historical times.

TAPHONOMY OF TERMINAL PLEISTOCENE AND HOLOCENE BONE DEPOSITS IN BOGUS CAVE, EAST-CENTRAL IOWA

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Bogus Cave has yielded an exceptionally rich and diverse collection of terminal Pleistocene and Holocene vertebrate remains. Nearly a cubic meter of matrix was excavated from stratified deposits in a constricted passage approximately 35 m from the mouth of the cave. Identified material from this excavation includes almost 9,400 mammalian cranial and dental specimens, which represent a minimum of 46 species and 772 individuals.

Most of the bones recovered are from the scats and meals of small mammalian carnivores. Five lines of evidence collectively support this conclusion. (1) Many skeletal specimens exhibit moderate to extensive corrosion from having been partially digested. (2) The bone assemblages are highly fragmented and contain thousands of unidentifiable pieces. (3) Carnivore gnaw marks and punctures are present on some of the larger bones. (4) Nearly all the plants and animals represented are consistent with the diets of small mammalian carnivores. (5) Small mammalian carnivores are the primary agents of bone accumulation in Bogus Cave today. In addition, a minor amount of vertebrate material was derived from non-predator-related deaths within the cave. These remains consist primarily of complete, unmodified bones from cave-dwelling species.

Undoubtedly, the representation of species within the bone deposits has been influenced by the predatory habits of the mammalian carnivores that accumulated them. This "mammalian carnivore filter" did not discriminate against many groups of mammals. The bone assemblages show no evidence of size bias as both small and large mammals, ranging from pygmy shrews to bison, are represented. The bone deposits also contain remains from diurnal and nocturnal species, as well as a host of others that are active both day and night. Additionally, mammals from a variety of habitats including forests, grasslands, and marshy areas are present. This apparent lack of selectivity is consistent with the opportunistic foraging habits of raccoons, coyotes, and other small mammalian predators.

AN UNUSUAL LATE TRIASSIC ARCHOSAURIFORM FROM GHOST RANCH NEW MEXICO

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The Ghost Ranch Quarry is notable for the large death assemblage of the Late Triassic theropod *Coelophysis*. Among the numerous *Coelophysis* skeletons was an armored reptile (GR 138) initially reported by one of us (AD) as a choristodere. GR 138 is characterized by an unusual suite of features. The skull combines the archosaurian characters of an ossified laterosphenoid and thecodont tooth implantation, with the absence of supratemporal, antorbital, and external mandibular fenestrae. The skull is remarkably short and tall with the preorbital region about 35% of the skull length, and lacks a prefrontal and postfrontal. The orbit is circular and the large rectangular infratemporal fenestra faces laterally with a bowed posterior margin. The mandible is as tall as the skull. The dentition is heterodont, with a large caniniform fang on each tooth-bearing bone, and small, serrated marginal teeth.

The postcranial skeleton is mostly obscured by hundreds of small, smooth, imbricated osteoderms of several morphologies covering the entire body excluding the skull. The pelvis is primitive, with a shallow acetabulum, a plate-like ischium, and a probable thyroid fenestra between the ischium and pubis. The femur has a weakly developed fourth trochanter. GR 138 has possible aquatic adaptations with dorsally directed external nares, elongate body with short limbs, a long, deep tail with tall caudal neural spines, and upright-standing osteoderms possibly forming a sculling tail.

Despite the lack of some key archosaurian features the presence of an ossified laterosphenoid, thecodont tooth implantation, dermal osteoderms, and fourth trochanter places GR 138 within the Archosauriformes, although its phylogenetic position within this clade is uncertain. The absence of supratemporal, antorbital, and external mandibular fenestrae are interpreted as character reversals and as apomorphies of this taxon.

NEW MATERIAL OF THE DRY MESA PTEROSAUR *MESADACTYLUS*

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In addition to a high diversity of dinosaurs, some pterosaur material, including appendicular elements, sacrum, and a cervical vertebra, has been recovered at the Dry Mesa Dinosaur Quarry in the Morrison Formation of Colorado. Most of these bones were referred to *Mesadactylus ornithosphyos*. Since the original description, more material has been uncovered. The collection now includes a minimally distorted basicranium with an intact occipital condyle and better-preserved appendicular elements than were originally available. One important element is a well-preserved femur with a prominent anterior bowing of the shaft, an anteverted femoral neck, and an intact head. Additionally, the vertebra was CT-scanned to reveal details of the pneumatization.

This report presents an updated description of *Mesadactylus*, based on information in the new material. We confirm that *Mesadactylus* is a basal pterodactyloid. It is similar, but considerably smaller than the other Morrison pterosaurs *Comodactylus* and *Kepodactylus.*

DENTAL VARIATION AND PHYLOGENETIC RELATIONSHIPS OF MIOCENE *LEPTODONTOMYS* (RODENTIA: EOMYIDAE) FROM CHURCHILL COUNTY, NEVADA

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A large sample of more than 200 specimens of *Leptodontomys* from the Monarch Mill Formation, Eastgate local fauna, Churchill County, Nevada was examined. These fossils include maxillae, mandibles, incisors, and isolated upper and lower cheekteeth. Eighteen qualitative dental characters of lower premolars were studied in greatest detail because they are most diagnostic for this group of rodents. Quantitative analyses of lower premolars of *Leptodontomys* from Eastgate included coefficient of variation, principal components analysis, correspondence analysis, and cluster analysis. These univariate and multivariate methods aided in the identification of multiple species groups of *Leptodontomys* from Eastgate.

A preliminary examination of the phylogeny of the genus *Leptodontomys* (*L. douglassi*, *L. oregonensis*, *L. quartzi*, *L. russelli*, *L. stirtoni*, species A, species B, and species C) was conducted. Three species of *Leptodontomys* (species A, species B, and species C) are proposed as new for the genus. More than 70 qualitative characters of the maxillae, mandibles, and upper and lower cheekteeth taken from the literature and characters identified herein were evaluated. Phylogenetic analyses show two of the Eastgate species, species A and species B, form a tritomy with *L. stirtoni*. In a second clade, *L. quartzi*, species C, and *L. russelli* form a monophyletic group. Within this clade, species C and *L. quartzi* are sister taxa, with *L. russelli* sister to species C and *L. quartzi*.

SQUAMATE DIVERSITY ACROSS THE EOCENE/OLIGOCENE BOUNDARY: NEW DATA AND THE APPLICABILITY OF PHYLOGENY

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The current record of squamates across the Eocene/Oligocene boundary in the Western Interior of North America shows an increase in diversity in spite of cooling and increased aridity and, consequently, is anomalous in comparison with the European record and that of other North American ectothermic reptiles. The implications of such a pattern for paleoecology are unsettling, because different responses by similar organisms to a similar stimulus would suggest that (predictive) generalities may not exist. However, it is unclear whether the pattern results from inadequate sampling of the late Eocene (Chadronian North American land-mammal "age").

We report on a diverse new fauna from the Chadron Formation of southwestern North Dakota, for which mammalian biostratigraphic evidence suggests an early Chadronian age. Among the lizards, at least 6 iguanids, 3 anguids, 2 amphisbaenians, 1 xenosaur, and 3 other distinct forms are present. One of the iguanids represents the earliest known record for the stem of Iguaninae. The fauna additionally includes the latest North American records of Acrodonta (*Tinosaurus*) and Varanidae (*Saniwa*). Among the snakes, at least 4 forms are present. Thus, the known squamate record in the Western Interior now includes a minimum of 21 Chadronian and 17 Orellan taxa, documenting a decrease in diversity that is at least qualitatively consonant with the record in Europe.

Phylogeny is important in assessing past biodiversity, and the discovery of several of the newly documented forms was anticipated from phylogenetic considerations. For example, the xenosaur lineage is known in the Western Interior prior to and after the Chadronian. We would additionally hypothesize that at least one helodermatid from this time remains unrecorded in the Western Interior. However, the logical applicability of phylogeny—an inherently global concept—to studies of regional diversity is restricted because of incommensurate areas of reference. Only when the taxa that phylogenetically bracket a ghost lineage are confined to the region of interest should the ghost lineage be counted in analyses of diversity of less than global scope.

TRACKWAY EVIDENCE OF POSSIBLE GREGARIOUS BEHAVIOR IN LARGE THEROPODS FROM THE LOWER JURASSIC MOENAVE FORMATION OF ZION NATIONAL PARK

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A recent paleontological survey initiated by the National Park Service in Zion National Park, southwestern Utah, has produced several tracksites with evidence of large theropod dinosaurs. These findings confirm the presence of a large theropod dinosaur from the Early Jurassic of Utah. At least one of these sites contains multiple trackways suggestive of gregarious behavior.

The tracksites are preserved in the uppermost surface of the Springdale Member of the Lower Jurassic Moenave Formation, where it contacts the overlying Kayenta Formation. They occur in a medium to fine-grained sandstone consistent with deposition in a low-gradient fluvial system. One of the tracksites covers an area 10 meters long by 20 meters wide and contains at least four trackways, all from large theropods (track lengths averaging 40 centimeters). One of these trackways shows two changes in pace with corresponding deformation of the tracks consistent with the animal accelerating and decelerating. Three other trackways are oriented parallel with equal spacing between them. The two outside trackways have an average foot-length of 44 centimeters and stride-length of 1.3 meters. The middle trackway has a foot-length of 40 centimeters and a stride-length of 1.0 meter. Velocity estimates incorporating stride-length and hip-height suggest that all three theropod trackmakers were walking at the same speed.

While gregarious behavior has been suggested for small theropods such as the Late Triassic coelophysoids and large theropods such as the Late Jurassic *Allosaurus,* little is known about the occurrence or behavior of large theropods in the Early Jurassic. The parallel, unidirectional arrangement of these three trackways, together with the regular intertrackway

spacing and consistent speeds, are highly suggestive of gregarious behavior. This ichnological evidence from the Moenave Formation demonstrates the presence of a large theropod in the Early Jurassic of Utah. It further represents perhaps earliest evidence of gregarious behavior in a large theropod.

DENTAL MORPHOLOGY AND VARIATION IN *TYRANNOSAURUS REX*: IMPLICATIONS FOR TAXONOMY, SYSTEMATICS, AND THE IDENTIFICATION OF SHED TEETH

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Although isolated theropod teeth occur frequently in upper Mesozoic rocks, an understanding of their taxonomic utility remains elusive and dental characters rarely factor into systematic discussions of the clade. This neglect of theropod tooth data is based on an impression that it is difficult or impossible to discriminate these elements. However, while theropod teeth *are* simple structures possessing few homologous landmarks from which measurements concordant with modern morphometrics can be made, theropod dental anatomy is still largely unexplored and opinions regarding theropod tooth usefulness are premature. A detailed study of the dentition of a single theropod, *Tyrannosaurus rex*, was conducted to serve as the beginnings of a standard against which to compare isolated teeth. An attempt was then made to devise a methodology by which cf. tyrannosaurid teeth could be confidently assigned to or discriminated from the standard. *T. rex* dental variation was quantified using several revised common measurements (e.g., total crown length; base length and width; denticle size), and new variables that describe base shape, "squatness," and apex location. Crown recurvature was described by collecting X,Y coordinate data from digital images of the mesial and distal lateral tooth profiles. The square root function $Y = a + bX^{0.5}$ was fit to the data after they were normalized to 1 (by dividing the data by the range of x values). The b value generated from this analysis provides a measure of the shape of a given crown face and can be examined on its own or with other variables. Statistical tests such as ANOVA and multivariate analyses (e.g., PCA) were used to examine *T. rex* positional variation and to compare teeth of presumed tyrannosaurid and non-tyrannosaurid affinities against the standard. Using these methods, it is often possible to decipher tooth positions for known *T. rex* teeth with statistical confidence and discriminate morphologically similar teeth (e.g., *Daspletosaurus*) from the *T. rex* standard, suggesting that expanding the standard should facilitate tooth identifications for additional theropods.

MICROSQUAMOUS EXOSKELETON OF AN ENIGMATIC VERTEBRATE FROM THE LATE ORDOVICIAN AND EARLY SILURIAN OF SIBERIA

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Microremains collected from the southern part of the Siberian platform are attributed to the Late Ordovician and Early Silurian. Some of these are complex scales or 'tesserae' from an unknown vertebrate with a microsquamous exoskeleton. Their interpretation as true tesserae remains problematic because very few show classical pentagonal edges to the base and no evidence of abuting junctions. Complex scales, or microsquamous ornamented bones could be the alternative skeletal forms. Across the geological strata, three to four species are recognised with morphological variation. The earliest is *Tesakoviaspis* sp.indet. (Caradocian), *T.* sp.nov.1 (in three separate Ashgilian localities), and two species *T* sp.nov. 2 and *T. concentrica* Kar.-Tal. 1978 are specific to the Llandoverian.

Their morphology shows variation in growth, also across species, with recognition of areal growth zones of small, oval tubercles surrounding a large, central primordial tubercle. Each of these is an odontode with centripetal tissue growth around a separate pulp cavity; completion of the bony base is later event. This is added below the odontodes to almost close the pulp cavity except for narrow, central openings, continuous with vertical vascular canals opening onto the visceral surface of the scale.

Thin sections of *T. concentrica* show a unique histology of atubular dentine arranged in well demarcated parallel layers, termed conical lamellin. The first coronal layers, appear as numerous, steep sided cones, but become gradually flatten in the later circumpulpal layers and are indicative of a new type of vertebrate dermal production. The acellular basal bone shows lines of growth where this is sequentially thickened with layers coincident with the increase in area of the scale. This bone is also permeated by vertically arranged Sharpey's fibre bundle spaces. The closest histology is that of *Sodolepis lucens,* assigned to the mongolepidids, putative chondrichthyans. There is no equivalent tissue in known Ordovician, or Silurian, agnathan vertebrates, such as astraspids, eriptychiids, or thelodonts.

PATTERN OF VERTEBRATE EXTINCTIONS ACROSS AN EVENT BED AT THE PERMIAN/TRIASSIC BOUNDARY IN THE KAROO BASIN OF SOUTH AFRICA

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The extinction of vertebrates around the Permo-Triassic boundary has long been regarded as a gradual event occurring over hundreds of thousands to millions of years. Our new field investigations of fluvial strata in the central and southern Karoo Basin of South Africa have revealed the presence of an event bed coinciding with a mass extinction of terrestrial fauna and flora over a much shorter period. This event bed is a laminated red mudrock within a sedimentary sequence that reflects a rapid transition from high to low sinuosity river channel systems.

A total of 101 identifiable vertebrate fossils were collected from 52 discrete stratigraphic levels spanning the uppermost Permian and lowermost Triassic strata in two in widely separated study sections. These yielded a minimum of 16 species, 9 species were found in Permian strata, and 7 were found in Triassic strata. In general the extinction could be described as "ecologically stepped" with the disappearance of small herbivores (*Diictodon, Pristerodon*) and small carnivores (*Cyonosaurus*) before the larger forms *Rubidgea, Theriognathus, Pelanomodon* and *Dicynodon*.

Not only is the pattern of species extinction and recovery similar in all studied sections, but it occurs in a similar sequence of sedimentary facies. The changes in fluvial style from meandering to low-sinuosity braided channels, combined with the onset of rubification of the floodplain soils and changes in taphonomic style of the vertebrate fossils are interpreted as the result of climatic drying causing de-vegetation and a corresponding decrease in bank strength. Thus, it is proposed that the extinction represents a faunal changeover from wet floodplain with *Glossopteris* flora supporting a *Dicynodon*-dominated fauna to dry floodplain with drought-tolerant horsetails supporting communities dominated by *Lystrosaurus*. This changeover is consistent with a relatively sudden, possibly catastrophic drought event of 50,000-year duration or less at the end of the Permian that may ultimately have been caused by a rapid increase in "greenhouse" gasses in the atmosphere.

ALBERTOSAURUS EN POINTE: ALLOMETRIC SCALING OF THEROPOD ROTATIONAL INERTIA AND TURNING PERFORMANCE

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When turning, animals with a parasagittal gait use gravity and friction to change both linear and angular momentum, using muscular effort to initiate a lean into the turn. The ability to pivot rapidly is inversely proportional to the rotational inertia (RI), which in isometrically scaling animals increases to the 5/3 power of body mass. However, RI is lower in objects with mass concentrated towards the center of mass (CM). This study tests the hypothesis that tyrannosaurids scaled allometrically, such that mass in larger individuals was more centralized, and that RI was reduced below that expected from isometry.

Body mass, mass distribution, and horizontal and vertical RI of tyrannosaurids were estimated using 3D 'wire-frame' computer models. Four tyrannosaurids known from relatively complete remains were chosen: subadult and adult *Albertosaurus*, *Daspletosaurus*, and *Tyrannosaurus*. Rotational inertia scaled to the 1.55 power of body mass, significantly lower than the 5/3 power predicted if the dinosaurs scaled isometrically. As a control, the subadult *Albertosaurus* was scaled isometrically to the mass of the larger tyrannosaurids. Its RI scaled to the 5/3 exponent, indicating that adult tyrannosaurids could turn faster than if they maintained juvenile body proportions.

To further test these results, RI was estimated for thirteen theropods of a wide range of body mass, and for non-dinosaurian carnivorous archosaurs. Theropods of masses spanning five orders of magnitude, from *Compsognathus* to *Tyrannosaurus*, had rotational inertias scaling to the 1.55 power of body mass with a high correlation coefficient, while the quadrupedal archosaurus scaled isometrically. We propose that the relationship for tyrannosaurids is applicable to other large, tailed bipeds, and allometric body scaling was more important than tooth loss or changes in posture for reducing rotational inertia.

ONTOGENY OF XENACANTH SHARKS: IMPLICATIONS FOR THE DEFINITION OF CHARACTER-STATES FOR PHYLOGENETIC ANALYSIS

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Nearly complete, articulated xenacanthids from the Westphalian D of Bohemia (Czech Republic) representing pre-adult stages provide new information about the early development of xenacanths. Most of the specimens are juveniles of *Orthacanthus bohemicus* and *Xenacanthus parallelus*. Study of the new material and comparison with adult individuals led to the revision of several characters related to the dorsal spine and unpaired fins that are often used in phylogenetic analyses.

The new material indicates that the dorsal spine of members of Xenacanthidae, always considered as the cranial (occipital) spine, was induced in front of the dorsal fin, behind the pectoral girdle, in similar fashion to the spine of the more primitive xenacanths Lebachacanthidae and Diplodoselachidae. The occipital location of the spine in sub-adult and adult animals of Xenacanthidae is consequent upon the differential growth of the proximal part of the spine early in ontogeny. By contrast, the dorsal spine of members of Diplodoselachidae and Lebachacanthidae is always located behind the pectoral girdle. The fossil record, generally represented by isolated skeletal elements and articulated sub-adults and adults, has given misleading picture concerning the ontogenetic origin of the spine in xenacanthids.

The new results support the presence of two anal fins and a diphycercal caudal fin as a synapomorphy of the crown-group xenacanths (Lebachacanthidae and Xenacanthidae). The development of two anal fins is correlated with the posterior prolongation of the dorsal fin. The number of calcified vertebrae related to the dorsal fin is defined early in ontogeny (embryonic stage); however, the number of calcified vertebrae of the caudal fin continues to increase during ontogeny until the late juvenile stage. In consequence, the ratio between the length of the diphycercal and anal fins, used in phylogenetic analyses, changes dramatically until the sub-adult or adult stage. Careful analysis of ontogenetic changes in the postcranial skeleton is needed to establish, more clearly, character-states concerning the position and structure of these anatomical elements.

ROBUSTNESS OF THE HUMERUS AS A LIMITING FACTOR FOR MAXIMAL BODY MASS IN LAND-LIVING MAMMALIAN PREDATORS

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Observations on extant mammals suggest that greater body mass confers important selective advantages on any land-living predator of large herbivores. Yet, throughout the Cenozoic, members of some lineages of such predators attained greater maximal body mass than those of other lineages of land-living mammalian predators of large herbivores. Studies of body sup-

port scaling in extant mammals suggest that the constraint on maximal body mass,implied by the above evolutionary pattern, may have been imposed by the increase in the stress due to bending, generated in the humerus during locomotion at a given speed, in larger animals. Above a certain body mass, a terrestrial mammal would no longer be able to attain the maximal speed of its smaller relatives, which would be a distinct disadvantage to any predator on large terrestrial herbivores. The critical body mass, above which the locomotor performance of a land-living mammalian predator would decline, should depend on the scaling relationship between humeral length and antero-posterior diameter within the predator's lineage. Members of lineages with the more robust humeri would be expected to attain greater maximal body mass than those characterized by the more slender humeri.

To test the above prediction, I measured humeral length and antero-posterior diameter in extinct species of several lineages of land-living mammalian predators, in addition to the published humeral dimensions in extant species of those lineages. I log-transformed and plotted length against the diameter and fitted a linear regression line and its 95% confidence bands to the data points for each lineage. The results support the hypothesis that robustness of the humerus has been a limiting factor for maximal body mass in terrestrial predatory mammals, but suggest that limb posture and massiveness of the distal limb segments have affected maximal body mass attained by members of individual lineages. I also propose an alternative explanation for the differences in maximal body mass attained by members of different lineages of land-living mammalian predators, but show that it fails to account for some of those differences.

BONE CABIN QUARRY: MYTHS, FABLES AND UNTOLD TALES

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Bone Cabin Quarry (BQC) located in southeastern Wyoming has been a rich source of Jurassic dinosaur and other vertebrate remains for over 120 years. Dinosaur skeletons from this quarry are now on display in museums throughout the world. Although popularized by the AMNH's work there (1898-1905), colorful stories associated with the quarry's discovery, name and contents continue. Recent archival research has shed light on several new details associated with the history of this renowned site.

Myths about a BCQ provenance for the AMNH-mounted *Allosaurus* and *Apatosaurus* (actually from Como Bluff and 9-Mile Crossing Quarries) still appear in the popular literature. The quarry name is often mistakenly associated with a small house of bones built in the 1930s. In addition, controversy still lingers over the timing of the quarry's discovery. Although traditionally assigned to the AMNH field crew under the direction of Walter Granger in 1897, it may have been known to sheepherders and other paleontologists as early as the 1870s. However, historical field notes and an 1881 U.S. Government Land Office township plat map document the first written record of this bone site. A survey crew, under the direction of William Owen, passed through this area of Wyoming during the location of section lines in the late 19th century. Working on the featureless prairies of the Flat Top Anticline without suitable materials for survey markers, they resorted to using dinosaur bones and bone fragments from the BCQ site to monument their sections.

Bone Cabin Quarry remains a world-renowned and prolific site. Recent fossil discoveries are providing new information about the Jurassic animals of North America. At the same time, ongoing historical research is providing additional information about the discovery and importance of this locality. It is likely that many other historic quarry sites in the Rocky Mountain West will continue to yield new evidence about their past and the treasures that they contain.

COPROLITES FROM BAURU BASIN IN BRAZIL

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Current work provides information about coprolites (52 samples)found in continental sediments from Upper Cretaceous in Adamantina and Marilia Formations of Bauru Basin in Southern Brazil. The coprolites are in association with remains of fishes, crocodiles, turtles, dinossaurs and biogenic structures. Almost tetrapod remains are represented by postcranial fragments and rare articulate skeleton that laying at same level of coprolites. This stratigraphic sequence reveals a high water availability such as ponds located in large and periodically flooded plains with fluvial streams ran from marginal fans.

The coprolites morphology is represented in cylindrical, ovoid and esborred shapes with superficial marks (transversal grooves and folds) a large number of samples are broken up that indicates an autochthonous and parautochthonous condition due a transport by fluvial agent after material becomes fossilized. Thin sections of these coprolites show microangular grains of quartz, calcite with silicified areas. Mineralogical composition by x-ray diffraction reveals substitution process by fluorapatite and quartz. Chemical analysis by x-ray fluorescence detected high concentrations of phosphate, calciun and silica.

The large forms with cylindrical shapes with bone fragments inside are atribuated to crocodiles. The most abundant presence of large esborred and ovoid shapes are respectively associated to turtles and sauropod remains, small ovoid and cylindrical shapes are related with fishes. The occurence of coprolites in this sediments in association with eggs and burrows suggests that these animals developed nests areas and lived in lacustrine enviroment with periodic seasonality influence.

ANCIENT GENE-FLOW: POST-GLACIAL COLONIZATION OF YELLOWSTONE NATIONAL PARK, WYOMING, USA

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Several factors contribute to the unique biogeographic history of the greater Yellowstone ecosystem. The park was the site of a continental ice cap during the last glacial maximum, and consequently was one of the last regions in North America to deglaciate 14,000 years ago and thus, constitutes a relatively young ecosystem. Additionally, Yellowstone is located at the intersection of three major biogeographic provinces (Rocky Mountain, Great Plains, and Great Basin) that differ in their floral and faunal species composition and abiotic properties. The deglaciation of this region provides an opportunity to study the assembly of an ecosystem by contributions from neighboring provinces. This problem can be tackled from a biogeographic perspective: source populations for different species can be predicted based on proximity of populations across the modern landscape. The same question can also be addressed from a phylogenetic point of view, determining the genetic affinities of populations within species and assessing their connectivity through space. A previous phylogeographic study has revealed four major clades of the long-tailed vole (northern Rockies, southwestern USA, Oregon/California border, and southern Rockies). We rely on ancient DNA data to provide a temporal perspective on the assembly of this community by assessing the relative contributions of the geographically distinct source populations through the last 3,000 years. We propose to use this type of phylochronologic data to predict the highways of colonization of the Yellowstone National Park ecosystem, one of the last remaining intact temperate ecosystems of the world.

TAPHONOMIC PROCESSES AFFECTING THE PIT 91 ASSEMBLAGE, RANCHO LA BREA

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Many studies of the Rancho La Brea "tar pits" have focussed on the paleobiology of the fauna, but little research has been done on taphonomic processes that affected these assemblages. The traditional scenario of animals becoming mired in asphalt suggests that relatively complete skeletal representation could be expected and that deposition was relatively rapid. We tested these hypotheses by collecting taphonomic data on over 18,000 specimens of large mammals from a single deposit, Pit 91.

Weathering data indicate that elements were not exposed for long, supporting the hypothesis that deposition was relatively rapid. However, in the short time between death and burial, it is clear that various processes affected carcasses as patterns of skeletal part representation indicate that complete skeletons are not present. Cranial elements predominate, and small bones are proportionally rare. These data are consistent with patterns that result from two different taphonomic processes, water transport and carnivore ravaging. (1) Winnowing by water is suggested by the predominance of elements from Voorhies Group III (skull, mandible). Consistent with this interpretation is the common occurrence of abrasion found on the specimens examined. (2) Carnivore ravaging is usually indicated by toothmarks, but these are rare in this assemblage. Among herbivores, the sample of *Bison* remains appears to have been ravaged by carnivores, as there are strong correlations between limb remains and both bone density and grease content. In contrast, weak correlations are found between *Equus* limb remains and bone density and marrow content. However, *Equus* bones contain less within-bone nutrients, and should have been less attractive to carnivores, which probably accounts for their higher survivorship in the assemblage. The different patterns of element representation for these two herbivores are consistent with carnivore ravaging, and would be difficult to explain through water transport alone, which should not discern between taxa. Overall, the data suggest a complex pattern of taphonomic influences that affected these unique asphalt deposits.

OVERVIEW OF MOLECULAR EVIDENCE FOR SUPERORDINAL/ORDINAL TAXA, AND TIMING OF THEIR DIVERSIFICATION

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Relationships and divergence times among the orders of placental mammals remain contentious. Likelihood-based analyses of large concatenations of nuclear and mitochondrial rRNA gene sequence data provide strong support for four major clades of placental mammals: Afrotheria (Afrosoricida, Hyracoidea, Macroscelidea, Proboscidea, Sirenia, Tubulidentata); Euarchontoglires (Dermoptera, Lagomorpha, Primates, Rodentia, Scandentia); Laurasiatheria (Carnivora, Cetartiodactyla, Chiroptera, Eulipotyphla, Perissodactyla, Pholidota); and Xenarthra. In most cases, there is robust support for relationships within and between these groups, which allows for only a few localized rearrangements. Of the four major groups, Xenarthra is supported by morphological synapomorphies whereas Afrotheria, Euarchontoglires, and Laurasiatheria are ostensibly without morphological support. Our results are consistent with the monophyly of all of the traditional placental orders except for Artiodactyla (paraphyletic) and Insectivora (diphyletic). Divergence times among placental mammals were estimated using linearized trees, quartet dating, and methods that allow rates of molecular evolution to vary on different branches of a phylogenetic tree. All methods support basal cladogenesis among placentals at approximately 10^5 million years. With a few caveats, molecular estimates of divergence times are consistent with the Long Fuse Model of placental diversification, which hypothesizes interordinal diversification in the Cretaceous followed by intraordinal diversification after the K/T boundary.

DIVERSE VERTEBRATE TRACK ASSEMBLAGES FROM THE EARLY CRETACEOUS OF MARYLAND: A NEW CHAPTER IN EAST COAST ICHNOLOGY.

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Hundreds of single-track specimens, individual trackway segments and multiple trackway specimens have been recovered as 'float' (resistant slabs dislodged from softer matrix by stream erosion) derived from the Patuxent Formation, (Potomac Group: Lower Cretaceous) of Maryland. Many of the discoveries represent first records for the Early Cretaceous of Maryland and, indeed, for the entire eastern U.S. Among these: sauropod manus and pes prints; diverse theropod tracks (wide size and shape range, including several of dromeosaurid affinity); isolated ornithopod (iguanadontid) manus and pes and small trackway segments; distinctive and diagnostic pes and manus-pes sets of hypsilophodontid origin; isolated ankylosaurian manus and pes prints; others of possible basal ceratopsid affinity; isolated manus and pes imprints of possible crocodilian affinity: manus-pes sets, isolated manus and pes imprints and natural casts of pterosaurian origin; avian footprints; and some footprints of possible mammalian origin.

This diverse ichnofauna demonstrates the potential of the Potomac group to shed new light on the dinosaur dominated vertebrate faunas of the Early Cretaceous of Maryland (and Eastern North America), by adding significantly to the faunal lists hitherto compiled on the basis of skeletal remains. The potential exists to use this ichnofauna (and skeletal remains) to compare general vertebrate faunal composition and diversity between eastern North America, the western USA (e.g., Cedar Mountain Formation), and Europe (e.g. Weald).

ECOLOGICAL DIFFERENCES BETWEEN TWO LATE HOLOCENE SITES FROM YELLOWSTONE NATIONAL PARK, WYOMING, USA

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Waterfall Locality is a late-Holocene paleontological site located at 6150 ft. elevation along Soda Butte Creek in northeastern Yellowstone National Park, Wyoming. The deposits derive from raptor pellets and carnivore scats collected by wood rats (*Neotoma cinerea*). The site contains 16 stratified layers alternating between organic and alluvial material. Twenty-two radiocarbon dates indicate that the deposits span the last 3,000 years. Over 20 mammalian species are represented by thousands of specimens. The fauna reflects the taxa of the local spruce and fir forest environment that currently surrounds the site. Waterfall Locality contains an abundance of long-tailed voles (*Microtus longicaudus*), red-backed voles (*Clethrionomys gapperi*), heather voles (*Phenacomys intermedius*), snowshoe hares (*Lepus cf. americanus*), pikas (*Ochotona princeps*), western jumping mice (*Zapus princeps*), red squirrels (*Tamiasciurus hudsonicus*) and northern flying squirrels (*Glaucomys sabrinus*).

Waterfall Locality provides an interesting contrast to Lamar Cave, another wood rat midden also spanning the last 3,000 years located 24 km southwest of Waterfall along the Lamar River. Lamar Cave is located in a sagebrush-grassland ecotone and is 1000 ft. lower in elevation. Despite the sites being located in close proximity, the two assemblages reflect their local habits: Waterfall Locality has an abundance of mesic, forest indicator taxa, which contrasts to the xeric, grassland species dominating the Lamar Cave fauna. Thus, these results indicate that these types of paleontological sites represent the local habitats from which they are derived and are not the result of long-distance transport.

REVISION OF *STENEOFIBER* (CASTORIDAE, MAMMALIA) AND EVOLUTION OF TERTIARY BEAVERS

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With the detailed description of a well preserved skull of *Steneofiber castorinus* (= *S. viciacensis*) the diagnosis of the early Miocene beaver genus *Steneofiber* has been revised. Detailed analysis of beavers from different localities led to a better overview of intraspecific variability and evolutionary trends within the beavers. New skull material of a small species of *Trogontherium* yields more information on the *Steneofiber-Trogontherium* lineage. The early Miocene *Steneofiber* will be described, the variability and evolutionary trends of Tertiary beavers will be discussed and so the picture of the evolution of beavers in the Tertirary become more clear.

MASS-BASED BIOMECHANICAL COMPUTATIONS ON SAUROPOD DINOSAURS

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Sauropod mass estimates are generally provided by measuring the volume of a model or by inference based on a two-dimensional life reconstruction. Such techniques do not lend themselves to systematic study in which alternative reconstructions vary ribcage volume, abdomen volume or the distribution of muscle mass along the axial and appendicular skeletons. It has therefore been difficult to substantiate or reject some proposals regarding the muscular abilities of sauropods, such as the popular suggestion that some sauropods were capable of elevating themselves into a bipedal or tripodal (hindlimbs plus tail) posture. The DinoMorph™ software provides a parametric framework with which to study the distribution of mass throughout a skeleton, and through the computational modeling of muscles, an ability to test the feasibility of proposals such as sauropod bipedalism. Dimensionally accurate three-dimensional digital reconstructions have been made of the axial skeleton, ribcage, and appendicular skeleton of *Camarasaurus* plus the two diplodocids *Apatosaurus* and *Diplodocus*. For a given reconstruction of the body plan, volumetric primitives are associated with individual bones, then parametrically adjusted to reflect a range of interpretations regarding the distribution of muscle mass and viscera. The center of mass is then computed for these sauropods and compared with estimates using other techniques. Major muscle groups are introduced as relevant to specific tasks, such as those that might elevate the sauropod by pivoting the axial skeleton about the acetabulum, with the presacral mass partly counterbalanced by that of the tail. The muscular tension to achieve and maintain the elevated posture can then be computed and compared for alternative taxa and for alternative estimates of their mass, assuming that dynamics does not play the dominant role in achieving the bipedal posture. Alternative models for the hindlimb posture and the contribution of postural adjustments along the axial skeleton and forelimbs are incorporated in this study.

THE FIRST PALEOMAGNETIC FRAMEWORK FOR THE *ISURUS HASTALIS–CARCHARODON* TRANSITION IN THE PACIFIC BASIN: THE PURISIMA FORMATION, CENTRAL CALIFORNIA

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Studies of formations spanning the Mio-Pliocene boundary in the Pacific Basin have shown a chrono-stratigraphic progression from the unserrated teeth of *Isurus hastalis* to serrated teeth usually assigned to *Carcharodon*. Such studies first concentrated on the Pisco Formation of Peru, and later on the Capistrano Formation of southern California. The present study focuses on a 250 m section of the Mio-Pliocene Purisima Formation of central California (Monterey Bay). The base of the formation has a K-Ar date of 6.9 ± 0.5 Ma. There are no *Carcharodon* teeth from the base, but teeth of the late form of *Isurus hastalis* (called *Isurus xiphodon* by some authors) occur there. The lowest known occurrence of *Carcharodon* teeth in this section is approximately 74 m above the base of the formation. At approximately 79 m above the base of the formation lies a horizon that corresponds to the beginning of the Gilbert Chron, dated at 5.89 Ma. *Carcharodon* teeth with feeble serrations are found there. There is a phosphatic hardground approximately 124 m above the base that represents a 1.3-million-year depositional hiatus between paleomagnetic boundaries dated at 4.98 Ma (top of Chron C3n.4n) and 3.57 Ma (base of Chron C2AN.3n). This horizon has produced a fairly large number of *Carcharodon* teeth. The sequence agrees with the record in Peru. There, onset of serrations occurs well after 8 Ma and is well established before 3.9 Ma.

We measured serrations and crown height only in teeth from the first position in the upper jaw. Taken as a single group, the Purisima *Carcharodon* teeth are generally similar to the sample form the Marblehead Bonebed (MBB) in the Capistrano Fm., with serrations first appearing in teeth over 11 mm crown height. Those 14–17 mm have feeble serrations. Large teeth from the phosphatic hardground show more advanced serration morphology than in the MBB, probably due to their younger geologic age. Graphic plots of the serration measurements vs. crown height for the Purisima sample show it to be similar to that of the MBB population, but somewhat intermediate between the MBB population and the modern population.

EVOLUTIONARY AND DEVELOPMENTAL ORIGIN OF THE EXTANT BIRD TARSOMETATARSUS FROM ITS THEROPOD DINOSAUR ANCESTRY

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As living bird tarsometatarsi develop, the metatarsals first fuse with each other distally; fusion then proceeds proximally toward the tarsal cap eventually forming a single bony unit of three metatarsals and distal tarsals. In the primitive state among dinosaurs, the metatarsals do not fuse with each other or to the distal tarsals. When present, pedal fusion in non-avian theropods proceeds in a manner not present in extant bird ontogeny: a distal tarsal is fused to a metatarsal prior to any intermetatarsal fusion. Although taxa such as *Avimimus*, *Elmisaurus*, and *Megapnosaurus* fused multiple metatarsals and distal tarsals, these tarsometatarsi did not form through the same ontogenetic sequence present in living birds. Juvenile avisaurid enantiornithine tarsometatarsal material demonstrates that early birds retained this primitive theropod ontogeny, though in a peramorphic condition with respect to the ancestral coelurosaurian state. Only along the stem leading to the ancestor of *Patagopteryx* and Neornithes did the ontogeny of the tarsometatarsus radically change to the condition retained by extant birds. Approximately contemporaneous with this change in the ontogeny of the pedal skeletal elements, the first webbed feet, lobed toes, and other modifications of the leg and foot appeared in theropod dinosaurs: these states were not present in more basal avian and theropod ontogeny, despite its long evolutionary history. This change in ontogeny was likely a key factor in the evolution of birds because it coincided with important ecological and locomotory diversification in theropods.

ORIGIN AND RELATIONSHIPS OF XENARTHRA AND PHOLIDOTA

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Xenarthra and Pholidota are often united with the extinct Palaeanodonta as Edentata, a primitive clade separate from all other placentals (Epitheria). Edentates are characterized primitively by fossorial skeletons and reduced dentitions often associated with myrmecophagy. Though said to share several synapomorphic features, close inspection suggests few if any of these characters are valid, hence evidence for Edentata is weak at best.

The oldest undoubted xenarthrans are late Paleocene dasypodids from Brazil. Definitive members of other xenarthran clades are unknown until much later (Oligo-Miocene), and anatomy of xenarthrans provides few clues to their phylogenetic source or relationships. Middle Eocene *Eomanis* from Messel, Germany, an edentulous form with scales, is the oldest known pholidotan. Palaeanodonts are known from early Paleocene-Eocene of North America, and also from Eurasia. The oldest members predate earliest records of both extant orders, and palaeanodonts show a mixture of pholidotan and xenarthran features, suggesting

they could be pertinent to the origin of one or both orders. Although some auditory features are shared with xenarthrans, palaeanodonts lack xenarthrous vertebrae (the diagnostic trait of Xenarthra), and other morphologic evidence favors closer relationship to Pholidota. Close correspondence between *Metacheiromys* and *Eomanis* suggests that Palaeanodonta is the sister taxon or ancestor of Pholidota. Palaeanodonts may share a Late Cretaceous (?) common ancestry with pantolestids, and may be distantly related to Leptictidae. The closest relative of Pholidota among extant placentals is uncertain; some anatomical and molecular data point to relationship with Carnivora, but the case is weak.

Eurotamandua is a problematic taxon from Messel. Described as the oldest and only non-Neotropical anteater, it lacks xenarthrous vertebrae. The significance of its anatomical resemblances to pilosans and palaeanodonts remains controversial. It is variously considered a xenarthran, close relative of palaeanodonts and *Eomanis*, or member of a clade Afredentata.

FUNCTIONAL SIGNIFICANCE OF PIGMENTATION IN MAMMALIAN TEETH: A CASE STUDY OF *BLARINA BREVICAUDA*

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Soricines are distinguished by the remarkable reddish pigmentation of their teeth. This coloration is caused by iron and has been noted in shrews as early as the Oligocene. Unlike other mammals with pigmented teeth, this pigmentation is distributed throughout the dentition. The hypothesis that iron pigmentation increases the resistance of teeth to abrasive wear (by contact with either food or exogenous grit) is explored by examining two predictions formulated on the basis of biomechanics of chewing and tooth wear. Firstly, that iron density will differ on different parts of individual molars, with cusps that are subject to more abrasion having a greater concentration of iron. Microwear studies have shown that crushing/grinding facets experience more abrasive wear (higher feature density and more pitting) than shearing facets. Secondly, that m1 iron density will be greater than on m2 and m3. Because of the enlargement of m1 in shrews, it is the first masticatory tooth to contact foods and thus these teeth might be subject to greater stresses and more prone to fracture and excessive wear.

Ten specimens of *Blarina brevicauda* were examined for percentage iron concentration with a SEM in conjunction with an energy dispersive spectrometer (EDS). The relative amount of iron present was recorded on each molar cusp (protoconid, metaconid, paraconid, hypoconid, and entoconid) for m1-3.

This study demonstrated that substantial iron variation exists between individual molar cusps and between different tooth positions. Specifically, the cusps associated with crushing and grinding, as opposed to shearing, had more iron incorporated into their enamel. Additionally, the enlarged first molar was shown to have a greater iron density than the more posterior teeth. Therefore, this study suggests that increased iron density is an adaptation to the teeth, and parts of teeth, which are subject to greater stresses and more prone to fracture and excessive wear.

EARLIEST OCCURRENCE OF OTOLITH-BASED GOBIIDS FROM NORTH AMERICA (BARTONIAN OF LOUISIANA AND MISSISSIPPI)

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The Family Gobiidae represents the most diversified group of Recent marine fishes with approximately 1,875 species. Although living species of gobies are quite abundant and Neogene gobiids are also common, the Paleogene fossil record is poorly represented with limited reports of occurrence. The evidence of Paleogene gobiids is notably sparse in North America, especially in the. The otolith-based fossil record of the Gobiidae was recently extended into the Priabonian (late Eocene) with the discoveries of abundant gobiid otoliths (57 specimens) from the Yazoo Clay (the Copenhagen Locality) in Louisiana. Radiometric dating places the age of the Yazoo Clay at approximately 34 Ma. Further investigations of the underlying Moodys Branch Formation (Bartonian) in Louisiana and Mississippi have also revealed gobiid otoliths. Gobiid specimens have been recovered from the Moodys Branch Formation at the Montgomery Landing Locality in Louisiana (11 specimens) and at the Fossil Gulch Locality in Mississippi (one specimen). The age of the Moodys Branch Formation at the Fossil Gulch Locality has been determined to be approximately 39 Ma based on Rb-Sr dating. The specimens from the Moodys Branch Formation in Louisiana and Mississippi represent the oldest fossil record of gobiid otoliths in North America and one of the oldest in the world. The oldest otolith-based European gobiid record is from the early Oligocene in southwest France. The oldest fossil record of gobiid otoliths is from the Harudi Formation (Lutetian) in western India based on a single specimen.

CRANIAL STRUCTURE AND PHYLOGENETIC RELATIONSHIPS OF THE ENIGMATIC CROCODYLIFORM *HAMADASUCHUS REBOULI* FROM THE CRETACEOUS OF MOROCCO

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Long poorly documented, crocodyliform assemblages from the Cretaceous of Africa have recently become much better known through a series of remarkable new discoveries. Here we present a detailed account of the cranial structure in *Hamadasuchus rebouli* from the Albian to Cenomanian-age Kem Kem beds of southeastern Morocco, based on three partial subadult skulls (one with an associated dentary) and one complete adult skull. Previously, only a partial dentary and isolated teeth referable to this enigmatic taxon had been reported. Distinctive features of *Hamadasuchus* include a premaxillary labial process, a distinct fossa surrounding the external nares, nearly vertical maxillae with finely serrated teeth, and hypertrophied exoccipital extensions adjacent to the basioccipital tubera. Phylogenetic analysis of a broad sampling of Crocodyliformes supports placement of *Hamadasuchus* in the Peirosauridae, in a position basal to other known members of that group. Surprisingly, *Sebecus* emerges as the sister-taxon to this clade, and *Baurusuchus* (which has traditionally been considered closely related to *Sebecus*) is placed as the sister-taxon to *Notosuchus* and *Malawisuchus*.

LOWER PERMIAN FISSURE DEPOSITS IN THE SLICK HILLS, OKLAHOMA, THE OLDEST KNOWN FOSSILIFEROUS PALEOKARST

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Caves and fissures that formed in the geological past, and were preserved through burial, are referred to as paleokarst or fossil karst. Sediments filling such structures often contain large concentrations of vertebrate bone; particularly well-studied examples include the australopithecine-bearing caves of southern Africa and the Triassic and Jurassic sites of southwest Britain, but paleokarst sites of Mesozoic and especially Cenozoic age are widely distributed. Known Paleozoic occurrences, by contrast, are presently limited to an Upper Permian site near Korbach, Germany, and at least two Lower Permian fissure systems in the Slick Hills of Oklahoma. The latter preserve an anomalous fauna of highly terrestrial Early Permian tetrapods, and also represent the oldest example of fossiliferous paleokarst in the terrestrial geological record.

Although the Bally Mountain site is the better studied of the two Slick Hills localities geologically, the still active Dolese Brothers limestone quarry near Richards Spur has yielded a much richer faunal assemblage. It is dominated in numerical terms by a single species, the early reptile *Captorhinus aguti*, but nearly 30 other terrestrial and relatively small (up to about a meter in length) amniotes and anamniotes occur in much lesser numbers.

We contend that the Richards Spur locality can be identified as a definite example of paleokarst and a probable subterranean cave system, and that comparison to Mesozoic and Cenozoic equivalents is likely to yield significant taphonomic insights. Recent work on blocks of fossiliferous clay from the site (as opposed to sieved samples) has shown that individuals of *C. aguti* are not only numerous but also extremely well preserved, often in nearly full articulation, without signs of either weathering or predator activity. These taphonomic characteristics suggest that this species was actually resident within the caves, either permanently or seasonally. Most other species, however, are represented by much less abundant material of widely varying completeness and preservational quality, indicating that they were probably transported in from outside.

PALEOCENE DINOSAURS? A CRITIQUE OF THE AGES ASSIGNED TO THE UPPER KIRTLAND FORMATION, SAN JUAN BASIN, NEW MEXICO

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Until recently, the age of the upper part of the Kirtland Formation (De-na-zin and Naashiobito members) has been somewhat problematic. Although Ar/Ar dating has firmly established the age of the De-na-zin Member at 73.37-73.04 Ma as late Campanian, the age of the overlying Naashoibito Member remains contentious. Many dinosaur taxa formerly cited as from the Naashoibito Member are actually from the underlying De-na-zin Member. Few diagnostic dinosaur genera are known from the Naashoibito Member, and some rest on problematic identifications. No radioisotopic dates are available and only three mammal species have been identified from this unit. Possibilities range from late Campanian to late Maastrichtian.

Recent sampling of a lignite at the top of the De-na zin Member yielded conflicting palynomorph data. Fassett maintains that the palynomorphs *Momipites tenuipolis* and *Brevicolporites colpella* indicate a Paleocene age for this lignite and the overlying Naashoibito Member, which locally contains numerous (non-reworked) dinosaur fossils. We sampled this same lignite and did not recover any Paleocene palynomorphs, but instead found *Proteacidites retusus* and *P. thalmanni* and *Tricolpites microreticulatus*, taxa that to date are only known from the Campanian and Maaastrichtian. The presence of *Pandaniidites typicus* and *Umoideipites krempi* further restrict the age of the sample to Maastrichtian. No taxa restricted to the Paleocene were recovered although several species that span the boundary were also present. We conclude that Fassett's sample was contaminated with Paleocene palynomorphs. The suggestion of a Paleocene age is also inconsistent with the presence of numerous non-reworked dinosaur remains in overlying strata.

ORIGIN OF THE MODERN TERRESTRIAL VERTEBRATE ECOSYSTEM DOCUMENTED BY AN EARLY PERMIAN ASSEMBLAGE FROM GERMANY

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Sedimentological analysis of the Bromacker locality in the Lower Permian Tambach Formation of central Germany indicates that it: (1) was near the center of a small, internally drained paleograben that lacked permanent bodies of water; and (2) preserves a truly terrestrial upland setting. A minimum numbers analysis demonstrates that the most common single component of the Bromacker assemblage is the small protorothyridid reptile *Thuringothyris*. However, the high-fiber herbivores *Diadectes absitus*, a new diadectid, *Eudibamus cursoris*, and a caseid synapsid dominate the assemblage, producing a much higher proportion of herbivores than at any other Lower Permian site worldwide. The terrestrial amphibian *Seymouria sanjuanensis* is also common, but top predators, represented by *Dimetrodon* and a possible varanopseid, are rare. No aquatic or semiaquatic taxa have been recovered.

The Bromacker assemblage records the initial stage in the evolution of the modern terrestrial vertebrate ecosystem, where a vast standing crop of herbivores supports a smaller

number of top carnivores. This interpretation confirms Olson's concept of an upland, terrestrial vertebrate chronofauna, which he called the "Caseid Chronofauna," existing at the same time as the well-known, water-based "Permo-Carboniferous" Chronofauna. The Bromacker assemblage, however, indicates that the upland chronofauna was initiated soon after the first herbivores appeared in the Late Pennsylvanian and was well established by Wolfcampian time, rather than in the Leonardian as initially thought.

TETRAPOD FOOTPRINTS FROM THE LOWER PERMIAN HENNESSEY FORMATION, OKLAHOMA CITY, OKLAHOMA

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During construction of the Kilpatrick Turnpike in Oklahoma City, a large block of the lower part (about 55 m above the base) of the Lower Permian Hennessey Formation was uncovered that contained tetrapod tracks. The dominantly fine-grained character of the Hennessey sediments, rarity of channels, and the presence of paleosol horizons and thin gypsum beds are evidence that in the Oklahoma City area much of it was deposited in a supratidal, possibly sabhka-like environment. Correlation of the Hennessey Formation to much of the Texas Clear Fork Group indicates a Leonardian age, and the tracksite in the lower Hennessey thus is of early Leonardian age

The best preserved footprints are two, nearly complete concave impressions that can be assigned to *Amphisauropus latus* Haubold, 1970, the presumed track of a seymouriamorph. These prints are noticeably wider than long: width is ~70 mm, length is ~55 mm, and the estimated divarication between digits I and V is ~130^{o} Digit IV is longest, and these plantigrade tracks superficially appear to be tetradactyl, but close examination indicates a faint impression of a small digit V on one, and the digit V of the other is broken off at the slab edge. Usually, digit tips of *Amphisauropus* are rounded, but many extramorphological variants show the pointed digits seen in these two prints.

A second, much smaller ichnotaxon is poorly represented. The best preserved track, also a concave impression, has three, relatively long, thin, pointed, slightly curved digits that increase dramatically in length from digit to digit. This track is longer than wide (width is <25 mm, length is <30 mm). All characters suggest assignment to *Dromopus*, the presumed track of an araeoscelid reptile, and we refer this track to aff. *Dromopus* sp. because it is not completely or well enough preserved for certain identification. These tracks are the youngest Permian vertebrate footprints in Oklahoma. This is the youngest report of *Amphisauropus* in North America, and its identification increases the similarity of European and North American Early Permian tetrapod ichnofaunas.

RECENT CROCODILIAN BONE-TENDON INTERFACE: APPLICABILITY TO FOSSIL BONES

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Among vertebrate fossils preservation of fine internal bone structure is common. That of muscles and tendons is, however, extremely rare. We are investigating bone-tendon interfaces of recent crocodiles using polished thin sections and decalcified histological thin sections whether the biological characters of tendon are traceable in the bone structure. Histological investigations on 20 bone-tendon interfaces of pectoral girdles and humeri of crocodile specimens (two *Crocodylus niloticus*, one *C. siamensis*, and one *Caiman latirostris*) were performed.

Histologically, three types of bone-tendon interface were clearly discriminated on insertion of tendon fibers: (1) into the bone, (2) into hyaline cartilage, and (3) into calcified fibrocartilage. All the interfaces were intercalated periosteum, or the layer of the osteoprogenitor cells, which present in internal layer of the former. Different from such direct insertion, common in mammals and lizards, as seen in epiphyses and no intercalation of periosteum. Morphological appearance of bones in both polished sections, and histological thin sections is nearly the same in each type.

In polished sections, however, differences of crystal arrangement of bones were revealed between tendon-inserted parts and elsewhere under a polarizing microscope. In particular, bone-inserted and fibrocartilage-inserted type, the crystal arrangement of tendon-inserted part is almost parallel to the direction of tendon fibers and showed undulatory extinction. In contrast, that of the non-inserted part is perpendicular to axial growth direction and showed constant extinction.

Consequently, tendon insertion type and direction of tendon (and probably its tension) are easily discriminable under a polarizing microscope. This result could be applicable to fossil crocodilian and extinct related taxa if the preservation of bones permits detailed observations.

A NEW PLATYNOTAN LIZARD FROM THE CAMPANIAN OF GOBI DESERT, MONGOLIA

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Upper Cretaceous deposits of the Mongolian Gobi Desert yield specimens of nine taxa of platynotan lizards. This is a preliminary report on a new platynotan lizard found by Hayashibara Museum of Natural Sciences-Mongolian Paleontological Center Joint Expedition Team from the red bed of the Djadokhta Formation at the Udan Sayr locality (central Gobi, Mongolia) in 2000. The new materials, consisting of a disarticulated skull (maxilla, premaxilla, vomer, pterygoid, palatine, ectopterygoid, and jugal), lower jaws and post-cranial elements are attributed to a single individual. They bear many synapomorphies for the platynotan clade such as: presence of plicidentine infolding at marginal tooth bases; marginal teeth widely spaced with expanded tooth based; replacement teeth developed posteriory without presence of resorption pits; maxillary teeth number 10-13; vomer strongly elongated approaching level of posterior end of tooth row; palatal shelf of vomer narrow; palatine equally wide as long; surangular blunt anteriorly in lateral view; anterior extension of spleninal retracted to or posterior to midpoint of tooth row; posterior extension of splenial terminates anterior to or below coronoid eminence; splenial-dentary suture loose, with much connective tissue between the two bones; anterior process of coronoid elongated and extensively exposed dorsally. In addition, this specimen shows plesiomorphies such as: neural spines low and broad; anterolateral process of pterygoid short and fits into a notch of ectopterygoid; pterygoid teeth present; jugal well developed and angulated. This specimen has no synapomorphy with Monstersauria or Varanoidea.

A MID-HOLOCENE FAUNA FROM A RINGTAIL CARNIVORE DEN, WESTERN GRAND CANYON

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Most fossil and subfossil Quaternary localities in the Grand Canyon of northwestern Arizona are records from dry cave and packrat midden deposits. Recovered taxa represent members typical of arid and rocky-landscape communities. To date there has been a biases in the recovered fossils, lacking representation of the riparian and alluvial plain communities adjacent to the Colorado River. The Weeping Cliffs exposure is in the Muav Limestone containing small caves, shelters, and crevices situated immediately above the narrow alluvial plain of the Colorado River, which is now submerged below Lake Mead. The ringtail (Procyonidae, *Bassariscus astutus*) is a small, nocturnal carnivore common to the Southwest and is a known predator of the crepuscular and nocturnal micro-vertebrate community. Weeping Cliffs # 2 and 3 represent accumulations of scats from a ringtail den and have been dated to the mid-Holocene (6,900 14C yr B.P.)—a period of time basically unknown in the Grand Canyon region. The deposits were wet screened through 500µm mesh and picked under 10x power. Skeletal remains include, anuran: *Scaphiopus*; lizards: *Coleonyx*, *Sceloporus*, *Uta/Callisaurus*, *Dipsosaurus*, *Cnemidophorus*; snakes: *Leptotyphlops*, other colubrids; birds; and mammals: *Neotoma*, *Peromyscus*, *Perognathus*, bats. This record of *Scaphiopus* represents the first record of fossil or subfossil amphibians from the Grand Canyon. *Dipsosaurus* is not living in the Grand Canyon today and fossil representatives have not been found on the Colorado Plateau or elsewhere in Arizona. *Leptotyphlops* is extralocal to the region today.

BONE RESORPTION, BONE LESIONS, AND EXTRA FENESTRAE IN CERATOPSID DINOSAURS

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While a typical ceratopsid dinosaur skull possesses two parietal fenestrae, some specimens exhibit "extra" fenestrae within the squamosal bone. Previous authors have interpreted these squamosal fenestrae as either trauma-related pathology or a non-traumatic, random character. A survey of chasmosaurine ceratopsid skulls shows that squamosal fenestrae in this subfamily are regular in their shape, relative size, and placement across several genera, indicating that they are probably non-traumatic in origin. For the first time, squamosal fenestrae are reported in centrosaurine ceratopsids. Squamosal fenestrae in these taxa tend to be more irregular in their placement. Two different mechanisms are proposed for the formation of squamosal fenestrae: non-pathological bone resorption, and pathological bone resorption as the result of unknown bone disease(s). Squamosal fenestrae in many chasmosaurine ceratopsids center on the thinnest portion of the squamosal, suggesting that the fenestrae simply removed structurally unnecessary bone from the frill. Specimens of *Centrosaurus* from Dinosaur Provincial Park (Alberta, Canada) suggest that squamosal fenestrae in centrosaurines originated as a small, circular lesion. With growth, this lesion may have punched through the squamosal, creating a fenestra. Similar lesions have been observed throughout the skull in the ceratopsid genera *Triceratops*, *Torosaurus*, *Centrosaurus*, cf. *Pachyrhinosaurus*, and *Styracosaurus*. Their etiology is unknown, although similar pitting affects the tips of postorbital horncores in mature specimens of several centrosaurine taxa, suggesting bone loss or resorption related to advanced age or other factors.

ORIGIN AND RELATIONSHIPS OF ARTIODACTYLA

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Artiodactyla are even-toed ungulates, characterized by cursorially-adapted skeletons with paraxonic feet and a double-trochleated astragalus. Recent discoveries of double-trochleated astragali in fossil whales show this diagnostic criterion of Artiodactyla is shared by early cetaceans. Molecular data have called into question the monophyly of Artiodactyla unless Cetacea is included. In spite of these new finds, morphological data still support the monophyly of the traditional Artiodactyla. The new fossils suggest two solutions: either including Cetacea within Artiodactyla, retaining a character-based definition of the order; or redefining Artiodactyla as a node-based definition, using the double-trochleated astragalus as a synapomorphy for the clade including Cetacea and the traditional Artiodactyla.

The question of artiodactyl origins remains as complex as it was a decade ago. The oldest known fossil artiodactyls, referred to the paraphyletic genus *Diacodexis*, appear suddenly in the earliest Eocene, roughly contemporaneously in North America (Wa_0), Pakistan (Bumbanian) and Europe (Sparnacian). The traditional view has been that Artiodactyla evolved from the "Condylarthra" during the Paleocene, probably from an arctocyonid such as *Chriacus*, or a similar form, or from Hyopsodontidae (sensu lato). However, the most recent morphological cladistic analyses place whales either as the sister taxon to Artiodactyla, with

mesonychids as a paraphyletic stem assemblage, or place whales + mesonychids as the sister taxon to Artiodactyla. The two most recent analyses differ in their placement of arctocyonids and hyopsodontids, but both fall outside the clade of artiodactyls, whales and mesonychids in these analyses.

The fact that artiodactyls appear almost simultaneously on 3 continents also complicates our understanding of their biogeography. It has been postulated that they arose in India, Asia, or North America, but at present there is little evidence favoring any of these over the others. However, clearly more work remains to be done in the earliest Eocene and late Paleocene to better understand the origin of the order.

FEEDING BEHAVIOR AND PARALLEL EVOLUTION OF SABERTOOTHED CARNIVOROUS MAMMALS

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A biomechanical approach is used to study feeding behavior in sabertoothed carnivorous mammals (machaeroidines, nimravines, barbourofelines, machairodonts, and thylacosmilines). 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 any given point along the mandible should be proportional to external measurements at an analogous location (interdental gaps) on the mandible. Thus, patterns of variation in these dimensions reflect the adaptation of the jaw to specific loads, related to the method of killing a prey. Extant carnivorans (felids, canids, and hyenids), known to have diagnostic mandibular strength profiles reflecting their respective feeding behavior, were used to interpret the profiles observed in sabertooths.

Variations in profiles of dorsoventral and labiolingual mandibular bending strength (Sx and Sy respectively) and relative strength distribution (Sx/Sy) reveal differences between each radiation, suggesting a high diversity of feeding behaviors in sabertooths. In addition, the distinct mandibular strength profiles of the scimitar-toothed and dirk-toothed ecomorphs imply different killing strategies.

All sabertooths had a powerful bite, as strong or stronger than felids of similar mandibular length. Loads exerted at the lower canine were better constrained in the sagittal plane (Sx/Sy greater than 1.7 in machairodonts or 2.3 in nimravids and thylacosmilines) than in extant conical-toothed carnivorans (Sx/Sy lesser than or equal to 1, except for *Acinonyx jubatus* and *Neofelis nebulosa*), indicating that labiolingual loads related to a struggling prey were relatively smaller during the canine bite. This observation supports both the canine shear-bite model proposed for sabertooths and the idea that the prey may have been nearly immobilized when the saber bite was delivered, thus protecting the sabers from dangerous, randomly oriented loads. Machaeroidines and *Nimravus brachyops* are exceptional in having intermediate Sx/Sy values (Sx/Sy ~ 1.5-1.73) reminiscent of *N. nebulosa*.

IT'S NOT ALL THERMOPHYSIOLOGY: MICROSCALE $\delta^{18}O$ AND $\delta^{13}C$ ANALYSIS OF *EDMONTOSAURUS* TEETH REVEALS ENVIRONMENTAL INFLUENCE ON ENAMEL MINERALIZATION

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Stable isotope analysis of vertebrate biominerals has been used to address questions regarding paleodiet, paleoclimate, trophic level, migration, foraging zone, and thermophysiology with varying degrees of success. Isotopes are applied less frequently to study growth rates and ontogenetic variability in vertebrates because non-remodeled mineralized tissues are required to provide a long-term growth history. Tooth enamel is preferred as it does not remodel after mineralization; however sampling may be difficult in dinosaurs due to thin enamel (~120 microns). We utilize a new microsampling technique in this study to address the following questions: Do microscale variations in tooth enamel from the hadrosaur *Edmontosaurus* provide evidence of ontogenetic variation in tooth mineralization rates and/or growth? Do $\delta^{18}O$ values reflect a physiological signal (e.g. due to thermoregulation), or are they more influenced by environmental variability?

$\delta^{18}O$ and $\delta^{13}C$ values from enamel carbonate were obtained by microsampling multiple teeth in a growth row from the dental batteries of a juvenile, subadult, and adult Edmontosaurus. Consecutive teeth in a growth row from *Alligator mississippiensis* were isotopically microsampled and compared to those of *Edmontosaurus* to establish isotope variability in an extant archosaur. To test for diagenesis, bulk samples from the phosphate component ($\delta^{18}O_p$ of modern and fossil tooth enamel, bone, and dentine from *Edmontosaurus*, *A. mississippiensis*, and extant ratites were analyzed and compared. Bonebed sediments and carbonate cements from the fossils were analyzed isotopically and compared to those of the biominerals to look for patterns of variation indicative of diagenesis.

Results support that: 1) enamel was mineralized in <1 year; 2) microscale $\delta^{18}O$ variation is due primarily to environmental variability (e.g. migration or changes in ingested water or food sources), not thermophysiology; 3) diagenesis may alter the absolute values of isotopes, but the relative pattern of variation is retained; and 4) microsampling provides a new perspective on interpreting oxygen isotopes that is not possible through bulk sampling alone.

CAMEL TRACKS AND TRACKWAYS FROM LATE PLIOCENE DEPOSITS, GRAHAM COUNTY, ARIZONA

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Numerous tracksites exist in the Bear Springs Badlands (middle Blancan) of Graham County, Arizona. The ichnofauna is dominated by abundant horse tracks, mastodon tracks, and camel tracks and trackways associated with fluvial and lacustrine mudstones. The tracksites may have been along the shoreline of an ancient "watering hole".

The camel tracks are well preserved with clear digital cushions (pads) and interphalangeal troughs. Tracks can be grouped into three categories: small (length 6–7 cm, width 4–6 cm), medium (length 8–9 cm, width 10–12 cm), and large (length 14–15 cm, 10–12 cm width). Two trackways have been discovered in the area. One trackway of a large camelid (length 15 cm, 10 cm width) reveals a stride of 2.7 m and a straddle of 2 m. The long stride and narrow straddle are indicative of a pacing gait.

BRIDGING THE ATLANTIC: NEW CORRELATIONS OF EARLY CRETACEOUS TITANOSAURIFORMES (SAUROPODA) FROM ENGLAND AND NORTH AMERICA

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In recent years, numerous discoveries of titanosauriformes in North America and England have fueled a significant expansion in Early Cretaceous sauropod research. Coupled with previously described taxa, the new specimens provide detailed correlations with sauropods from England that show strikingly similar morphologies, and also provide valuable time constraints for the North American titanosauriform radiation. New titanosauriformes include several specimens from the Cedar Mountain Formation (CMF) of Eastern Utah: the brachiosaurid *Cedarosaurus* from the Yellow Cat Member, the titanosauriform *Venenosaurus* from the Poison Strip Member, and a titanosaurid characterized by extremely short vertebral neural spines, also from the Yellow Cat Member.

The English brachiosaur "*Pelorosaurus*" from Valanginian sediments of West Sussex, shares with *Cedarosaurus* a slender, elongate humerus and anterior caudal vertebrae with a distinctive plani/concave morphology. "*Eucamerotus*" from Barremian sediments of the Wessex Fm. on the Isle of Wight, is represented by two dorsal vertebrae with elongate centra, deep pleurocoels, and high neural arches. Similar features are found on *Cedarosaurus*. A nearly complete specimen from Late Barremian beds in the Vectis Fm, Isle of Wight, shares with *Venenosaurus* an ulna with a well developed olecranon, and a complete set of slender, elongate metacarpals whose distal ends are flat and rugose. A probable titanosaurid forelimb, originally described as "*Pelorosaurus*" from the Wealden beds of Sussex, includes a short, broad humerus, and an ulna with a high olecranon. This specimen closely resembles the forelimb of a basal titanosaurid from the Cloverly Fm. of Wyoming. Titanosaurs, characterized by strongly procoelous caudal vertebrae, are found as fragmentary specimens in Barremian and Albian Age beds in England, and in the Yellow Cat Member of the CMF. These correlations between the sauropod taxa of Utah and England support ages of Lower Barremian for the Yellow Cat and Upper Barremian for the Poison Strip Members of the Cedar Mountain Formation.

FIRST TEMPORALLY CONSTRAINED ASIAN PALEOCENE/EOCENE BOUNDARY RECORD

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The late Paleocene through early Eocene was a very important period in the evolutionary history of mammals. In the Holarctic continents, the modern mammalian orders, Perissodactyla, Artiodactyla, and Primates *sensu stricto*, made their first appearances in the fossil record during the Paleocene/Eocene transition. Asia has increasingly been considered as a center of origination of some mammalian orders because of a series of important discoveries of Paleocene and early Eocene mammalian fossils there. To test this hypothesis and to provide the better evidence for intercontinental correlation, we conducted a biostratigraphic, chemostratigraphic, and magnetostratigraphic study across the Paleocene/Eocene boundary in the Hengyang Basin, Hunan, China. The Hengyang Basin, one of only two currently known Asian sites with continuous Paleocene/Eocene sedimentary rocks, is located in the south-central part of Hunan Province. The Lingcha Formation, exposed in a basin-forming syncline, is distributed in the northeastern part of the basin and mainly composed of red mudstone intercalated with sandstone. It contains two fossil layers: the upper (Bumbanian Asian Land Mammal Age) yielding about 12 mammalian species, including *Orientolophus hengdongensis*, *Propachynolophus hengyangensis*, *Cocomys lingchaensis*, *Hapalodectes hetangensis*, *Hsiangolestes youngi*, *Hunanictis inexpectatus*, and *Matutinia nitidulus*, and the lower (Gashatan ALMA) yielding one crocodilian species and one mammalian species, *Archaeolambda* sp. Our carbon isotope and paleomagnetic results from the Lingcha Formation indicate that the carbon isotope excursion that marks the Paleocene/Eocene boundary is at the bottom of the upper Lingcha fauna, which allows us to correlate the upper Lingcha fauna to Wasatchian 0 faunal zone in North America. The new species, *Prolimnocyon chowi* found in the Gashatan Bayan Ulan fauna, Inner Mongolia, indicates that Hyaenodontidae appeared first in Asia, and then spread to North America during the Paleocene/Eocene transition.

TAXONOMIC REVISION OF AFRICAN *ELEPHAS RECKI*

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The African *Elephas* lineage (*Elephas ekorensis*, *Elephas recki* and *Elephas iolensis*) has been crucial in interpretation of biostratigraphic and chronological data on hominid and other localities. The division of *Elephas recki* into five time-successive subspecies (*Elephas recki brumpti*, *E.r. shungurensis*, *E.r. atavus*, *E.r. ileretensis* and *E.r. recki*) has been especially important in this endeavor, although the arrangement and identification of these taxa have been debated in recent years. Recent analyses by the author of *E. recki* chronology and morphological variation do not support its definition as a single species. Examination of published records of *Elephas recki* specimens and localities show that the five subspecies are not sufficiently distinct in time intervals, but instead show significant overlap, with some localities having mul-

tiple subspecies represented in their samples. Metric analysis of fossil and modern elephant molars further shows that dental variation in specimens currently attributed to *Elephas recki* exceeds that of many other elephantid species, with some subspecies variation exceeding species-level variation in other taxa. Furthermore, cladistic analysis using non-metric characters indicate that the currently defined *Elephas recki* group is in fact polyphyletic. These three lines of evidence suggest that a revision of the taxon is overdue. By combining the metric analysis with non-metric characters in a way that excludes chronological or taxonomic identifications, it is possible to distinguish several groups within the current sample of *Elephas recki*. One of these groups most likely represents *Elephas recki sensu stricto*, with additional groups representing other taxa or possibly new taxa within the *Elephas* lineage. These data have important implications for the diagnosis and interpretation of elephantid diversity and evolutionary pattern and process in the African Plio-Pleistocene.

EVOLUTION OF *PLIOPENTALAGUS* DENTITION BASED ON THE NEW MATERIAL FROM CHINA AND THE RELATIONSHIPS WITH *AZTLANOLAGUS* (LAGOMORPHA)

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Abundant fossil remains of *Pliopentalagus*, ancestral genus of Amami rabbit (*Pentalagus furnessi*), were recently found from three localities of different geologic age (Late Miocene, Early Pliocene, and Late Pliocene, respectively) in Anhui Province, China. Fossil material of *Pliopentalagus* consists of many skulls, jaws, and post-cranial elements. Among the number of studies possible from these *Pliopentalagus* material and extant *Pentalagus*, those on the lower dention have been done. The morphological changes of lower dentition, in general, of the *Pliopentalagus–Pentalagus* lineage through time include the enlargement of the size and further complication of the enamel crenulation. Those of p3 include: 1) ratio of posterointernal reentrant angle becomes larger, while ratio of enamel lakes becomes smaller, and 2) depth of anterior reentrant angle becomes deeper. There is a small anteroexternal fold on the trigonid of p4-m2 in majority of older forms, while it disappears in younger forms. This small fold of the trigonid is present on p4-m2 of some specimens of *Aztlanolagus*. The small fold on the trigonid of p4-m2 is known only on *Aztlanolagus* and older forms of *Pliopentalagus*. Thus, although it was previously thought that *Aztlanolagus* may have evolved from *Nekrolagus* in North Ameriaca, the new *Pliopentalagus* fossils from China suggest the idea that the ancestrer of *Aztlanolagus* originated in Asia rather than in North America.

TOOTH REPLACEMENT AND TOOTH-RELATED INNERVATION IN TELEOST FISH

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Most teleost fish undergo numerous tooth replacement cycles throughout their lifetimes. Replacement teeth in teleosts may develop either outside ("extraosseous") or inside ("intraosseous") the bone to which they will attach in the process of becoming functional. Extraosseous development of replacement teeth is primitive in teleosts; intraosseous development of replacement teeth, the derived state, has evolved independently in at least three lineages. Morphological changes associated with the evolution of intraosseous development of replacement teeth involve both location of replacement teeth (relative to functional teeth) and encasement of replacement teeth in bone. Denervation experiments in a living fish have demonstrated that presence of tooth-related nerves may be essential for odontogenesis of replacement teeth. Therefore, dental innervation patterns must have altered during the evolution of intraosseously-developing replacement teeth. I use a comparative approach to investigate these changes, examining tooth-related innervation of fifth ceratobranchials in two extant exemplar taxa: the cyprinid *Danio rerio* (extraosseous) and the cichlid *Cichlasoma cyanoguttatum* (intraosseous). Specimens were demineralized, embedded, and sectioned in a microtome, then stained with hematoxylin and eosin to aid histological observations. Immunohistochemical fluorescence techniques were employed to stain tooth-related nerves in order to visualize nerve cells expressing various neuropeptides. Differences in anatomy and neuropeptide expression are summarized and related to the tooth replacement cycle. Results may bear on our understanding of the role of nerves in mammalian odontogenesis and tooth eruption and replacement, which are difficult to study directly as the result of diphyodonty. Further research in this area may involve documenting variability in tooth-related innervation in more detail in piranhas and their relatives (characiforms), where taxa show extraosseous, intraosseous, or intermediate (e.g., both, or replacement teeth partially encased in bone) development of replacement teeth.

MISUSE OF CLAY MINERALOGY AS A CORRELATION TOOL IN THE MORRISON FORMATION (UPPER JURASSIC) OF THE WESTERN INTERIOR, U.S.A.

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A discrete change in dominant clay minerals within the upper Morrison Formation is purported to exist across much of its depositional area. This change, from predominantly illitic clay below to predominantly smectitic clay above, is assumed to be the result of an increase in the input of volcanic ash over the Rocky Mountain region, and might therefore be used as a time-correlative marker horizon. If true, this clay-change horizon would provide valuable control in exposures devoid of other long-distance correlative features. Several biostratigraphic studies have been published that utilize this "clay change" as a main datum for correlation. Unfortunately, these workers placed this putative change only visually, not by the use of X-ray diffraction (XRD) or other quantitative, less subjective techniques.

In southeastern and central Wyoming, it is difficult to visually locate a discrete horizon of clay change in the field. In Montana and South Dakota, several studies utilizing XRD have shown that no consistent clay change exists, making it unusable as a correlation tool in these areas.

In attempting to further test the utility of this clay change in correlation, I collected samples from the Morrison Fm. at several localities in southeastern Wyoming and analyzed them using XRD. This study has shown that although there is a change in clay mineralogy within the Morrison Fm. of southeastern Wyoming, it occurs at a much higher stratigraphic level than placed in earlier studies.

In addition, I compiled data from previously published studies that used XRD on clay-rich rocks of the Morrison Fm. throughout the Colorado Plateau. Of the 41 localities sampled, only 3 showed a discrete change from non-swelling to swelling clays.

It is most likely that any clay changes seen in the Morrison Formation reflect changes in depositional environment and/or diagenesis and should not be used as time markers. If true, then correlations and biostratigraphies that use this horizon as a temporal datum need to be reexamined.

A METHOD TO ESTABLISH THE PROVENANCE OF BONES AFTER COLLECTION: IMPLICATIONS FOR TAPHONOMY, BIOSTRATIGRAPHY, AND PALEONTOLOGICAL RESOURCE MANAGEMENT.

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The temporal and spatial context of a fossil bone (its provenance) can be obscured by many processes, both natural and human. Bones may be reworked from one horizon to another or recovered from geologically complex or mixed sediments. In addition to these problems, the increasing value attached to fossils encourages commercial exploitation of limited and in many cases protected resources, and such exploitation can cause problems such as incomplete or false stratigraphic and locality information. Many such problems could be addressed though reliable and quantitative post-collection tests of provenance. Earlier studies have suggested that the trace element composition of fossil bones reflects the local depositional environment and therefore could be used to indicate provenance, but limits of resolution were not previously tested. Research on a large and well-documented sample of bones from Pleistocene excavations in Kenya, East Africa, demonstrates how trace element chemistry of fossil bone can be used as a natural tracer or fingerprint to uniquely characterize all bones from a single depositional unit and/or excavation site. Most bones from a single depositional unit of c.1000 yrs duration can be correctly assigned to their original excavation site, even when excavations are separated by <100 m laterally. Despite this high level of geochemical resolution within a single depositional unit, bones from successive stratigraphic levels also can be distinguished accurately on the basis of trace element chemistry. Such high levels of resolution may not be reproducible in all depositional settings (and certainly not in marine settings), but we see no geological reason why the geochemical variation in our test site should be unusually high; hence, the observed REE variation are likely representative of levels of variation that would be expected in other terrestrial vertebrate-bearing deposits. This is supported by the fact that all previous studies of bone REE geochemistry have successfully discriminated between depositional horizons. This method (which requires <0.005g of bone) can be used to assess mixing within populations of fossil bones, to test provenance (and therefore age) assignments, to indicate deliberate alteration of fossil bones, and to identify fossils that have been collected or traded illegally.

THE LATEST MIDDLE EOCENE PONDAUNG MAMMAL FAUNA, MaNMAR

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We reconstruct the terrestrial mammalian fauna from the Eocene Pondaung Formation in central Manmar (the Pondaung fauna). The Pondaung fauna consists of six orders of mammals, including 22 genera: Primates (five genera), Creodonta (two genera), Rodentia (one genus), Artiodactyla (four genera), Perissodactyla (nine genera), and Ungulata order undetermined (one genus). Among these genera, more than half (12 genera) are endemic to this fauna, indicating high endemism. Both artiodactyls and perissodactyls are abundant: the former is less diversified in familial and generic numbers but slightly more dominant in collection size than the latter. The paleoenvironment of the Pondaung fauna is estimated as subtropical/tropical forest near the sea shore with large rivers, on the basis of the inferred paleoecologies of the included mammalian species and the geologic and geographic evidences. The Pondaung mammal fauna is correlated to the latest middle Eocene. In East Asia, the Pondaung fauna is more similar to the middle/late Eocene faunas of southern East Asia rather than to those of middle and northern East Asia. The Pondaung fauna has close relationship with the late Eocene faunas of Africa/west Eurasia, suggesting faunal migration from southern East Asia to Africa/west Eurasia during the latest middle to late Eocene.

A PRELIMINARY ASSESSMENT OF THE EVOLUTION OF THE CERVICAL MUSCULATURE IN DIAPSIDA WITH AN EMPHASIS ON DINOSAURIA

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Understanding the evolutionary changes in the musculoskeletal system is essential for functional interpretation of fossil organisms. In order to infer such changes in the cervical region in Diapsida toward the derived avian condition, I conducted detailed dissections of extant diapsids including birds. In lepidosaurs, serial arrangements of epaxial muscular slips clearly extend from the dorsal to cervical regions. In archosaurs, such arrangements tend to be modified, forming a more differentiated cervical musculature. Several muscles in archosaurs have different insertions than in lepidosaurs. For example, *m. iliocostalis capitis* inserts on the basal tubera in lepidosaurs and on the paroccipital process in archosaurs. Several more major

changes occurred within Archosauria. The main tendon of *m. transversospinalis cervicis* inserts on the atlas neural arch in non-avian diapsids, but its putative avian homolog, *m. longus colli dorsalis pars cranialis*, has shifted its main insertion to the epipophysis of the axis. In non-avian diapsids, the most lateral series of the *m. transversospinalis* group in the dorsal region (e.g., the crocodylian *m. tendinoarticularis dorsi*) is incorporated into *m. transversospinalis cervicis* in the cervical region. Its avian homolog is better developed and makes up the distinct *m. ascendens cervicalis*, while retaining the same origin and insertion.

Some of these evolutionary changes are traceable in the fossil record through a survey of osteological correlates. For example, the presence of the epipophysis on the axis in non-avian dinosaurs suggests that a shift of the *m. transverospinalis cervicis* insertion to the axis might be a synapomorphy of Dinosauria. The *m. tendinoarticularis* origin in crocodylians is recognized as a scar on the prezygapophysis with a similar scar also found in several sauropods and ornithischians. In Aves, this scar has been replaced by a more prominent, knob-like process, which may correlate with strong development of *m. ascendens cervicalis*. This knob-like process is already present in several basal ornithurines, suggesting the development of this 'avian' muscle outside of the crown-clade Aves.

STAGES IN THE ORIGIN OF VERTEBRATES: ANALYSIS FROM ACTUAL FOSSIL EVIDENCE

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Vertebrate, specifically fish microfossils, often dismissed as useless "scrap" or neglected by geologists and palaeontologists, provide data for example, for range and distribution of taxa, for phylogeny of organisms and for assessing response of taxa to events. Isolated microremains (fish microvertebrates, ichthyoliths), such as thelodont and "shark" scales and "shark" teeth can and do provide evidence about the functional morphology and relationships of higher taxa such as the Thelodonti and Chondrichthyes. Their taxonomy (para- or scio-) is as valid as that built on neurocrania. More and more, vertebrate microfossils are helping assess the origin or at least the earliest occurrences of higher taxa; examples exist in the Cambrian, the Ordovician, the Silurian, and the Devonian. Even Tetrapoda should be expected as microfossils if they can be recognized as such before the macrofossil evidence, large bones, footprints etc., appeared. Specialized sensory scales related to neuromasts are identified for a thelodont, *Loganellia* sp., from the Early Silurian of Devon Island, arctic Canada. New early "shark" remains, scales and teeth from the Devonian of arctic and eastern Canada and Australia, including the Early Devonian (Emsian) taxon, *Doliodus problematicus* from the Campbellton Formation extend the range of chondrichthyan families and add insights into the earliest stages of certain vertebrates. *Doliodus*, apparently a basal member of the Omalodontida, exhibits the presence of the dental lamina. It seems probable, however, that, based on some of the new "shark" remains known only from microfossils, the higher taxon Chondrichthyes as currently understood is not a "natural" or monophyletic group.

EVOLUTION OF CETACEAN DIVERSITY

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The number of described cetacean genera varies greatly over their evolutionary history. Starting from nothing in the earliest Eocene, Cetacea originates in the late early Eocene, and experiences a rapid diversification in the middle and late Eocene, reaching around 20 genera. This diversification involves animals that are utilizing a variety of environments (fresh water, coastal, marine), and spreading around the world from their apparent origin in Indo-Pakistan. The number of cetacean genera crashes at the end of the Eocene, with only three described from the early Oligocene. This time also represents the extinction of the archaeocetes and the origin of the Mysticeti and Odontoceti. By the late Oligocene, the number of genera had recovered to levels similar to those in the middle Eocene, and had begun a huge expansion that peaked in the middle Miocene, reaching a maximum of over 100 genera. The number of genera decreases smoothly to around 40 extant today.

While we hope that this count reflects the actual number of genera present in the past (diversity) it can be confounded by many factors. The count is probably too high in some instances due to the prevalence of genera based on limited, non-diagnostic material, or possibly oversplitting. The count is too low due to non-preservation of fossils; non-deposition, destruction, or covering of fossil bearing, marginal marine rocks; and lack of collecting or publication effort. Each of these factors is investigated as a potential cause of bias in the estimation of cetacean diversity. In some instances, individual causes may have significant effects on both true diversity, and the amount of bias. As an example, the low diversity in the early Oligocene may be due to destruction of marginal marine early Oligocene rocks due to a significant drop in sea level at the beginning of the late Oligocene. The sea level change is due to the growth of Antarctic ice at that time, which is likely to have had a significant effect on whale evolution and diversity by itself. All of these confounding factors are investigated to determine their effects on cetacean diversity.

THE BIOGEOGRAPHIC RELATIONSHIPS OF EARLY CRETACEOUS VERTEBRATES AND PLANTS: EVIDENCE FOR VICARIANCE AND DISPERSAL AT A CONTINENTAL SCALE

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The fragmentation of Pangaea, during the Mesozoic, has been cited as an explanation for the disjunct distributions of various extinct and extant organisms. This hypothesis, however, has not been tested rigorously using the required combination of large data-set, cladistic biogeographic method, and statistical evaluation. In addition, several recent studies have claimed that dinosaurs, chameleons, turtles, and several other groups, display phylogenetic relationships and geographic distributions that conflict with the Pangaean fragmentation hypothesis.

We present a large data-set composed of the phylogenetic relationships, geographic distributions and stratigraphic ranges of approximately 300 Mesozoic terrestrial and freshwater taxa (dinosaurs, crocodiles, platynotan lizards, osteoglossid fish, angiosperms and conifers). This data-set has been subjected to the cladistic biogeographic technique known as Component Analysis. This method searches for one or more 'optimal area cladograms' that represent the geographic relationships imposed on phylogeny by a set of geological/environmental events. These analyses were run using the entire data-set and also 'time-sliced' portions of the data-set in which only taxa from a particular time-window (e.g. 'Cretaceous' or 'Late Cretaceous') were considered. The optimal area cladograms were then evaluated for statistical significance using a randomisation test.

These analyses produced a statistically significant area cladogram for the Early Cretaceous. Comparison of this area cladogram with palaeocoastline reconstructions indicates that continental fragmentation and collision, coupled with changes in sea level, provide plausible causes for the sequence and timing of biogeographic events. The majority of the detected 'events' can be interpreted as vicariance produced by sea level rise and continental fragmentation: however, the results also suggest that dispersal occurred during the late Early Cretaceous when marine regression re-connected Europe and Asia. It seems, therefore, that major tectonic and eustatic events during the Mesozoic imposed a fundamental distribution pattern on a wide array of different organisms.

ABDOMINAL VISCERAL ANATOMY IN THEROPOD DINOSAURS

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Many workers have assumed that theropod abdominal visceral anatomy was, at least in part, similar to that in birds, i.e., a pulmonary air sac extended posteriorly into the dorsal abdomen. That assumption is based on conventional wisdom that theropods utilized an avian-style lung air-sac system. However, one of us (JAR) has previously described preservation of theropod abdominal visceral anatomy inconsistent with the presence of abdominal air-sacs in theropods: in *Scipionyx*, the entire descending colon is situated in the extreme dorsal abdomen?, he region that almost surely would have housed an abdominal air sac should it have been present. Recently, some have claimed that in *Scipionyx*, the two-dimensional preservation of soft tissues has resulted in distortion and dislocation of abdominal contents from their original, or true, anatomical positions. To clarify this situation, we surveyed gastrointestinal anatomy in crocodilians, birds and lizards by abdominal radiology of barium-fed experimental animals. Results indicate a surprisingly tight correlation between overall visceral anatomy in *Scipionyx* and crocodilians. We conclude that soft tissues preserved in *Scipionyx* were likely to have been preserved *in situ* and that presumptions that theropods possessed abdominal air-sacs should be viewed with skepticism.

OUT OF THE CRETACEOUS: FOSSILS AND CLOCKS AGREE ON THE EVOLUTIONARY TIMESCALE OF CROWN BIRDS AND MAMMALS

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Several recent molecular clock studies have estimated a Cretaceous divergence among modern bird and placental mammal ordinal lineages, but the current fossil record generally supports an early Tertiary appearance. Because these views are perceived as mutually discordant, it is frequently argued that either the fossil record or the genetic analysis is biased or flawed. However, here we argue that a significant portion of the observed disparity may be caused by different accents on stem and crown groups. We suggest that most of the fossil record of modern birds and mammals better reflects crown group originations or at least morphologically recognizable groups—including part of the stem. In contrast, most large-scale molecular clock studies have emphasized ordinal and supraordinal stem divergence times while comprehensive molecular studies on crown group timescales are mostly lacking.

Here, we present a first molecular analysis on crown origins of the major orders and families of birds. Analysis focusing on the time of origin of the most recent common ancestor of various ordinal and family-level clades of extant birds removes much perceived disparity between molecular clock and fossil data. Both sets of data support two major pulses of divergence within crown orders and families. We show that these two pulses in bird evolution may be coincident with major diversifications in placental mammal groups and potentially are related to major climatic and environmental changes (glaciation and extinction) during those intervals.

INTERNAL CRANIAL OSTEOLOGY OF THE OLIGOCENE GLYPTOSAURINE *HELODERMOIDES TUBERCULATUS* (SQUAMATA: ANGUIDAE)

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Glyptosaurine squamates compose an extinct subfamily of anguid lizards that span from the lower Eocene into the middle Oligocene. The internal cranial osteology of any anguid, modern or extinct, is not understood. A specimen of the Oligocene glyptosaurine, *Helodermoides tuberculatus*, discovered in the 1970s from the panhandle of Nebraska showing good exposure of the internal cranial osteology was studied. *Helodermoides tuberculatus* is the last representative of the Glyptosaurinae. Unfused osteoderms over the cranial elements, and their subsequent removal, allows complete exposure of the underlying internal cranial osteology in this specimen. Comparison of other members of North American gerrhonotine anguids, such as *Gerrhonotus, Elgaria* and *Barisia*, with the glyptosaurine *Helodermoides tuberculatus,* may offer new criteria for an improved phylogenetic analysis of the Anguidae. Previous phylogenetic matrices were limited to using a few osteodermal and osteological characters. The description of the internal cranial osteology provides more insight into the phylogenetic positioning of primitive anguid subfamilies and gives the scientific community needed osteological descriptions.

THE PRINCIPAL MORPHS OF LOWER PERMIAN TETRAPOD TRACKS

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The diversity of Lower Permian terrestrial tetrapods is represented by temnospondyls, seymouriamorphs, diadectids, pelycosaurs, captorhinomorphs, and early diapsids. Among these the amniotes indicate a first significant divergence of locomotory abilities. This tendency is accompanied by more conservative locomotory adaptations of some non-amniote groups. The character transformation concerns the autopods, in particular the consolidation of sole as well as the length and arrangement of the digits. Changes in the proportions of the body and limbs result in a more erect gait and increasing agility. These evolutionary trends are reflected by distinct imprint morphologies of animal?s tracks and new modes of trackway pattern such as the first appearance of overstep. The osteologically established diversity can be correlated with six principal morphs of Lower Permian track type, the ichnogenera *Batrachichnus* and *Limnopus* for temnospondyls, *Amphisauropus* for seymouriamorphs, *Ichniotherium* for diadectids, *Dimetropus* and *Gilmoreichnus* for pelycosaurs, *Hyloidichnus*, *Varanopus* and *Erpetopus* for captorhinomorphs, and *Dromopus* and *Tambachichnium* for diapsids like araeoscelids. From the evidence from several extensive track sites of Lower Permian age across Pangea, all other hitherto differentiated and named ichnotaxa can be related to these basic morphs. So, the formerly more descriptive differentiation of salamandroid, stegocephaloid and lacertoid tracks, maybe characterizing the Carboniferous, have to be extended in the Lower Permian due to the progressive evolution of the locomotory apparatus of synapsids and captorhinomorphs, in particular. Other terrestrial adaptations of early tetrapods, e. g., microsaurs, could be expected in the track record. However, to date there is no evidence of a separation from the *Batrachichnus* assemblage.

As one of the main results, the origin of the amniotes can be dated by the first appearance of principal track morphs at least in the Late Carboniferous. In this context, the proposed anatomically related interpretation of tracks is a useful means for faunal and stratigraphical interpretations of Permocarboniferous red beds.

PRELIMINARY REPORT ON THE RECENTLY DISCOVERED GRAY FOSSIL SITE (MIOCENE), WASHINGTON CO., TENNESSEE: WITH COMMENTS ON OBSERVED PALEOPATHOLOGIES—THE ADVANTAGES OF A LARGE SAMPLE

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The Gray Fossil Site, a newly discovered Miocene terrestrial deposit near Gray (Washington Co.), Tennessee, provides a rare opportunity to study the paleoecology of middle Appalachia. Recovery of the rhino *Teleoceras* dates the sediments to between ~4.5-18 Ma. Preliminary interpretations suggest a sinkhole that initially acted as a natural trap and subsequently as a water hole/pond. Core samples indicate that the deposit covers ~4-5 acres and is up to 35 meters thick. The highly laminated, organic laden, silty sediments are rich in both plant and animal remains. Surface collections have yielded proboscidean, rhinoceros (*Teleoceras*), tapir, mustelid, canid, ursid, alligator, snake, turtle, amphibian, and fish. Miocene-aged deposits are rare within the Appalachians; therefore, this new locality provides a unique comparison to the classical Miocene records of Gulf Coast and Great Plains. Furthermore, the richness of this deposit will provide unprecedented quantities of fossil material for morphological analyses.

Tapir (undet. sp.) is the most abundant taxon at the Gray Site with an estimated MNI > 100. Among these remains is an individual that exhibits abnormal bony outgrowths on the carpals, metacarpals and phalanges of the left manus. The cross-element distribution, restriction to the external (dorsal) surfaces, and absence of this pathology on the associated right manus, suggest that these ossifications are unrelated to age, disease, and/or genetic disorder. Furthermore, X-rays of the elements have yielded no obvious trauma, implying that the pathologies are the result of a soft tissue injury. Degloving, which can stimulate osteoblasts within the periosteum to deposit bone in the affected area, is common among living *Equus* and is a likely source of the pathology. Once noted, this condition has been observed on numerous tapir specimens from the Gray Site, implying a high incidence of pre-mortem soft tissue damage to the limbs of these animals. Aside from the obvious analyses of population dynamics, these findings illustrate the importance of such large fossil assemblages to the interpretation of "everyday life" of extinct taxa.

TAPHONOMY AND GENESIS OF THE NEOGENE BAHÍA INGLESA FORMATION BONEBED, NORTHERN CHILE

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The marine Bahía Inglesa Formation bonebed crops out in an area of arid badlands 10 km south of Caldera on the north-central coast of Chile. The bonebed contains a diverse fauna of over 52 species including sharks, rays, bony fish, crocodiles, seabirds, true seals, whales and dolphins. Based on its contained fauna and the biostratigraphy of the overlying formation, the bonebed is probably late Miocene to early Pliocene in age. Sedimentologic evidence indicates that the bonebed formed in shallow water in a series of basins that received little clastic input. Taphonomic field data were collected from a 1.5 km by 0.25 km transect of the bonebed, and the data collection points were accurately recorded using GPS. Taphonomic data included measurements of bone size, shape, dip and orientation, and field identifications of skeletal elements and taxa were also recorded. Key lines of taphonomic evidence include dominance of disarticulated and fractured remains with infillings of exotic sediment; only moderate abrasion on most fossils; absence of calcareous shelly fauna apart from phosphatic steinkerns; large size of vertebrate remains and rarity of material of less than 5 mm diameter; increase in vertebrate clast size toward basement outcrops; preferred orientation of long bones; mixing of temporally and environmentally discrete taxa; absence of terrestrial taxa; abundance of bioerosion-related surface modification on remains; current-scoured base of bonebed with *Skolithos*; presence of plastic rip-up clasts of pre-existing bonebed. The overall taphonomic signature is interpreted to indicate that the bonebed was formed by repeated reworking and winnowing of a vertebrate-bearing sequence during a period of marked regression that brought the sequence above storm wave base and, later, into normal wave base. Protection of the bone accumulation was subsequently achieved by early cementation by phosphate during a rapid transgression, which resulted in burial of the accumulation as the locus of deposition moved shoreward.

THE PALEOCENE/EOCENE BOUNDARY DEBATE:AUBRY VS. HEDBERG ON CHRONOSTRATIGRAPHIC PRINCIPLES

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In several recent papers, M.-P. Aubry and her co-authors have argued that "Hedbergian" principles are violated by the International Commission on Stratigraphy when selecting Global Stratotype Sections and Points (GSSPs) for the formal divisions of the geological time scale. The current debate on the P/E boundary has been a major focus of their arguments, but Aubry et al. have obscured matters by confusing the very different concepts of "unit stratotype," "synthem," and "(global chronostratigraphic) stage." The P/E boundary option most repugnant to Aubry et al. (Carbon Isotope Excursion = P/E = hanetian/Ypresian boundary) is perfectly compatible with Hedberg's views. In contrast, another option proposed by Aubry et al. recognition of new ~1 m.y. duration age/stage between Thanetian and Ypresian) is inconsistent with Hedberg's views. I favor formalizing the Late/Upper Paleocene Age/Stage and Early/Lower Eocene Age/Stage, thus allowing "Thanetian" and "Ypresian" to continue to denote the European synthems of traditional scope.

As for chronostratigraphy in general, Aubry et al. have misrepresented Hedberg by: 1) distorting the "base defines boundary" principle; 2) distorting the arbitrary nature of chronostratigraphic boundaries; 3) contending that GSSPs may be placed at unconformities; 4) claiming that chronostratigraphy must remain independent of any aspect of Earth history; 5) claiming that the definition of a chronostratigraphic boundary must precede its correlation; and 6) implying that traditional unit stratotype boundaries can be adjusted by no more than 0.3 m.y. when defining formal age/stage boundaries with GSSPs. Numerous statements of Hedberg prove that he did not hold the narrow views attributed to him by Aubry et al. If taken seriously, the unit stratotype-sanctifying philosophy of Aubry et al. would require the creation of perhaps dozens of new Phanerozoic ages/stages of relatively very short duration, wherever there was a significant gap between two successive historical stage unit stratotypes. For all of the above reasons, the arguments of Aubry et al.have no merit.

A NEW EARLY MIOCENE MAMMALIAN FAUNA IN TABEN-BULUK AREA (DANGHE, WESTERN GANSU, CHINA) AND IMPLICATIONS FOR THE TECTONICS AND PALEOENVIRONMENTS ON THE NORTHERN TIBETAN PLATEAU

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The Taben-Buluk area features a >3,000 m sequence of terrestrial sediments along the northern foothills of the Tibetan Plateau. Discovered by the Swedish paleontologist Birger Bohlin in the early 1930s, the area has become a classic due to the later establishment of the late Oligocene Tabenbulukian mammal age. However, the extremely complex tectonics in the area proves to be a major obstacle in subsequent efforts to relate the fossil evidences to tectonic events. Our field studies attempt to place the Taben-buluk faunas in stratigraphic context, and, together with previously published paleomagnetic data, to establish a new chronology based on the fossil evidences. A well-established chronology is expected to shed lights in the timing and magnitude of the uplift of the northern Tibetan Plateau, a subject of recent controversies. Our new stratigraphic framework suggests a much later northern Tibetan orogeny (late Miocene) than had previously been assumed.

A new fossil assemblage was discovered in the middle Danghe section. This important fauna features the co-occurrence of an early catarrhine primate "*Kansupithecus*," a shoveltusked elephant *Platybelodon*, and the aquatic plants *Nuphar*, *Typha* and *Cyperacites*. The new fossil mammals indicate an early Miocene age, and combined with paleomagnetic data, permit a much tighter constraint on the geologic range for the Tertiary section exposed in the Danghe area than had previously been possible. Fossil plants and vertebrates suggest a paleoenvironment containing a mixed flora of deciduous trees typical of arid climates in north China.

DIVERSITY IN BONE COLLAGEN FIBER ORIENTATION PATTERNS AMONG PRIMATES AND OTHER MAMMALS

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Paleobiological reconstructions of fossil mammals are usually based on the macroscopic study of hard tissues. The additional analysis of microstructural features, however, provides the potential for a more complete understanding of the functional biology and behavior of fossil species. We here examine a single bone microstructural feature: collagen fiber orientation (CFO). The orientation of collagen is of interest due to its relationship to the mechanical loading of bones. The majority of previous studies have examined CFO in heavily remodeled bones, and in a limited number of species and skeletal elements. Therefore, the degree of both systematic and ontogenetic variability that exists for this character is largely unknown.

In this study, ground histological sections from the midshaft humerus, ulna, radius,

femur, tibia and fibula are imaged in circularly polarized light, thus facilitating the identification of regional patterns of CFO, as revealed by variation along a 256 gray scale. Taxa examined include strepsirhine and haplorhine primates, as well as chiropteran, dermopteran, and tupaiid specimens. The taxonomic sample is designed to encompass a range of evolutionary relationships, and to provide comparisons among species with varying positional behaviors and life histories (and therefore potentially varied tissue type distributions). Section thickness and lighting parameters are standardized for all sections, allowing for the quantitative comparison of gray values. Gray level histograms and average pixel gray-scale values are derived for whole sections, as well as for sectors within sections. Results reveal variation in CFO—in both primary and secondary tissues—across sections, among skeletal elements, and among taxa. For example, CFO patterns differ between humeri and femora, and preliminary assessments indicate that these relate to differential use of the limbs in locomotion. As part of an ongoing study of bone microstructural variation and its ecological correlates, this study of extant taxa will provide the foundation for studies of CFO and other microstructural attributes in fossil mammals.

TWO PREVIOUSLY UNREPORTED SAUROPOD DINOSAURS FROM THE UPPER JURASSIC MORRISON FORMATION OF OKLAHOMA

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Between 1935 and 1942, J. Willis Stovall directed the excavation of thousands of dinosaurs bones from quarries in the Morrison Formation of the Oklahoma panhandle, near the town of Kenton. Sauropods previously reported in this material are *Apatosaurus*, *Camarasaurus*, and *Diplodocus*. *Apatosaurus* material from the Kenton quarries has traditionally been regarded as *A. excelsus*, following Stovall's referral of the material to *Brontosaurus excelsus*. To date, no characters have been cited that support the referral of this material to either *A. excelsus* or *A. louisae*. OMNH 01368 is a disarticulated cervical rib of a large sauropod from Kenton Pit 1. The specimen lacks an anterior projection and is therefore referrable to *A. louisae*, a species previously unrecognized from Oklahoma. This and other specimens from the quarry pertain to one or more individuals at least 35% larger than CM 3018, the holotype of *A. louisae*. Furthermore, the capitular and tubercular synchondroses of OMNH 01368 are unfused, indicating that the animal was not skeletally mature, and that the range of body size at maturity in *Apatosaurus* was very large.

OMNH 01138, also from Kenton Pit 1, is a sauropod metacarpal II that was previously catalogued as *Camarasaurus*. The specimen is proportionally and absolutely longer than any metacarpals that can be reliably referred to *Camarasaurus*. It is more similar in morphology and proportions to the elongate metacarpals of *Brachiosaurus*, a second sauropod taxon that has not been previously reported from Oklahoma. The vertebrate fossils from the Kenton quarries have never received a thorough analysis and description, and represent an underutilized record of morphological and taxic diversity.

TECTONO-TAPHONOMIC EXPRESSION OF CAMPANIAN-MAASTRICHTIAN BASIN ADJUSTMENTS IN THE BIGHORN BASIN, NORTHWESTERN WYOMING: DEAD DINOSAURS HAVE TRANSPORTATION TALES TO TELL

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The nature and distribution of taphonomic modes of dinosaur fossils occurring in the Campanian-Maastrichtian stratal succession of Elk Basin, Wyoming, can provide information about transportation, deposition, and diagenetic processes within the basin, some possibly due to regional tectonic adjustment. Tectono-taphonomic signatures suggest potential Bighorn Basin and Western Interior Seaway response to allostratigraphic events such as the Laramide Orogeny. tectono-taphonomic evidence of the Laramide Orogeny is suggested in the lower portions of marginal marine to non-marine, and sometimes, volcaniclastic sediments of the Meeteetse Formation, as well as in non-marine to marginal marine sheet sandstone units of the Lance Formation. Lance Formation sheet sandstone units located in Elk Basin, Wyoming are in general sedimentologically graded beds that fine upwards. The top of the second Lance Formation sheet sandstone in Elk Basin, Wyoming preferentially contains desiccation features and occurrences of articulated dinosaurs, along with dinosaur, small vertebrate, and invertebrate ichnofossils. Disarticulated dinosaur bone occurs preferentially in the bases of the first and third volcaniclastically influenced sandstone units in the Meeteetse Formation. Small channel (less than one meter in diameter) conglomerate lag deposits containing disarticulated dinosaur bone clasts are found in the lowest Meeteetse Formation sandstone. Disarticulated vertebrate bone contained within lag deposits and other units deposited hydraulically can suggest transport mechanisms that moved bone away from the initial site of carcass deposition. Tectono-taphonomic deposits suggest carcass reworking as well as potentially a hydraulic response to basin adjustments to changes in base-level, resulting in the reworking of sediments and faunal inclusions.

NEW INSIGHTS ON THE ANATOMY OF *POSTOSUCHUS KIRKPATRICKI* (ARCHOSAURIA: CRUROTARSI)

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Postosuchus kirkpatricki is currently one of the most completely known rauisuchids. Many features of the osteology of *Postosuchus* have been clarified recently by a new specimen from North Carolina, a headless, articulated skeleton from New Mexico, and specimens from other collections along with a reexamination of the type and paratype skeletons. This study has contributed to a redescription of the animal by the author and has clarified many of the issues associated with it, including the relationship of *Postosuchus* to other crurotarsans.

Examination of the material indicates that *Postosuchus* was at least facultatively bipedal, and possibly an obligate biped. Also, this study has shown that the pelvis of *Postosuchus* is different from that of *Chatterjeea*. A bifurcated infratemporal fenestra has also been confirmed. Endocasts and impressions of the brain have allowed for an understanding of the brain morphology of a rauisuchid for the first time, and indicate that the brain of *Postosuchus* was similar to modern crocodilians, but with a better developed hindbrain for balance and coordination.

MORPHOLOGIC DIVERSIFICATION OF CANIDAE AND FELIDAE IN NORTH AMERICA

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An innovative, quantitative approach, synthesizing novel and established methods for describing the dentition of carnivorans, is used to document the morphologic diversification of the Canidae and Felidae in North America. 18 discrete characters covering the four functional regions of the carnivore tooth row (incisors and canines, premolars, carnassials, and postcarnassial molars) categorize the dentition. This approach to morphological description minimizes the effect of phylogeny on the emerging patterns. Disparity (measured as average and maximum pairwise dissimilarity among genera), occupied morphological space, and the number of dental types (character state combinations), are used to examine the morphological diversification of these families.

I test two hypotheses: 1. Once an efficient system for consuming flesh evolved, the dental system remained unchanged; 2. Morphologic and taxonomic diversification are concordant in Canidae and Felidae. Preliminary results suggest that maximum disparity of dental types in Canidae occurred relatively early, with little change observed for the duration of the Cenozoic, supporting hypothesis one. This maximum coincided with the "cat gap," a period during which catlike carnivores were absent in North America. Maximum average disparity occurred late in canid history, in the interval with fewest taxa. This implies that more extreme morphologies and fewer intermediates were present during this interval; there were fewer canids, but they were making a living in more disparate ways. The extinction of morphological intermediates in North American Canidae may be the result of the diversification, both taxonomic and morphologic, of felids and hyaenids during this time interval, which coincides with the maximum disparity and taxonomic richness for Felidae. Morphologic and taxonomic diversification are discordant in Canidae, contradicting hypothesis two, while in Felidae diversification is concordant, supporting hypothesis two.

CONTINUED EXCAVATION OF THE FIRST DINOSAUR COMMUNITY FROM CHIHUAHUA, MEXICO (*Presented at the Society of Vertebrate Paleontology annual meeting, Oct., 2001, Bozeman, MT*)

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Prospecting of Late Cretaceous Aguja Formation deposits in Canon de Santa Elena National Area of Protection in Chihuahua, Mexico continues to yield remains of a diverse coastal community which includes vertebrate, invertebrate and floral components. Numerous skeletal and plant remains cropping-out in fluvial deposits across a 1 km by 0.5 km area were mapped on a meter square grid system during field work conducted from May, 1999 to May, 2001, near the former community of Los Altares, just north of the Chihuahua-Coahuila border. Permits for collection and study were issued by the Mexican National Consejo de Paleontologia, and the Mexican National Institute of Ecology.

Dinosaur remains include maniraptoran, tyrannosaurid and ceratopsian (cf. *Chasmosaurus mariscalensis*) teeth and limb elements, with hadrosaur elements dominating the assemblage. Recent collection emphasis has focused on the excavation of a disarticulated hadrosaur (*Kritosaurus* sp.) skeleton from which most of the large limb elements and portions of the skull and vertebral column have been recovered. Taphonomic analysis of this specimen indicates that a preferential post-mortem orientation of long bones occurred prior to burial in anoxic muds.

Associated flora from fluvial sands lateral to the *Kritosaurus* skeleton include conifer (Araucariaceae) and palm (*Sabalites* sp.). These sands also yielded skeletal elements from gar, bowfin, turtles and goniopholid crocodiles. Nearby estuarine sandstones, both in lateral facies and near the base of the Aguja Formation, bear remains of ostreine oyster reefs and gastropods. Through acetic acid treatment these sandstones have also yielded teeth from the sharks *Scapanorhychus* sp., *Squalicorax* sp., and *Cretolamna* sp.; and batoids, including *Ptychotrygon agujaensis*, *Protoplatyrhina* sp., *Squatirhina* sp., and a hypolophid.

No other dinosaur specimens, except an unidentified ceratopsian element reportedly from the Late Cretaceous Ojinaga Formation, are known from the state of Chihuahua. This ceratopsian fragment more likely came from the San Carlos Formation. Mexico has only six localities outside of Chihuahua where dinosaur body fossils have been reported; four are Cretaceous in age and two are Jurassic.

DISCOVERY OF DINOSAUR REMAINS IN COASTAL DEPOSITS NEAR OJINAGA, MEXICO

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Preliminary site surveys and surface prospecting of Late Cretaceous San Carlos Formation outcrops near Ojinaga, in Chihuahua State, Mexico, have yielded numerous dinosaurian remains. Vertebrate specimens are found in Campanian-age deltaic mudstones. Deltaic deposits stratigraphically overlie estuarine mudstones bearing oyster reefs comprised of *Flemingostrea* sp.. Dinosaur remains belong to a tyrannosaurid, hadrosaurs and ceratopsians.

Associated vertebrate materials come from gar (*Lepisosteus* sp.), softshell turtles (*Aspideretes* sp.), other chelonians, and goniopholid crocodiles. Specimens are preserved in the collections of Mexico's National Institute of Anthropology and History.

This new site has high potential for recovery of additional taxa through both macro-fossil extraction and screen-washing of bulk samples. Dinosaur localities are rare in Mexico. Only six areas outside of Chihuahua State have yielded dinosaur remains. Although a suite of dinosaurs have been reported from the San Carlos Formation in Texas, the only previous record of dinosaurs from the Ojinaga, Mexico area is a ceratopsian bone fragment, reportedly from the Ojinaga Formation. The only other dinosaurian remains known from the state of Chihuahua were found nearly 140 km south in Campanian-age Aguja Formation outcrops near the Coahuila border at Los Altares, in the Canyon de Santa Elena National Area of Protection.

USING REMOTE SENSING DATA FOR VERTEBRATE FOSSIL RECONNAISSANCE

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Although paleontologists are increasingly using satellite data to create color composite images for navigation and field reconnaissance, digital processing techniques have not been integrated into the paleontological mainstream. Remote sensing data, including those from the Enhanced Thematic Mapper (ETM) are widely used to address regional geologic problems, but at 30 x 30 m resolution, are generally dismissed as too coarse for pinpointing outcrops at finer scales. The results of an ongoing remote sensing project in sediments of Mesozoic age in Madagascar suggest that digital processing techniques such as Maximum Likelihood Classification (MLC) and Principle Component Analysis (PCA) greatly increase the probability of identifying and locating new terrestrial fossil sites. Indeed, georectified ETM data are remarkably accurate when used even with a hand-held GPS unit. Two methods were used to examine ETM data from fossil-bearing sediments in southwestern Madagascar. MLC was applied to three most separable bands (753) using eight spectral classes defined from geologic maps, airphotos, and spectral signatures of known fossil localities. Two fossil site classes are highly correlated with the general pattern of Triassic outcrops on 1:100,000 regional geologic maps. To assess the accuracy of these classes, 27 fossil site coordinates were plotted on the MLC map; 56% were correctly assigned to a "fossil-bearing" spectral class; an additional 18% were placed within 15 m of a correct class assignment. A PCA transformation of the largest linear gradients in 4 bands successfully enhanced topographic features and differentiated carbonates from non-marine sediments. PCA images produced in the field on a laptop computer facilitated the discovery of surprisingly small outcrops (<10 m^2), demonstrating the feasibility of these methods. MLC and PCA hold great promise for discriminating fossiliferous from non-fossiliferous sediments, and should prove increasingly fruitful as they are more widely used. These techniques can be easily applied to any potentially fossiliferous sediments, making them especially useful in remote or little studied regions of the world.

SEXUAL DIMORPHISM IN *SMILODON* AT RANCHO LA BREA FROM POST CRANIAL ELEMENTS: SIZE BIAS THROUGH PILFERAGE

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Recent literature describes *Smilodon* as having a relatively small amount of sexual dimorphism (by large felid standards) based upon cranial and dental measurements of material from pit 13, at Rancho La Brea. By use of sophisticated statistical techniques 6% dimorphism in skull length was established. Without questioning the measurements or statistics behind this figure, there is a hidden trap involved.

The traditional approach in paleontology is to focus on cranial and dental features for good and clearly established reasons. There can be exceptions, such as collection bias. A *Smilodon* skull is the ultimate coffee table decoration. A *Smilodon* sabre, as Van Valkenburgh has observed, is unmatched as a personal totem. Kurten describes cave bear skull collections from the cave of Hohlestein and the Sibyl's Cave, where personal skimming left permanent collections with grotesque size bias. The original numerical card catalogue lists 25 complete *Smilodon* skulls from pit 13, with a subsequent (possibly fragmentary 11 later added to the alpha-numeric catalogue). Over the last century, until the vision of George C. Page returned the collection to a dedicated on site facility, curation and storage of this vast resource was rather informal. That only 11 skulls remain to be measured from pit 13 is unfortunate, but factual.

Postcranial material is less vulnerable to this sort of vandalism by pilferage. Measurement of the femora from pit 13 produces a bimodal distribution with some overlap. Sexual dimorphism is less than in the living lion, but consistent with large felids. Measurement of femora from pits 61/67, 77, and 3 (separated stratographically) produces similar results. Male/female ratios are slightly male heavy, as is the case for *Atrox* at Rancho La Brea. Apparently male *Smilodon* show the same predisposition to entrapment that characterizes *Atrox*. The data also shows that change in size through time for *Smilodon* is by no means linear.

PROBABLE DROMEOSAUR TRACKS AND OTHER DINOSAUR FOOTPRINTS FROM THE CEDAR MOUNTAIN FORMATION (LOWER CRETACEOUS) UTAH

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A new dinosaur track locality in the Cedar Mountain Formation, Arches National Park, has yielded a diverse assemblage of saurischian (theropod and sauropod) and ornithischian (ornithopod and ?ankylosaurid) tracks from two stratigraphic levels. The lower horizon is a ripple marked sandstone containing only shallow theropod tracks impressions, with good morphological detail. The upper horizon is a trampled surface with deep tracks attributed to theropods, sauropods, ornithopods and ?ankylosaurids.

In the upper bed, two deep theropod tracks are preserved as didactyl impressions with only a trace of the proximal part of a third digit (presumably II). If this interpretation is correct, it is probable that these represent dromeosaur footprints. The tracks are the right size (foot length 30-37 cm) to match the foot of *Utahraptor*.

Tracks have previously been reported from five Cedar Mountain localities, and an additional undocumented site, but in five of the known sites no more than two identifiable tracks have been recorded. At the Long Walk Quarry the track tally is slightly higher, but it is only at the new Arches National Park site that several dozen tracks (more than 50) have been recorded. Several deep tracks are well-preserved allowing for the manufacture of molds that represent 3D replicas of the track maker's foot.

THE POSTCRANIAL ANATOMY OF THE LATE PALEOZOIC FAMILY LIMNOSCELIDAE AND ITS SIGNIFICANCE FOR DIADECTOMORPH TAXONOMY

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The late Paleozoic Diadectomorpha is generally considered to be the sister group of the crown group Amniota. This group consists of three families: Limnoscelidae, Tseajaiidae, and Diadectidae. The Limnoscelidae is presumably the most basal family within this group and therefore is critical in studies of diadectomorph and basal amniote interrelationships. At least four genera have been reported as belonging to Limnoscelidae: *Limnoscelis*, *Limnosceloides*, *Limnoscelops*, and *Limnostygis*. All of these genera, except *Limnoscelis*, are represented by fragmentary postcranial materials. The anatomy of these various limnoscelid genera was reviewed and their phylogenetic validity evaluated. Some characters previously used for generic distinction are no longer accepted by current cladistic standards. Furthermore, a survey of the postcranial anatomy of the limnoscelids suggests that most of the genera assigned to the Limnoscelidae are probably not valid taxa. The genus with the most confidently valid structure is *Limnoscelis*. Therefore, Limnoscelidae could potentially be considered a monogeneric family and *Limnoscelis* a significant anatomical model for the postcranium of taxa near the amphibian to amniote transition.

VERTEBRATE BONEBEDS FROM THE MORRISON FORMATION, BIGHORN BASIN, WYOMING: A REVISED STRATIGRAPHIC ANALYSIS

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Late Jurassic vertebrate fossils, particularly dinosaurs, have been discovered at several locations in the Bighorn Basin, Wyoming, but specifically in the neighborhood of Coyote Basin. A detailed study has been undertaken of the stratigraphy of the Morrison Formation in the area of the historic Howe Quarry and quarries recently worked by the Virginia Museum of Natural History (VMNH). In addition, there are numerous other sites nearby, including ones worked by the Smithsonian, the Yale Peabody Museum, and the University of the Pacific, which were also used for this study. One question specifically addressed is where the boundary between the Morrison Formation (Jurassic) and the Cloverly Formation (Cretaceous) lies. This new study attempted to show if the current method of determining the boundary is appropriate. The stratigraphy of the area was examined using two previous differing studies in order to see which, if either, model was the more robust. Dinosaurs from the VMNH and Howe quarries were used to supplement the stratigraphic data in determining the age of specific beds.

Units identified by previous authors were recognized within the study area, but there is some doubt as to whether these units can be identified beyond this region. The VMNH site is here considered to be within the lower part of the Morrison Formation. The geologic age of the dinosaurs from the VMNH and Howe quarries is in agreement with the age determined stratigraphically. The determination of the Jurassic/Cretaceous stratigraphic boundary has not been resolved. However, since the Pryor Conglomerate member of the Cloverly Formation can be identified throughout this area, it is proposed as the Morrison/Cloverly boundary. Further study of Morrison and Cloverly formation outcrops to the north will help to determine if the stratigraphic units in the Coyote Basin can be extended to a more regional level.

THE USE OF THREE-DIMENSIONAL DIGITIZED ELEMENTS TO EXAMINE FORELIMB MORPHOLOGY AND ARTICULATION IN NORTH AMERICAN JURASSIC SAUROPODS

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Scapulacorocoids, humeri, radii and ulnae from *Diplodocus*, *Apatosaurus*, and *Camarasaurus* were modeled using a point digitizer to create accurate three-dimensional elements. The elements were assembled using a three-dimensional modeling program. For taxa in which no complete forelimb with adequate preservation exists, individual elements were scaled to the appropriate size and articulated. Hypotheses regarding forelimb orientation could then be tested. Articulation modeling of three-dimensional elements supports the hypothesis that the radius was anterior and the ulna was posterior in sauropods. The humerus was oriented such that the deltapectoral crest faced anteromedially. The humerus rested primarily on the radius with much of the ulnar proximal surface forming a very large, flat area for insertion of the *M. anconaeus*. Finally, the scapulacorocoid appears to have been oriented more horizontally than most illustrations depict; vertical orientation of the scapula would greatly hinder forelimb protraction. Three-dimensional models also help illustrate the limited range of forelimb motion in North American Jurassic sauropods.

A LATE PUERCAN (PU3) MICROFAUNA FROM THE SAN JUAN BASIN, NEW MEXICO

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Recent fieldwork in the San Juan Basin has led to the discovery of the first Late Puercan (Pu3) microfossil locality from this region that can be worked by underwater screening. Preliminary work indicates that our diverse, new, local fauna from the head of Willow Wash corrects a sub-

stantial sampling bias against small mammals.

The Split Lip Flats local fauna includes at least one new genus and species of "ptilodontoid" multituberculate, a species of *Mesodma*, a new species of the marsupial *Peradectes*, and a new genus and species preliminarily referred to Cimolestidae. There are also representatives of rare taxa, including the nearly complete lower dentition of *Cimolestes simpsoni*, new specimens of Van Valen's enigmatic possible cimolestid "Genus B," and mioclaenid "condylarths" *Tiznatzinia* and *Valenia*.

The Pu3 interval is poorly understood; faunas of this age are rare. Although the best-known Pu3 faunas are from the San Juan Basin, small mammals have not, until now, been well-represented. Our discovery increases the known mammalian diversity of the Pu3 in the San Juan Basin, and will result in more precise correlation with other Pu3 faunas. It also expands our understanding of Paleocene faunal composition, diversity, and biogeography during a period of high generic turnover rates and rapid radiation of mammals. This is crucial to determining the evolutionary dynamics controlling faunal recovery following the last mass extinction.

MAMMALIAN FAUNAL STASIS: NEW DATA FROM THE LOWER PORTION OF THE HELL CREEK FORMATION IN GARFIELD COUNTY, MONTANA

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Terrestrial sediments from the Hell Creek and Tullock Formations in northeastern Montana (Garfield County) preserve a unique record of environmental and biotic change across the Cretaceous-Tertiary boundary. More than thirty years of fieldwork by crews from the University of California Museum of Paleontology has led to a comprehensive collection of fossil vertebrates from localities in the area. High-resolution litho- and biostratigraphic studies, radiometric age determinations, and magnetostratigraphic correlations in the area have further increased the utility of this faunal database for assessing biotic change during this time interval.

In the summer of 1999, fieldwork began in the previously underrepresented lower portion of the Hell Creek Formation. Underwater screenwashing led to the recovery of numerous vertebrate remains, including more than two hundred mammal specimens. These collections significantly expand the temporal range of the faunal database and permit detailed study of mammalian evolution over an approximately 3 million-year interval. Preliminary results suggest a typical Lancian mammal assemblage from the lower portion of the Hell Creek Formation. Thus, mammalian faunas represented through most of the Hell Creek Formation indicate a nearly 2-million-year period of relatively stable taxonomic composition prior to rapid taxonomic turnover caused by immigration and evolutionary radiation in the earliest Paleocene (Tullock Formation).

A REVISION OF THE GENUS *TITANOSAURUS* (DINOSAURIA: SAUROPODA) AND ITS IMPLICATIONS FOR TITANOSAUR SYSTEMATICS

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Titanosauria is the most diverse and geographically widespread sauropod clade, represented by more than thirty genera that occupied all continental landmasses (except Antarctica) during the Cretaceous. The distribution of titanosaur body fossils is complemented by the abundant record of their "wide-gauge" trackways, which first appear in the Middle Jurassic. Despite the breadth of their distribution, the novelty of their locomotor style, and their centrality in paleobiogeographic scenarios, titanosaur origins have only recently been agreed upon, and their interrelationships remain poorly established.

A central issue in titanosaur systematics is the validity of the genus *Titanosaurus*, which was coined by Lydekker in 1877 and has since become the namesake for several higher-level taxa (e.g., Titanosauria, Titanosauroidea, Titanosauridae). The type species, *T. indicus*, comprises a partial femur and two incomplete caudal vertebrae that were distinguished from known dinosaurs by their procoelous articular faces. Over time, the distribution of procoelous caudal vertebrae has broadened to encompass most titanosaurs, including 13 species that have been referred to *Titanosaurus*. If accepted as valid, these species distribute the genus across Argentina, Europe, Madagascar, India, and Laos, and throughout 60 million years of the Cretaceous.

A re-evaluation of all *Titanosaurus* species recognizes as diagnostic only two: *T. colberti* and *T. araukanicus*. All other species, including the type species *T. indicus*, are non-diagnostic, rendering the genus invalid. Coordinated suprafamilial, familial, and subfamilial ranked taxa are likewise invalid, but the unranked taxon Titanosauria remains valid. Based on the most recent cladistic analyses, Titanosauria and its constituent subgroups are phylogenetically defined to provide a stable taxonomic base for further investigations within the group. The notion of Titanosauria as a "Gondwanan" group is reconsidered in light of these systematic revisions.

TOWARD A PHYLOGENY OF THE THELODONTS

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Thelodonts are Paleozoic jawless vertebrates, characterized by their exoskeletal covering of tiny, monodontode scales, and useful for biostratigraphic correlation of Silurian and Devonian rocks. Opinions on their phylogenetic relationships differ, with some authors arguing that they are monophyletic and others that they are a paraphyletic assemblage of distantly related taxa. Historically, one of the problems with reconstructing thelodont phylogeny had been that few of the many named thelodont species were known from well-preserved, articulated skeletons as well as disarticulated scales. Another problem was that traditional thelodont taxonomy grouped species with (as we now know) very different body morphologies together because their scales were histologically similar.

Recent re-study by Märss and Ritchie of the important, articulated thelodonts from Scotland, the discovery of articulated specimens of fork-tailed thelodonts in northern Canada by Wilson and Caldwell, and current studies of both articulated and disarticulated specimens of new thelodonts from Arctic Canada by Märss, Wilson, and Thorsteinsson mean that many additional species are now known from both skeletons and scales. The ideal situation would be for most of the important thelodont genera to be represented by disarticulated samples showing scale morphology and suitable for thin sectioning to reveal scale histology, together with articulated squamations showing body form and variations in scale types. This ideal situation is seldom realized, but recent studies show that at least a dozen genera and more than 20 species now meet most of these criteria.

In this paper we present comparisons of these best-known thelodonts, and attempt a phylogenetic analysis using characters of scale morphology, scale histology, scale variation, body form, fin position and shape, and gut form. Results should help to clarify not only the relationships among thelodont taxa, but also the relationships of thelodonts to other major clades of jawless vertebrates.

RODENTS FROM THE EARLY MIOCENE OF UGANDA: PRELIMINARY RESULTS OF RENEWED INVESTIGATIONS

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Early Miocene localities near the Napak volcano, northeastern Uganda, have yielded an abundant, taxonomically diverse, and well-preserved rodent fauna. Study of the rodents is a component of a larger investigation by Laura MacLatchy and colleagues focusing on early Miocene primate evolution in Uganda. The rodent collections are from the localities NAP (Napak) IV, V, and CC. Rodents were reported previously from NAP IV and V by W. W. Bishop in the 1950s-1960s and described by René Lavocat. Our samples from these two localities complement the collections made by Bishop. NAP CC is a new locality with tremendous potential for rodents and other taxa. This site is significant because it may be one of the older Napak localities, and amongst these, it is the most fossiliferous. Stratigraphic correlations and revised radiometric age determinations are currently underway by John Kingston and Al Deino, respectively. To date, NAP CC has yielded *Diamantomys leuderitzi, Paranomalurus soniae, P. bishopi, Paraphiomys pigotti,* and *Bathyergoides* cf. *B. neotertiarius.* The sample includes a rare partial skull and mandibles of *Paranomalurus bishopi.* Taxonomic composition of the new material from NAP IV, V, and CC is comparable with that from the well-documented Early Miocene sites of Kenya. As noted by Lavocat, the composition and relative proportions of different taxa from Napak compares best to the older Kenyan localities, such as Songhor, than to somewhat younger localities, such as Rusinga (ca. 17.8 Ma). In contrast to both Songhor and Rusinga, new collections at Napak suggest a relatively higher percentage of anomalurids (scaly-tailed flying squirrels; extant taxa are forest dwellers) to other rodent taxa. This hypothesis needs substantiation by additional collecting in Uganda and a thorough reevaluation of the material collected by Bishop. Detailed analysis of the rodents from Uganda will promote a better understanding of the differences between the Ugandan and Kenyan Early Miocene faunas.

CENOMANIAN VERTEBRATE FAUNAS OF THE WOODBINE FORMATION, TEXAS

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The Cenomanian Woodbine Formation (Gulf Series) in Texas, documents a distinct reorganization in vertebrate faunas concomitant with the emerging dominance of angiosperms. Marine invertebrates provide biostratigraphic constraint on the faunas. Woodbine vertebrates are underlain by the middle Lower Cenomanian *Budaiceras hyatti* (ammonite) Zone in the Grayson Formation, and overlain by the Middle Cenomanian *Colinoceras tarrantense* (ammonite) Zone in the Tarrant Member of the Eagle Ford Formation.

Little of the Woodbine vertebrate fauna is described with the exception of the chrondrichthyans and brief description of the few mammalian specimens. More recent discoveries from the formation include the new tetrapods *Woodbinesuchus* (a goniopholid crocodyliform) and *Protohadros* (a derived ornithopod dinosaur), as well as dinosaur trackways. New microvertebrate localities have yielded the first specimens of salamanders, frogs, lizards, and snakes. Phosphatic pebble lags are the most common productive facies for microvertebrate faunas. Faunal components vary between producing localities from a dominance of fully marine or brackish-water forms (mostly chondrichthyans), to others with an abundance of aquatic and terrestrial tetrapods. Common bony fishes in these faunas include *Lepidotes*, amiiforms and pyncondonts. In addition to small amphibians and squamates, the more fresh-water microfaunas contain turtles, crocodyliforms, theropods, nodosaurs, ornithopods, and multituberculate and marsupial mammals.

ANATOMY OF THE BRAIN AND VESTIBULAR APPARATUS IN TWO PTEROSAURS: IMPLICATIONS FOR FLIGHT, HEAD POSTURE, AND BEHAVIOR

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Comparison of birds and pterosaurs, the two archosaurian flyers, sheds light on adaptation to an aerial lifestyle. The neurological basis of control holds particular interest in that flight demands on sensory integration, equilibrium, and muscular coordination are acute. We compared the brain and vestibular apparatus in two pterosaurs: a more basal form (*Rhamphorhynchus*, Jurassic, Solnhofen, Germany) and a derived pterodactyloid (*Anhanguera*, Cretaceous, Santana, Brazil). One skull of each was acid-prepared and then CT scanned to construct digital endocasts. We can confirm some previous findings: e.g., in both

taxa the cerebrum and cerebellum are expanded, displacing the optic lobes ventrolaterally, and olfactory areas are small. Although the general organization resembles birds, our findings corroborate the notion that pterosaurs had relatively smaller brains relative to body mass than do birds. This disparity probably has more to do with phylogeny than flight in that birds evolved from nonavian coelurosaurian theropods that already had established trends for greater encephalization. The enormous size of the cerebellar auricle (flocculus) was unexpected in the pterosaur endocasts, in both cases reaching or exceeding the volume of the optic lobes. Likewise, the semicircular canals are relatively very large. These findings are related in that the cerebellar auricle's role in extant taxa is largely to receive inputs from the vestibular system (semicircular canals, etc.). Thus, these pterosaurs clearly had a highly refined organ of equilibrium. Perhaps most exciting, orientation of the vestibular apparatus relative to the long axis of the skull was very different in these two species, suggesting dramatically different head postures. In *Rhamphorhynchus*, the long axis was more or less horizontal, whereas in *Anhanguera* it strongly angled down. These different head postures probably reflect differing behaviors, perhaps in regard to feeding, but also, given aerodynamic effects, in regard to flight.

STUDYING THE TRACKS OF EXTINCT ANIMALS—NEW METHODS AND NEW INFORMATION

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Vertebrate paleoichnology has the potential to resolve long-running debates of osteological reconstructions. Recognition of the hypothesis testing potential of tracks and development of more quantitative descriptive techniques will allow this area of study to become more integrated into "mainstream" paleontology.

Fossil footprints are a direct record of the locomotion of extinct animals. Thus, they can be used to test hypotheses of the locomotory mechanisms of extinct animals. Recent applications of this concept have resolved debates about the osteological reconstruction of some dinosaurs, such as iguanodontids, and other extinct animals including pterosaurs, although, other reconstructions e.g. of ceratopsids, remain contentious. New data from sauropod and ceratopsian trackways contribute to this debate and provide evidence for tighter constraint of osteological reconstructions.

An enduring problem in paleoichnological studies has been that of comparing footprint shapes quantitatively. The study of the shapes of vertebrate footprints, while necessary for ichnotaxonomy and analysis of track assemblages, has traditionally been sidelined in favor of tracksite documentation and more general track identification. Most recent studies on shape analysis have used linear measurements to define parameters which approximate the shape rather than quantitatively describing the shape itself.

Several new methods may be used in order to resolve ichnotaxonomic problems. Footprint shapes may be quantitatively described and compared mathematically, statistically or graphically. Preliminary studies have highlighted some problems and shown some promise in distinguishing certain footprints. Progress is being made in removing shape variation due to non-taxonomic factors.

New data and further development of new analytical techniques has and will improve the quality and utility of information from fossil trackways. Ichnological and osteological data has already started to become more integrated and this continuing trend will greatly increase our knowledge of the functional morphology, behavior and distribution of extinct animals.

THE MYTH OF LATEST CRETACEOUS CONTINENTAL DRAINING: RECONCILING PALEONTOLOGICAL AND GEOLOGICAL DATA SETS

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Paleontologists have recognized the similarity between latest Cretaceous (K) and Paleocene vertebrate paleofaunas of the North American Western Interior and faunas of the Recent Gulf Coast for nearly a century. Despite this, and the presence of marine and paralic deposits in Paleocene strata of the western Dakotas and eastern Montana, deposition in Wyoming and Colorado was reconstructed as entirely continental during the latest K and Paleocene. This interpretation relied on a lack of open marine shales to indicate absence of marine influence on the sedimentary basins. An overly simplistic, 2-D division between "marine" and "terrestrial" paleoenvironments thus emerged. The basal Lance Formation (68-65 Ma) and its equivalents (Medicine Bow, Ferris, and Hell Creek formations) in particular, are often depicted as sheet-like, continental successions. The presence of coastal and marine faunal elements (e.g., selachians, albulids, elopids, aspidorhynchids, sciaenids, and hesperornithiforms) has been largely overlooked or explained as representing "freshwater communities." Paleoclimatic studies have suggested that the unusual warmth of the Rockies region, as indicated by floral and faunal proxies, may have benefited from ameliorating effects of the Western Interior Sea up until the Eocene. The recognition of brackish water estuarine, distributary channel, and interdistributary bay deposits in the Ferris Fm. (66-63 Ma) and marine-influenced, paleovalley fills in the Hanna Fm. (?62-55 Ma) of southern Wyoming's Hanna Basin area was a major step in the resolution of these apparent paradoxes. Newly emerging paleontological and sedimentary data reveal that many of the latest K-Paleocene sedimentary successions in Wyoming's Laramide basins comprise a mosaic of flood plain, coastal and delta plain, bay, and estuary deposits. These successions represent depositional sub-environments of large fluvial deltas fed by river systems with high sediment yields. The terminal K marine regression was therefore not a continent-scale, eustatic drainage event, but simply the result of a massive influx of sediment.

PATTERNS OF EVOLUTIONARY CHANGE IN AN ADAPTIVE RADIATION: HYAENODONTIDAE (MAMMALIA: CREODONTA) FROM THE EARLY EOCENE OF WYOMING

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Study of the large collection of hyaenodontid remains from the early Eocene Willwood Formation of the Bighorn Basin, Wyoming, allows documentation of evolutionary patterns in some of the earliest known members of the family. Of biostratigraphic interest are a range extension of *Galecyon* from Wa-3 into Wa-6 and local extinction of *Pyrocyon* at approximately mid Wa-6. There is also an ephemeral increase in hyaenodontid diversity at during Biohorizon B. During this interval, at least three small-bodied, rare lineages, each closely related to a more broad-ranging, larger-bodied lineage, are present in the Bighorn Basin. In each case, the small lineage is sympatric with its larger, more abundant relative. The overall pattern of hyaenodontid evolution in the Willwood Formation is primarily one of anagenetic change, over which are superimposed a few more abrupt shifts, primarily at the beginning of Biohorizon B. Although all lineages show evidence for both size and morphologic change through the Wasatchian, the amount of change varies between lineages. In particular, while some lineages (i.e., *Pyrocyon*) show pronounced change in both size and morphology, others (i.e., *Prolimnocyon*) show little morphologic change, but appreciable size change. Morphologic differences indicative of dietary preferences also became much more pronounced during the early Eocene. While the carnassials and distal premolars of the earliest North American hyaenodontids are morphologically homogenous (except for *Arfia*), by the later Wasatchian there is clear evidence for more hypo- (*Prototomus*) and hypercarnivorous (*Pyrocyon*) forms. As such, the Bighorn Basin record of Hyaenodontidae helps document the nature of evolutionary change during an adaptive radiation. In this case, at the least, the primary contribution of speciation appears to have been the generation of taxonomic diversity, with morphological and ecological diversity being the products of within-lineage evolution.

DIMINUTIVE METOPOSAURID SKULLS FROM THE UPPER TRIASSIC BLUE HILLS (ADAMANIAN: LATEST CARNIAN) OF ARIZONA: ONTOGENETIC AND PHYLOGENETIC IMPLICATIONS

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Although metoposaurs represent one of the most commonly recovered vertebrate fossil groups from the Late Triassic in North America, collection of small specimens remains exceedingly rare. We identify two such specimens (MNA V8415 and UCMP V7308/175145), unearthed in the Petrified Forest Formation (Adamanian: latest Carnian) of east-central Arizona, as *Buettneria perfecta* and *Apachesaurus gregorii* respectively.

Sculptural elongation, when present on metoposaur crania, is generally considered indicative of adult morphology. We propose that the absence of this elongation in one of the two similarly sized individuals permits the ontogenetic differentiation of these two specimens, signifying immaturity in MNA V8415. Further, cranial suture patterns present on this juvenile are consistent with those that distinguish the adult morph of *Buettneria perfecta*. The uniformity of juvenile and adult sutural patterns in *Buettneria perfecta* implies stability of this character suite throughout the ontogenetic development of metoposaurs, thereby lending confidence to their application as species-specific characters.

Metoposaurs exhibit minimal variation across genera and species. Although a monophyletic Metoposauridae is well supported, morphological stability combined with abundant heterochrony has made evolutionary relationships amongst species difficult to assess. A new phylogenetic analysis—based on the reinvestigation of 21 characters across six species—strongly supports a monophyletic Metoposauridae. *Apachesaurus gregorii* and *Arganasaurus lyazidi*, previously regarded as basal metoposaur taxa, were found to be the most derived members of the clade. Characters supporting this nested position are associated with a secondarily derived reduction of the posterior cranium, likely attributable to a greater reliance on aquatic environments and plausibly the result of heterochronic mechanisms. This modified topology postulates that *Dutuitosaurus ouazzoiui* best represents the basal metoposaur condition, with elongate presacrals, separate pleurocentra, and retention of a notochordal notch.

A TAPHONOMIC ANALYSIS OF A FIRE-RELATED LATE TRIASSIC VERTEBRATE FOSSIL ASSEMBLAGE

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The Snyder quarry is a unique Late Triassic bonebed located near Abiquiu in north-central New Mexico. The locality is stratigraphically high in the Petrified Forest Formation of the Chinle Group and tetrapod biostratigraphy and lithostratigraphy place the quarry in the Revueltian land-vertebrate faunachron, which is mid-Norian (~210-215 Ma). This locality has yielded the remains of a wide variety of organisms, including phytosaurs, aetosaurs, theropod dinosaurs, reptiles, metoposaurs, osteichthyan fish, bivalves, conchostracans, and decapods as well as plant material.

A taphonomic analysis of the skeletal and plant material, as well as the sedimentology of the quarry, reveals that this deposit is the result of a catastrophic mass mortality event. The sediments of the deposit contain rip-up clasts from the surrounding floodplain, a significant portion of the bone and wood is aligned, there is a high density of bones over a large area, and there is a moderate degree of hydraulic sorting of the skeletal material. These data are evidence for very rapid movement and deposition of the bonebed. There is no evidence of abrasion on the bones, and there is a significant amount of associated charcoal, which is buoyant, indicating that transport was minimal.

The skeletal material is associated, and in rare cases articulated, demonstrating that the animals were in a state of partial decay prior to transport and deposition. There is no evidence of weathering of the bones or of vertebrate scavenging, which is further evidence for the rapid burial of the material. Also, an age profile was constructed for the phytosaurs, revealing a high percentage of subadult or young adult animals. Scanning electron microscopy and reflectance microscopy work on the charcoalized wood show that the internal structure of the cell walls has been homogenized, and the reflectance of the material is substantially higher than other forms of coal. This indicates that the wood was burned in a moderate temperature (<450˚C) ground fire. Thus, the evidence from the Snyder quarry deposit best fits the scenario of a catastrophic Late Triassic wildfire.

EGGSHELL DIVERSITY OF THE UPPER CRETACEOUS OF DINOSAUR PROVINCIAL PARK, ALBERTA, CANADA

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The richly fossiliferous rocks of Dinosaur Provincial Park have produced only about 220 fossil eggshells, all of which occur as isolated fragments. Eggshell fragments were recovered from the Dinosaur Park and Oldman formations mainly by screen-washing of sediments from bonebed and microvertebrate sites. Of the 30 fragments examined using scanning electron microscopy, seven distinct types of eggshell were recognized based on characteristics such as pore morphology, shell thickness, ornamentation, and microstructure. Twenty-six fragments are characterized by the presence of an inner mammillary zone and outer squamatic/prismatic zone and can be attributed to theropods. Among these 26 fragments are five eggshell types, including three with thick shells that resemble previously described dromaeosaurid, troodontid, and oviraptorosaur eggshell. The other types of theropod eggshell are thin and may belong to either avian or non-avian theropods. Of the remaining fragments, two are characterized by a single structural zone of radiating, acicular calcite and thus can be identified as hadrosaurid eggshell. Finally, two shell fragments have a single structural zone of coarse, tabulate wedges, which is indicative of crocodilian eggshell. Although the sample size of eggshell from Dinosaur Provincial Park is small, the diversity of eggshell types is unexpectedly high with seven oospecies. In strong contrast with the diversity of skeletal taxa at Dinosaur Provincial Park, which is dominated by ornithischians, theropods comprise more than 85% of the oologic fauna.

LOWER JAW CHARACTER TRANSFORMATIONS OF EARLY SARCOPTERYGIANS AND THEIR PHYLOGENETIC AND FUNCTIONAL SIGNIFICANCE

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This study presents a first-time description of *Achoania* lower jaw, new observations on lower jaws of *Psarolepis*, *Diabolepis* and onychodonts, and a comparative review of possible evolutionary trends in sarcopterygian lower jaws.

New findings include: 1) *Achoania* confirms the five-coronoid condition in stem group sarcopterygians (lying in a shallow trough floored by the meckelian bone and carrying no strong fangs). 2) A new sarcopterygian genus in review suggests that the most anterior and the posterior coronoids were lost in the transition from the five-coronoid condition to the three-coronoid condition typical of tetrapodomorphs and dipnomorphs. 3) Juvenile *Diabolepis* lower jaw with marginal dentary teeth in a single linear row lends ontogenetic support to the theory that marginal teeth represent the primitive dipnoan condition. 4) Mixed tooth growth pattern in *Diabolepis* (dipnoan-like radially arranged tooth rows mixed with non-dipnoan-like addition of new teeth among old teeth) suggests that dipnoan dentition growth pattern developed stepwise from non-dipnoan pattern. 5) Onychodonts probably have no coronoids.

Lower jaw features mapped onto successive nodes in a simplified cladogram reveal general trends of character changes. For instance, stem group sarcopterygians differ from *Mimia* by the anterior extension of prearticular ventro-mesial to the coronoid series, strong parasymphysial tooth whorls and weakly developed coronoid fangs. The new genus in review and more crown-ward groups develop a stable three-coronoid condition with enlarged adductor fossa. *Youngolepis*, *Diabolepis* and *Melanognathus* reveal stepwise changes (both morphologically and ontogenetically) to the dipnoan dentition. *Kenichthys*, osteolepids, and *Eusthenopteron* reveal a trend toward loss of parasymphysial fangs and development of strong coronoid fangs, a trend later reversed in *Ichthyostega*. These changes may reveal different feeding mechanisms among sarcopterygians.

MINERALOGICAL STUDY USING OPTICAL MICROSCOPY ASSOCIATED WITH ENERGY DISPERSIVE X-RAYS (SEM/EDS): TECHNICAL APPLICATIONS AS A SUPPORT TO THE TAPHONOMIC STUDY OF A FOSSILIFEROUS SITE FROM THE BRAZILIAN UPPER CRETACEOUS

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Fieldwork was carried out at the "Tartaruguito site" located at the Municipality of Pirapozinho (22˚13'144"S, 51˚26'006"W), São Paulo State, Brazil (Bauru Group, Adamantina Formation), in order to establish the extent to which taphonomic agents affected that fossil assemblage. This site provided a great number of well preserved testudines remains, besides some crocodylomorphs and fish material. Since the degree of bone preservation depends not only on time but mainly on environmental factors, it is important to analyze macro and microstructures of the bones. For that purpose, transverse polished thin-sections of a turtle carapace collected at this site were prepared and analyzed to determine the mineralogical assemblage present in this specimen.

The thin sections were examined by petrographic polarizing microscope (transmitted light) and analyzed by energy dispersive spectroscopy (EDS) in a low vacuum scanning electron microscope (SEM). At plane polarized light it shows a brown groundmass of fossil bone exhibiting some dark contour lines. These structures are filled by colorless grains that occur in well-developed crystals and in rounded, sub-rounded and elongated shapes. In crossed polarized light, the colorless grains show extreme birefringence being identified as calcite ($CaCO_3$), sometimes with some clear and well developed grains of quartz (SiO_2) inclusions. The fossil bone is composed of calcium phosphate apatite ($CaCO_3$) and shows an amoeboid shape, being identified by the following features: anisotropy, high relief and low birefringence, light yellow or yellowish brown, and rarely show pleochroism. Some grains show zonal distributions of the color and all grains present wave extinction and commonly have a fibrous aspect. The cryptocrystalline variety of apatite, collophane, appears isotropic in the outer zone. EDS/SEM analyses confirm the presence of the minerals mentioned above, presenting a semi quantitative results as follows: calcite 90.29% Ca with 6.66% P; apatite with 67.77% Ca and 19.56% P. No analyzes were performed for the quartz.