

FIRST DESCRIPTION OF AN ARTICULATED MANUS OF A HEGETOTHERIINE NOTOUNGULATE, BASED ON A SPECIMEN FROM THE MIDDLE MIOCENE OF QUEBRADA HONDA, BOLIVIA

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Hegetotheriids were small to medium-sized South American endemic ungulates of the suborder Typotheria, and their fossil record extends from the early Oligocene to the early Pleistocene. The family is traditionally divided into two subfamilies, Pachyrhukhinae and Hegetotheriinae, though the monophyly of the latter is still uncertain. Most of the skeleton has been described for some species of both groups, but the manus has only been documented in pachyrhukhines. In this study, we provide the first description of the manus of an hegetotheriine based on UTAF-V-001591, a well-preserved partial skeleton of *Hemihegetotherium trilobus* from the middle Miocene (Laventan South American Land Mammal Age) Quebrada Honda Fauna of southern Bolivia. The manus of this specimen preserves two carpals, metacarpals (Mc) II–V, all phalanges of digits II–III, and a partial proximal phalanx of digit IV. It also includes a partial mandible (confirming its identification as *H. trilobus*), an articulated pes (with the cuboid, metatarsals (Mt) II–V, and phalanges of digits III–V), and several partial limb bones. The manus of *H. trilobus*, like that of the pachyrhukhines *Pachyrhukhos*, *Propachyrucos*, and *Paedotherium*, is tetradactyl with three relatively robust digits (II, III, IV), a reduced digit V, and apparently no pollex. Manual digit reduction could have occurred either early in the evolution of hegetotheriids (prior to the divergence of these two groups) or in parallel in hegetotheriines and pachyrhukhines. A mesaxonic pes with robust Mt II–IV, reduced Mt V, and no digit I has been documented in the hegetotheriines *Prohegetotherium*, *Hegetotherium*, and *Hemihegetotherium achataleptum* and the pachyrhukhine *Pachyrhukhos*. (*Propachyrucos* and *Paedotherium* are also tetradactyl but have digit proportions that are less strictly mesaxonic.) The overall form of the pes of *H. trilobus* resembles that of *H. achataleptum*. Although Mt V has not previously been reported in *H. achataleptum*, facets on Mt IV of this species have been interpreted as suggesting a small Mt V was present. This interpretation is supported by the articulated pes of this specimen of *H. trilobus*, which preserves a small Mt V. In addition to clarifying the anatomy of *H. trilobus*, the specimen described here will provide new data for studies of the functional morphology of hegetotheriines and may yield characters useful for clarifying phylogenetic relationships among hegetotheriids.

Grant Information

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Technical Session XX (Saturday, October 29, 2016, 2:30 PM)

JUST HOW DIFFERENT? QUANTIFYING VERTEBRAL DIVERSITY IN TEMNOSPONDYLS

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The size and shape of vertebrae within the vertebral column are influenced by ecology and phylogeny, in addition to body size. Parameters such as total vertebral number, degree of regionalization, dimensions and angles of vertebral processes have been correlated with locomotor type, performance, and axial mobility. Despite studies across a wide range of extant taxa, and a history of vertebral morphology changing to suit new forms of locomotion, these data have not been expanded towards understanding basal tetrapod biomechanics. Yet, this ancestral assemblage underwent major biomechanical innovations which enabled the evolutionary water–land transition, critical to the explosive diversification of land vertebrates. Temnospondyls were a diverse set of stem-amphibians that arose in the Middle Mississippian (346 Ma) and went extinct in the Early Cretaceous (120 Ma). Early works on temnospondyls described and categorized their diversity of ecologies, habitats, and gross morphologies, including complex vertebral morphologies. However, no study has quantified temnospondyl vertebral diversity in, or addressed their effects on, biomechanical metrics such as overall spinal stiffness, or lever arms of epaxial musculature. We conducted a 2D geometric morphometric study of shape differences and investigated the biomechanical consequences of pre-sacral vertebral morphology in the temnospondyls by calculating, plotting, and analyzing principal components to determine disparity patterns. We document the diversity of the intercentera and neural spines. Principal components separate the temnospondyls into clusters consistent with their phylogeny and, biomechanically relevant, habitat. The clade Rhachitomi had terrestrial and aquatic members that clustered with other temnospondyls of similar habitats but in different clades. This project lays the groundwork for a series of quantitative studies to understand differences within this diverse group and to better understand key innovations in the axial column for terrestrial locomotion.

Poster Session I (Wednesday, October 26, 2016, 4:15–6:15 PM)

THE VERTEBRATE ASSEMBLAGE OF THE MADSEN BONE BED, LOWER JUDITH RIVER FORMATION (MCLELLAND FERRY MEMBER, CAMPANIAN), NORTH-CENTRAL MONTANA

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The Judith River Formation is a relatively poorly sampled geologic unit in comparison to other formations deposited in the Campanian of North America. The formation is chronostratigraphically and lithostratigraphically equivalent to the uppermost Foremost and Oldman Formation in Alberta. The lower half of the Judith River Formation, the McClelland Ferry Member, was deposited during the regressive phase of the western interior sea, and as such records the transition from marine to non-marine environments. The fauna of this unit is particularly poorly sampled. Here we report on the vertebrate assemblage of a recently excavated bonebed in the upper, sandy

interval of the McClelland Ferry Member located near Malta, Montana. Approximately 70 vertebrate fossils were collected from the multi-taxic bonebed. The site is mixed and includes both macrovertebrate and microfossil components, but majority of the fossils collected are larger than 5 cm. The bones were identified to the lowest taxonomic level and an illustrated faunal list has been compiled. The fossils originated from a diverse set of terrestrial and freshwater species. Of the bones excavated, 42% belong to hadrosaurid dinosaurs, 23% belong to saurischian dinosaurs, 23% belong to Testudines, and 10% belong to crocodylians. Stratigraphically, the site occurs in strata that are equivalent to the Comrey Sandstone zone of the Oldman Formation, allowing comparison of this fauna with sites in Alberta, which are located over 100 km further west. The single sampled microsite from the Comrey zone in the Manyberries region of Alberta has a greater relative abundance of fish and salamanders, with hadrosaurs being the most abundant reptile. However, the difference in fossil size distribution of these two sites may account for some of the differences in faunal composition. The microvertebrate fauna of the lower McClelland Ferry Member of the Judith River Formation is reasonably well documented, but there are few, if any, microfossils known from the upper portion this member, which records the maximum regression of the western interior sea. The analysis of the Madsen Bonebed contributes new data on the faunal composition and paleoecology of the Judith River Formation.

Technical Session VIII (Thursday, October 27, 2016, 3:45 PM)

FIRST COMPLETE SKULL OF A FOSSIL FLYING SQUIRREL FROM THE MIOCENE OF CATALONIA

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Flying squirrels (Sciuridae: Pteromyini) are relatively common and diverse in the European Miocene, although they are mostly known from isolated cheek teeth, mandibles and maxillary fragments. Due to the lack of postcranial material, their inclusion into the Pteromyini has been questioned, because truly diagnostic characters only occur in the carpus. Here we report two skulls that, on the basis of dental morphology, are assigned to *Miopetaurista neogrivensis*, a large-sized 'flying' squirrel known from the middle to early late Miocene of Eurasia. The recovered material comes from sites ACM/C5-D1 and ACM/C8-AF of Abocador de Can Mata, located in the Vallès-Penedès Basin (Catalonia, Spain) and with an age of 11.6 Ma. Although the skulls are almost complete, both are crushed, either dorsoventrally or laterally in a slightly oblique angle. The main fragments are only slightly displaced and not plastically distorted. To reconstruct the original skull shape, these specimens were micro-CT scanned and the different bone fragments were digitally individualized. The virtual models of each fragment were then matched with one another by fitting the fractures so as to reconstruct uncrushed bones, mirroring them when required. Finally, a complete 3D model of the undistorted skull was generated as a composite of the models of the two specimens. In addition, CT-scanning enabled the observation of the internal morphology of key anatomical structures, such as the tympanic cavity. The robust appearance of the skull is very similar to that in extant large-sized squirrels, particularly the flying squirrels *Aeromys* and *Petaurista*. Furthermore, it shares with those taxa a short and wide rostrum, and short and robust postorbital process. Other details are strikingly similar, such as the inflation of the bulla, the presence of a marked jugal process in the zygomatic arch and the number of septa (2 to 3) in the tympanic cavity. Most of the smaller flying squirrels show more elongated muzzles, longer postorbital processes and a higher number of septa. Pending the study of postcranial material, the remarkable number of similarities indicates that *Miopetaurista* is indeed a flying squirrel.

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Colbert Prize (Wednesday–Saturday, October 26–29, 2016:15–6:15 PM)

USING ICHNOFOSSILS AND PALEOSOLS TO RECONSTRUCT THE MIDDLE MIOCENE PALEOENVIRONMENT OF QUEBRADA HONDA, BOLIVIA

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The Neotropics are home to exceptional levels of mammalian diversity, but few fossil-producing localities document the history of this unique fauna. La Venta, Colombia, and Quebrada Honda, Bolivia are well-sampled, roughly contemporaneous (13–12 Ma) sites that preserve the remains of many extinct nonvolant Neotropical mammals (59 and 30 genera, respectively). Almost no mammalian genera are shared between the two sites, and this could reflect climate and/or habitat differences. In this study, we use paleopedology and ichnology as independent lines of evidence to elucidate the habitat of Quebrada Honda and test this hypothesis. The paleosols of Quebrada Honda are weakly to moderately developed and composed primarily of brown-to-red silts, silty sands, and mudstones. They are interpreted as Entisols and Inceptisols that formed in floodplains. The suite of ichnofossils present within the paleosols include cm-to-dcm-scale, horizontal-to-vertically oriented mottled, passively filled burrows, and cm-scale subvertically-oriented meniscate and pelleted back-filled burrows. Horizons of *Celliforma* and *Coprinisphaera* are present in the paleosols, as are dcm-scale calcified burrows with cylindrical chambers. These ichnofossils are interpreted as dwelling, feeding, and breeding structures of solitary social insects, and dwelling structures of small mammals, respectively. Rhizoliths include mm-scale rhizotubules, cm-scale rhizohaloes, and dcm-scale rhizocretions. The rhizotubules and rhizohaloes are interpreted as roots of grasses and other small herbaceous plants while the rhizocretions

are interpreted as taproots of medium to large plants such as shrubs and trees. Together, paleosol and ichnofossil data suggest that Quebrada Honda fossils were preserved in savannahs proximal to alluvial systems in a seasonal, humid to sub-humid climate with mean annual precipitation (MAP) of ca. 1000 mm. This inferred paleoenvironment differs from that of La Venta, which has been reconstructed as a mixture of river-associated tropical forests and successional stages thereof with MAP of 1,500–2,000 mm, and indicates that dissimilar habitats could account for many of the differences between the mammal faunas of these two important fossil sites.

Grant Information

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Colbert Prize (Wednesday–Saturday, October 26–29, 2016:15–6:15 PM)

SOFT TISSUE RECONSTRUCTION AND VISUAL FIELDS OF DINOSAURS AND THEIR EXTANT RELATIVES

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The visual abilities of dinosaurs as they relate to ecology and behavior have been the subject of recent interest. Reconstructing orbital soft tissues has received little attention, and, if not taken into account, the eyeballs of dinosaurs may be mis-sized or positioned inaccurately, leading to poor estimates of visual fields and spurious conclusions about behavior and ecology. Intact heads of 15 species of avian, crocodylian, and squamate specimens were subjected to high-resolution, iodine-enhanced microCT scans (diceCT), and several dozen additional avian specimens were microCT scanned without diceCT. Orbits of specimens were dissected to validate the CT studies and to identify the osteological correlates for orbital soft tissues, including the extraocular muscles, cranial nerves, Harderian gland, lacrimal gland, nasal gland, eyelids, supraorbital membrane, subocular ligament, and nasolacrimal duct. Soft tissues, endosseous labyrinths, and cranial endocasts were segmented in Avizo and soft tissues were modeled in Maya. Eyeball size was measured directly and compared with estimates using regressions from the literature based on optic nerve foramen diameter and other measures. To assess which proxies for eyeball size are most robust (and hence useful for restoring extinct taxa), different estimates of eyeball size and position were modeled in Maya for each extant sample taxon based on several different criteria (including diameters of the orbit, scleral rings, and optic nerve foramina). To test these proxies, eyeball models were re-inserted along with accessory orbital soft tissues into digitized skulls. If the digital models of the eyeball accessory tissues, and/or bones overlapped, the model was rejected as an overestimate. The results indicate that reconstructing accessory soft tissues in the orbits of extant diapsids can provide upper limits on estimates of eyeball diameter and axial length whereas lower limits are currently less constrained (although under study). Optical parameters including focal length and monocular visual field, which depend in part on eyeball size, shape, and position, were modeled based on these constraints. Visual fields based on these optical parameters were modeled and tested against empirical measurement of visual fields in the literature. The outcomes of these extant studies will subsequently inform reconstructions of dinosaur visual abilities in a later phase of this project.

Grant Information

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Poster Session I (Wednesday, October 26, 2016, 4:15–6:15 PM)

BRIDGING THE GAP BETWEEN ASIAN AND EUROPEAN FAUNA WITH THE GAZELLES OF THE CHU FORMATION IN THE KOCHKOR BASIN, KYRGYZSTAN

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Kyrgyzstan has a very limited published vertebrate fossil record, despite the Neogene terrestrial sediments that blanket much of the country. Recent fieldwork in Kyrgyzstan has produced a large number of fossils, and here we describe new bovid material from the Kochkor Basin of Kyrgyzstan that we can confidently assign to *Gazella*. Most Neogene fossil sites in the Kochkor Basin are ungulate dominated, and gazelles are currently the fourth most common taxon after *Chilotherium* (rhino), *Hipparion* (horse) and *Pliocervus* (deer).

The *Gazella* sample from Kochkor contains over a dozen horn cores, a partial skull, multiple jaws and teeth and extensive postcranial material, all of which are consistent in size, suggesting the presence of only one species of gazelle. *Gazella* is found in several localities and strata, but all are confined to the late Miocene Chu Formation from horizons estimated to be roughly 7 million years old from biostratigraphic and paleomagnetic dating.

The specimens are significantly smaller than previously collected *Gazella* material from other parts of Central Asia, which is mostly assigned to *Gazella dorcadoides*. The type material for *G. dorcadoides* is larger, more robust, and has more posteriorly curved horn cores than the Kyrgyz specimens. The Kyrgyz *Gazella* material is also significantly smaller than gazelle material of the Chinese 'Hipparion Faunas' typically used for comparison. We hypothesize that the *Gazella* from Kochkor Basin is a new species, representing an earlier evolution of a smaller-bodied lineage adapted to high elevation and cold.

Poster Session I (Wednesday, October 26, 2016, 4:15–6:15 PM)

A TALE OF TWO TEMNOSPONDYL-DOMINATED FAUNAL ASSEMBLAGES FROM THE MIDDLE TRIASSIC OF CENTRAL INDIA

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Denwa Formation of Central India has yielded a Middle Triassic faunal assemblage dominated by the temnospondyls. It is divided into the Lower, Middle, and Upper Denwas among which the Middle and the Upper part yield vertebrate fossils. The Upper

Denwa Formation has red mudstones, calcirudites and greenish silt-fine sand alternations whereas the Middle Denwa Formation is dominated by violet mudstones along with fine sand and heterolithics. The temnospondyl fossils present in those two types of mudstones are markedly different by their sizes. The violet mud dominated Middle Denwa comprises primarily of *Cherninia denwai* among the temnospondyls along with a few remains of dicynodonts and rhyncoosaurs. The red mudstone bearing Upper part of Denwa has *Cherninia denwai* and *Stanocephalous crookshanki* along with rare dicynodonts, fish scales, and archosaur remains. At least three new species of temnospondyls, that are yet to be identified, are also present there. The temnospondyls belonging to the violet mud is larger and robust, up to nearly 1 m in skull length while the same in overlying red mud looks impoverished with maximum skull length of the temnospondyls hardly reaching 0.5 m. The thickness of the bones of the skulls or interclavicles is almost 1 cm at places within violet mud of Middle Denwa while that within the red mud of Upper Denwa is merely 0.2 cm. Specimens of *Cherninia* present both in violet and red mud, also maintain size discrepancy. The sedimentology of the two units does not show any major differences in the depositional pattern. Only the red-coloured mudstones and the presence of calcirudites are specific to the Upper part of Denwa. The geochemistry of the red mudstones, not very directly though, indicates a hot, semi-arid climate. Also the presence of calcirudites in the Upper part of Denwa Formation is suggestive of intermittent periods of aridity. Layers of fish scale beds alternating with temnospondyl rich red mudstones are also indicative of intermittent aridity. The presence of fewer amounts of unio bivalves in the red mud than in the violet mud further indicates unfavourable habitat conditions. On the contrary numerous roots and rootlets are present in the violet part indicating more vegetation. The lack of nutrient supply combined with higher aridity of climate is perhaps accountable for the distinctly smaller size of temnospondyls in the red mudstone dominated Upper Denwa Formation in contrast to the robust temnospondyls present in the milder climate, more nutrient and favourable condition bearing violet mudstone of Middle Denwa Formation.

Poster Session II (Thursday, October 27, 2016, 4:15–6:15 PM)

EARLIEST CARBONIFEROUS DIPNOI: POST-HANGENBERG RECOVERY AND THE DAWN OF A NEW ERA OF LUNGFISH.

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A new specimen of a large skull from lowest Tournaisian deposits (VI palynozone, less than 1 my from the Devonian–Carboniferous boundary) of southern Scotland represents the earliest occurrence of a dipnoan following the Hangenberg extinction event in the Famennian. Comprising a near-complete cranial dermal skeleton, the arrangement of the skull roofing bones resemble that of the well-known Carboniferous genus *Ctenodus*. Alongside other dipnoan remains, including toothplates, operculi, isolated skull bones and post-cranial material, the fossil record of lungfish in 'Romer's Gap' can now be demonstrated to comprise a diverse and morphologically disparate fauna indicating rapid post-extinction recovery and niche partitioning by the middle-upper Tournaisian (CM palynozone). The resemblance of the new specimen to *Ctenodus* implies that lungfish skull morphology was evolving at a slower rate than tooth morphology. The new lowest Tournaisian specimen does not exhibit reduction of skull roofing bones seen in younger Carboniferous and more recent lungfish whereas new Tournaisian lungfish dentitions are highly variable in form. Diversification of lungfish dentition is associated with the contemporaneous appearance of the earliest record of an established brackish to freshwater bivalve fauna, a possible key food source for lungfish. Furthermore, the new material from the lowest Tournaisian is large with estimates of full body size ranging between 20 cm to exceeding 1 m in length. Tournaisian lungfish were among some of the largest organisms to inhabit the waters in the post-Hangenberg extinction world and demonstrate a trend in increasing body size following extinction rather than body size stasis or reduction as previously proposed for sarcopterygian taxa at this time.

Grant Information

Callidus Services Ltd.

Poster Session I (Wednesday, October 26, 2016, 4:15–6:15 PM)

THREE DIMENSIONAL MORPHOMETRIC ANALYSIS OF THE CRANIAL ONTOGENY OF *MASSOSPONDYLUS CARINATUS* BASED ON CT RECONSTRUCTIONS

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Understanding ontogenetic variation in dinosaurs is necessary because it informs taxonomic hypotheses, elucidates larger macroevolutionary patterns, and allows for the inference of behavioural traits such as parental care, feeding and locomotion. *Massospondylus carinatus* Owen 1854 is an emblematic South African basal sauropodomorph dinosaur, and it presents an ideal study system for dinosaurian cranial ontogeny because it has a range of referred specimens aged from hatching to adult. This study reconstructs individual skull bones of a size series of *M. carinatus* using CT scans and qualitatively and quantitatively assesses the ontogenetic variation between these bones. The results show clear differences in the development between facial bones and braincase bones (both in the amount of growth and in the correlation between size and shape). Several morphological differences are also identified between juveniles and adults. There is a possibility that several species are represented in the *M. carinatus* sample, based on both the qualitative and quantitative assessments.

Grant Information

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