

cropped out at the same quarry in Mifune Town. To evaluate the taxonomic reconstruction of the vertebrates from the Mifune Group, I present here the taphonomic and sedimentological data of the bonebed in the Mifune Group. The facies of bonebed 1004-A is a greenish gray siltstone alternated with thin fine sandstone beds representing reverse grading, and siltstone that contains large amounts of plant fragments. Therefore this facies is interpreted as a levee and flood plain deposit. Although the collected specimen is still insufficient, taxonomic composition of bonebed 1004-A might be monodominant. The material consists of isolated theropod, a few crocodyliforms, and turtle elements. The facies of bonebed 1004-B, lying under 1004-A, is a pebbly sandstone accompanied by rip-up mud clasts. The sandstone units show fining-upward, are cross-stratified, and have an erosional basal contact. This facies may suggest channel-fill fluvial deposits. About 1100 specimens indicate that this bonebed has multidominant and high diversity taxa; the taxonomic composition consists of at least 3 lineages of theropods, hadrosauroid, ankylosaurid, crocodyliforms, 6 genera of turtles, actinopterygians, and eutherian mammals. Because there are several degrees of abrasion stages and breakage classes, it suggests variable accumulation processes on each of the bones. It is considered that the remains in bonebed 1004-A were preserved in the overbank deposit without reworking, while reworking and concentration of fossils from the previous sediments formed bonebed 1004-B in the meandering river system. Although both marine and paralic depositional settings are abundant in the Upper Cretaceous of Japan, these results indicate the terrestrial and freshwater vertebrate paleocommunity was also diverse in the Late Cretaceous of the active margin of East Asia.

Technical Session XIV, Wednesday 9:30

#### ANATOMY OF THE BASAL THEROPOD *TAWA HALLAE* AND ITS IMPLICATIONS FOR EARLY DINOSAUR PHYLOGENY

IRMIS, Randall, University of Utah, Salt Lake City, UT, USA; NESBITT, Sterling, University of Texas, Austin, TX, USA; SMITH, Nathan, Field Museum of Natural History, Chicago, IL, USA; TURNER, Alan, Stony Brook University, Stony Brook, NY, USA; DOWNS, Alex, Ruth Hall Museum of Paleontology, Abiquiu, NM, USA

Much of our understanding of early theropod dinosaur evolution relies on the Late Triassic taxa *Herrerasaurus* from South America and *Coelophysis bauri* from western North America, two disparate body plans that share few derived character-states. *Tawa hallae*, a basal theropod from the Petrified Forest Member of the Chinle Formation in northern New Mexico (Ghost Ranch), fills this morphological gap. Known from multiple well-preserved and nearly complete skeletons, *Tawa* provides new osteological data for understanding basal theropod evolution and early dinosaur relationships. *Tawa hallae* shares several characters with neotheropods, such as a subnarial gap between the premaxilla and maxilla, pneumatic openings in the cervical vertebrae, and a symmetrical, blade-like fourth trochanter on the femur, whereas it also retains some plesiomorphic features that are widespread among basal dinosaurs, including a restricted antorbital fossa on the maxilla, a short pre-acetabular process of the ilium, and an elongated metatarsal I. To test the phylogenetic relationships of *Tawa* and basal dinosaurs, we performed a parsimony analysis on a comprehensive dataset consisting of 41 taxa and 315 characters. *Tawa* is recovered as the sister-taxon to Neotheropoda with strong character support values. The transitional mosaic of character-states present in *Tawa* strengthens the placement of herrerasaurids, *Chindesaurus*, and *Eoraptor* as basal theropods rather than basal saurischians. Crucially, *Tawa* helps polarize character-states within Neotheropoda, demonstrating that many features previously thought to be coelophysoid synapomorphies may actually represent neotheropod plesiomorphies. This further splits the traditional Coelophysoidea into a paraphyletic grade of basal neotheropods, which reduces several Late Triassic and Early Jurassic theropod ghost lineages. These data suggest that *Tawa* is vital to understanding character evolution and phylogenetic diversification among early dinosaurs and neotheropods alike.

Technical Session XIV, Wednesday 12:00

#### UNCOVERING THEROPOD EGGS: WATER VAPOR CONDUCTANCE AND NESTING STRATEGY OF *TROODON*

JACKSON, Frankie, Montana State University, Bozeman, MT, USA; JACKSON, Robert, Montana State University, Bozeman, MT, USA; VARRICCHIO, David, Montana State University, Bozeman, MT, USA; ZELENTSKY, Darla, University of Calgary, Calgary, AB, Canada

The water vapor conductance rate ( $G_{H_2O}$ ) calculated for a fossil egg provides important information on nesting environment when compared to eggs of modern reptiles and birds. Most avian eggs are exposed to the atmosphere during incubation, and the eggs exhibit low porosity and gas conductance that aid in water conservation, while permitting adequate oxygen and carbon dioxide exchange. In contrast, reptiles typically incubate their eggs underground or in vegetation mounds characterized by high humidity and low oxygen conditions. Accordingly, their eggs are far more porous and typically have  $G_{H_2O}$  values four to eight times greater than those of birds. *Troodon* egg clutches consist of tightly packed, elongate eggs standing near vertical within the substrate. A lithologic change occurs at roughly two-thirds of the egg length. Potential incubation modes hypothesized for troodontid eggs include complete burial within a substrate or partial burial with the upper portion covered by a vegetation mound or by an attending adult. To test these hypotheses, we analyzed eggshell thin sections from five locations on the asymmetrical *Troodon* egg. The pore density in the upper half of the egg is 2x greater than in the lower portion. This variation in porosity suggests the presence of distinct incubation media for the lower and upper portions of the egg. The mean  $G_{H_2O}$  of 46 mg water per day Torr calculated for the entire egg is comparable to the 45 mg of water per

day Torr of an avian egg of comparable mass. This low water vapor conductance supports previous interpretations that the eggs were partially buried and incubated by an adult.

Physical Drivers and Marine Tetrapod Evolution, Monday 9:15

#### PHYSICAL DRIVERS OF EVOLUTION AND THE HISTORY OF THE MARINE TETRAPOD FAUNA OF ANGOLA

JACOBS, Louis, Roy M. Huffington Department of Earth Sciences, Southern Methodist University, Dallas, TX, USA; POLCYN, Michael, Roy M. Huffington Department of Earth Sciences, Southern Methodist University, Dallas, TX, USA; ARAÚJO, Ricardo, Roy M. Huffington Department of Earth Sciences, Southern Methodist University, Dallas, TX, USA; STRGANAC, Christopher, Roy M. Huffington Department of Earth Sciences, Southern Methodist University, Dallas, TX, USA; MATEUS, Octávio, Departamento de Ciências da Terra (CICEGe-FCT), Universidade Nova de Lisboa, Lisbon, Portugal

Modern marine species populations are often evaluated in terms of bottom-up, resource limited structure, or top-down, predator controlled structure. In a larger timeframe, investigation of physical drivers in marine tetrapod evolution relies on the recognition of patterns and the correlation in timing of physical events with biotic change. However, it has been demonstrated through the study of fossil cetaceans that a broader deep-time perspective within a top-down or bottom-up framework is informative. Here we examine the fossil record of Cretaceous marine tetrapods in Angola to discern patterns that may reflect physical drivers of evolution, and that are also relevant to population structure. In modern marine ecosystems, distribution patterns reflecting primary productivity are indicative of bottom-up control. In the fossil record, productivity-controlled distribution patterns can also be perceived. Physical parameters resulting in environmental stability, sea-level change, oceanic anoxic events, paleoclimate, and paleogeography are examined in comparison with taxonomic diversity and life history patterns. Mosasaurs originated during a time of high global temperatures and shallow temperature gradients. As upper-trophic-level species of modest size and plesio-pedal limb structure (capable of terrestrial locomotion), early mosasaurs were subject to both top-down and bottom-up pressures. The attainment of larger size coupled with emigration and biogeographic distribution in areas of high primary productivity, and niche differentiation shown by  $\delta^{13}C$  values, indicate bottom-up pressures. Productivity along the African coast since the formation of the Atlantic Ocean facilitated the co-occurrence of diverse marine tetrapods through time, and has culminated today in the Benguela large marine ecosystem. Just as the current Benguela ecosystem has tetrapod species populations dominated by both bottom-up (cetaceans) and top-down strategies (sea birds and pinnipeds), so too did the Cretaceous community, with mosasaurs and plesiosaurs having predominantly bottom-up population structure, while sea turtles and pterosaurs were more subject to top-down pressures.

Poster Session IV, (Wednesday)

#### ON THEIR KNEES: DISTAL FEMUR ASYMMETRY IN UNGULATES AND ITS RELATIONSHIP TO BODY SIZE AND LOCOMOTION

JANIS, Christine, Brown University, Providence, RI, USA; SHOSHITAISHVILI, Boris, Brown University, Providence, RI, USA; KAMBIC, Robert, Brown University, Providence, RI, USA

Distal femur asymmetry (where the medial trochanteric ridge is larger than the lateral one) has been observed in horses, where associated with a stay apparatus, and bovids, where associated with open habitat preference. We measured femora of 63 species of ungulates (including 21 extinct species, plus 3 proboscideans, and 3 carnivorans) and plotted the degree of asymmetry against a body size estimate (average femur cross-sectional diameter). Carnivores, camelids, and proboscideans show little asymmetry. Within other ungulates there is a clear correlation between the degree of asymmetry and body size. Within ruminant artiodactyls asymmetry also correlates with habitat: open habitat species have more asymmetric femora than closed habitat ones, a pattern also seen among rhinos and tapirs. Among equids, extinct brachyodont species (assumed to be closed habitat) have a lesser degree of asymmetry than hypsodont ones (open habitat). Both the lack of asymmetry in camelids and proboscideans, and the greater degree of asymmetry among open habitat forms, imply a correlation with locomotor behavior. Most ungulates use the gallop gait at high speeds, during which they land on a single hind limb from a period of suspension. Neither camelids (habitual pacers), nor proboscideans (whose fast gait is an amble), would be likely to experience this type of hind limb stress. (Interestingly, the included chalicotheres and brontotheres show little asymmetry, indicating an elephant-like, versus rhino-like, gait.) Additionally, open habitat ungulates would be more likely to habitually gallop than closed habitat ones. We propose that distal femur asymmetry in ungulates is related to supporting the body mass, including a large gut mass, during the gallop. (The issue of gut mass may explain why large cursorial carnivores do not exhibit femoral asymmetry.) By analogy with humans, where a larger lateral trochanter resists lateral dislocation of the patella, the larger medial trochanter in ungulates may resist medial patella dislocation. Scaling factors (e.g., gut mass versus muscle cross-sectional area) would make this issue more acute in larger galloping ungulates, hence their greater degree of femoral asymmetry.

**Program and Abstracts**

October 2010



**70th Anniversary Meeting  
Society of Vertebrate Paleontology**

David L. Lawrence Convention Center, East Lobby &  
Westin Convention Center Pittsburgh  
Pittsburgh, Pennsylvania USA  
October 10–13, 2010