how the stem lineage of a southern Old World clade could occur in North America. In the context of an Asiatic origin of Trionychidae, two primary hypotheses exist that can explain this conundrum and that are supported to varying degrees by the available fossil evidence. However, though abundant, the fossil record is still too poorly understood to rigorously distinguish between these two primary hypotheses.

Poster Session I, (Wednesday)

NEW FOSSIL-BEARING PLEISTOCENE CAVE BRECCIAS FROM ZAMBIA (CENTRAL AFRICA)

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Central Africa almost completely lacks depositional environments preserving fossils and environmental records. The deep history of the Zambezi Ecozone is therefore severely understudied in terms of the temporal context of climate-environment-biome interactions. Newly discovered Middle Pleistocene fossiliferous cave deposits in Zambia allow, for the first time, integrated analysis of vertebrate faunal and floral (pollen from speleothems) fossil evidence within a tight temporal framework derived from uranium rich speleothems interbedded with fossiliferous sediments. The Kalenda Hill Cave system (KHC) contains huge amounts of fossilferous clastic and chemogenous deposits including large masses of soil-buried calcified and de-calcified breccia in front of the existing cave mouth. The Middle Pleistocene mammalian assemblage includes skull fragments, teeth and postcranial elements of suids, bovids, equids and many other mammalian orders. So far predominantly open habitats are indicated by these mammals. Fossil speleothems are preserved as sediment inclusions as well as fossil flowstone sheets covering and underlying the fossil bearing breccias. High uranium contents of speleothems allow recovery of mass spectrometric U-series dates indicating rarely sampled Middle Pleistocene (OIS 6-11; 169.9 ka ±4.3; 256 ka +34 -26; 265 ka +32 -25; 358 ka +19 -17; 384 ka +28 -23) which is consistent with the mammal fauna and corresponds tightly to the monsoon index as calculated according to several models (insolation 23°N+a insolation 23°N–0°, caloric half year, and ice volume). Flowsone layers also contain well preserved pollen floras including Salicaceae, Flacoutiaceae, Fabaceae, all of which are indicative of humid climates. The KHC complex is geographically close to the hominid-bearing Kabwe (Broken Hill) site, which is among the very few hominid sites in the Zambezi Ecozone and which may be broadly contemporaneous to the KHC complex.

Technical Session XV, Saturday 9:15

LONG-AXIS ROTATION: A MISSING RANGE OF MOTION IN DINOSAUR FUNCTIONAL ANALYSIS

KAMBIC, Robert, Brown University, Providence, RI, USA; GATESY, Stephen, Brown University, Providence, RI, USA

Measuring joint ranges of motion is a logical first step in reconstructing locomotion and other behaviors in extinct taxa. Although maximum angles of flexion/extension and abduction/adduction are typically reported for limb joints, these values do not fully characterize range of motion. This study addresses the third rotational degree of freedom, long-axis rotation (LAR), which can significantly impact limb kinematics and kinetics. For example, at proximal joints such as the hip and shoulder, small rotations about the femoral/humeral axes can impart large displacements on the distal limb. LAR moments (torques) can equal or even exceed those of flexion/extension, thereby acting as a critical influence on bone loading and joint morphology. We explored the full rotational range of hip motion in a de-muscled guineafowl preparation with intact ligaments and cartilage. Using a rod attached to the femur, the hip was moved through extremes of flexion/extension, abduction/adduction, and internal/external rotation while being recorded by dual fluoroscopic video systems at 60 Hz. Sets of three radio-opaque markers implanted in the ilia and femur were digitized to calculate 3-D coordinates and accurately animate CT-based bone models. A joint coordinate system (JCS) was set up to quantify each joint angle for over 12,500 poses. When plotted as a 3-D graph, these data map out a volume of angular space in which the joint could operate. Superficial points form a complex surface that reveals considerable interaction among LAR and other rotational degrees of freedom. Illustrations of extreme bone position alone may be appropriate for hinge-like, ginglymal joints, but most others require more thorough sampling of coordinated rotations at movement maxima. Range of motion studies could benefit from a well-defined JCS that fosters measurement and communication of LAR and other angles with an explicit rotation order. *In vivo* 3-D kinematic/kinetic studies of extant taxa will reveal the role of LAR in locomotion and serve as much needed reference data for extinct tetrapod analysis.

Romer Prize Session, Thursday 9:00

EFFECTS OF THE PERMO-TRIASSIC MASS EXTINCTION ON SYNAPSID DISPARITY OVER TIME

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The Permo-Triassic mass extinction had devastating effects on both species richness (taxonomic diversity) and disparity (morphological diversity). The relationship between these quantities at and following the extinction has been heavily studied in marine invertebrates, but relatively little attention has been given to disparity patterns in terrestrial vertebrates. Non-mammalian synapsids, the dominant group of terrestrial vertebrates in the Permian, have been central to studies of tetrapod survivorship and ecosystem remodeling across the P-Tr boundary. However, previous studies have generally been limited to using richness metrics, rather than quantifying disparity directly to provide a more complete view of the extinction and its results. Here I present a broad scale quantitative analysis of synapsid disparity before and after the Permo-Triassic extinction event. Disparity metrics were calculated based on geometric morphometric analysis of synapsid crania representing all major taxa at a global scale (including faunas from all continents except Australia). In the Upper Permian peak of synapsid morphological disparity (both in breadth and density of morphospace occupation), background species turnover results in an only temporary loss of disparity, with other synapsids colonizing the morphospace occupied by extinct taxa. Following the extinction, there is a significant reduction in total occupied morphospace as well as increased clustering, with the formerly broadly occupied area being split into two discrete clusters. Furthermore, there is evidence for a fundamental shift in the pattern of synapsid cranial morphospace occupation in the Triassic, with Triassic turnover resulting in morphospace contraction and increased marginalization even in those taxa with high richness. Areas lost as a result of species turnover are generally not recolonized by other synapsids. No geography-specific signal is recovered: different faunas display similar patterns of turnover when scaled for sample size, suggesting that the factors underlying synapsid morphospace reduction in the Triassic were operating globally.

Edwin H. and Margaret M. Colbert Poster Competition (Thursday)

A SIMPLE METHOD FOR ESTIMATING BRAIN VOLUME OF BIRDS AND ITS SIGNIFICANCE FOR PALEONEUROLOGY

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Brain volume gives us very useful information to discuss the behavior and the cognition of animals. But it is difficult to obtain accurate brain volume from extinct species because fossils are often partly or largely broken. The purpose of this study is to estimate brain volumes of birds from little osteolocial information. Brain volumes of extant birds were calculated from MRI or CT images. Then the correlations among brain volume and maximum brain width, length and height were assessed by multiple regression analysis and correlation analysis. Values between brain volume and maximum brain width showed a strong linear correlation. In the extant birds, it is thus possible to estimate brain volume accurately from maximum brain width by using a standard line. Brain volumes of fossil Neornithes were also calculated using this estimating method. In consequence, the brain volume values estimated by the foregoing method satisfactorily fitted with the reported values. I also examined whether this method can be used for other taxa including *Archaeopteryx*, the most primitive bird. The brains of *Archaeopteryx* and some theropod dinosaurs were not estimated accurately because they have more or less the elongated reptile-type brain. Animals being the more distant from Neornithes in phylogeny tend to have the more primitive reptile-type brain. Even in *Archaeopteryx*, the estimated value was approximately 35% smaller than the reported value. However, pterosaurs showed the wide bird-type brain. Thus this brain volume estimating method might be applicable for not only extant but also extinct Neornithes and it can be a powerful tool to obtain more information that never before available from fossil specimens.

Poster Session II, (Thursday)

EVOLUTION OF GIGANTIC TORTOISES FROM THE NEOGENE OF EUROPE

KEAR, Benjamin, La Trobe University, Melbourne, Australia; GEORGALIS, Giorgios, Aristotle University of Thessaloniki, Thessaloniki, Greece

Gigantic tortoise fossils have been recorded from the Neogene strata of Mediterranean Europe (Greece, France, Spain) for over 130 years; however, their phylogenetic relationships have never been examined. Comparative morphological observations based on postcranial elements have prompted provisional assignment of all current remains (representing up to 11 species) to a single genus, *Cheirogaster*, and hypothesized a sister taxon relationship with the African giant tortoise *Centrochelys*. This implies dispersal of a common ancestor into Europe sometime prior to the late Eocene (the oldest occurrence of *Cheirogaster*) and a long period of subsequent diversification culminating in a speciation maximum during the Miocene (7 recognized taxa). Significantly, this evolutionary scenario contrasts with paleogeographical reconstructions and recent molecular analyses of modern European testudonans (*Testudo+Eurotestudo*), which suggest the absence of an Arabian-Anatolian land bridge until the Early Miocene and thus a probable Asian origin for European fossil tortoise taxa prior to the influx of testudonans from Africa <10 million years ago (Late Miocene). A preliminary re-examination of Upper Miocene-Lower Pliocene Cheirogaster remains from Greece (Samos, Lesbos and mainland Attica, Macedonia) supports taxonomic separation from other European species including the type, *C. maurini* from the Upper Eocene of