Tetrapods originated in the Late Devonian (~360 Ma), but were tied to aquatic environments until the appearance of amniotes in the Late Carboniferous (~310 Ma). Amniotes, primarily basal synapsids, rapidly filled terrestrial niches, ultimately freeing vertebrate ecosystems from their dependence on aquatic productivity, and culminating in the taxonomically and ecologically diverse therapsid faunas of the Middle-Late Permian (270-252 Ma). Amniote origins are a classic example of adaptive zone invasion. Based on a new phylogeny of basal synapsids drawing strongly on both cranial and postcranial data, this invasion was characterised by the explosive appearance of higher clades and ecotypes in the latest Carboniferous (~304 Ma), resulting in sudden increases in taxonomic diversity. This was accompanied by apparently elevated rates of morphological character evolution. However, a number of observations suggest caution interpreting this result. (1) Temnospondyls, a diverse clade of non-amniote tetrapods show a similar diversity increase that is clearly linked to a sudden increase in fossil record sampling in the latest Carboniferous; (2) stratigraphic fit of Carboniferous basal synapsid nodes is poor, and phylogenetic ghost lineages are abundant, suggesting extremely poor lineage sampling and systematically underestimated branch durations; (3) evolutionary rates measured 'per branch' do not show the same elevated Carboniferous rates as those divided by time. Thus it is likely that amniote diversification occurred more gradually, originated prior to their first fossil occurrences, and is currently masked by poor sampling and sparse preservation of appropriate facies. By contrast, the Permian amniote record is sampled well. Early Permian synapsids show a phylogenetically co-ordinated pattern of evolutionary rates. The branch leading to the bizarre, herbivorous caseids shows relatively high numbers of state changes. However, maximal sustained rates are evident between successive nodes on the line leading to Therapsida (i.e., within the clade Edaphosauridae + Sphenacodontia), and were key to the evolutionary diversification of early amniotes.

Symposium 4 (Friday, November 4, 8:45 am)

TETRAPOD EVOLUTION THROUGH THE PERMIAN AND TRIASSIC: ROCK RECORD, SUPERTREES, AND DETECTING EVENTS

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Studies of macroevolution depend on an adequate fossil record, and investigators should ensure that their data are sufficient to test relevant hypotheses. In such studies it is therefore appropriate to assess the data for error, whether from geological (incomplete rock record) or human (variable study effort) failings. Error is relevant only to the question in hand, so a fossil record that works well for one study may be inadequate for another; so, a statement that, the dinosaur fossil record is good or bad is meaningless. Some studies of vertebrates through the Permian and Mesozoic have applied inappropriate sampling proxies (SPs) that do little to reveal whether the record in question is *good, bad, or adequate*. This is because many popular SPs are redundant with the signal they seek to assess or correct (e.g. 'number of formations' is often correlated with 'number of contained fossils' because the measures are linked).

A key macroevolutionary theme is clade diversifications, whether following a mass extinction, the evolution of an important novelty, or some other cause. In exploring the greatest mass extinction of all time, at the end of the Permian, some investigators have assumed that the tetrapod fossil record is inadequate. However, preliminary studies have shown that the times of lowest diversity in the Early Triassic were times of most intense sampling. Taking this further, we present new evidence on the mass extinction and the recovery from three sources: biodiversity through time; ecosystem or alpha diversity; and disparity (= morphological variance), to explore pre- and post-extinction models. SPs, including number of formations, number of specimens, and specimen completeness are deployed at regional and global scale to monitor error and evenness of sampling in these cases. Recovery from the mass extinction occurred in three phases, with rapid initial filling of ecospace by putative 'disaster' taxa, then building ecosystem complexity, and finally addition of top carnivore taxa, some occupying entirely novel niches. Generally, disparity races ahead of diversity, as taxa explore morphospace and then fill in the gaps.

Poster Session I (Wednesday, November 2)

MAMMALIAN FEMORA FROM THE CRETACEOUS-PALEOGENE BOUNDARY OF NORTHEASTERN MONTANA

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Multituberculates are an extinct group of nontherian mammals that lived for ~120 million years (Late Jurassic to Eocene) and are found on nearly every continent. Assumed to be ecological analogs and potential competitors of early rodents based on dentition and overall size, multituberculates have been inferred to possess postcranial adaptations for a wide range of locomotion (e.g., terrestrial, arboreal, and saltatorial) based largely on the exceptional preservation of skeletons from Asia. Whereas mammalian teeth and jaws are common in the latest Cretaceous (Lancian North American Land Mammal Age, NALMA) and earliest Paleocene (Puercan NALMA) faunas of North America, postcranial bones are relatively rare and usually found as isolated elements. This material however remains the only way to test hypotheses of differential extinction and recovery based on locomotion, and has the potential to contribute to the taxonomic and ecological picture as indicated by the dental record. This study describes select femora from the Cretaceous-Paleogene (K-Pg) boundary of northeastern Montana from the Hell Creek Formation (upper Cretaceous) and Tullock Member of the Fort Union Formation (lower Paleogene). These strata represent some of the best sampled and stratigraphically constrained deposits in the world for studying the K-Pg mass extinction, and these specimens are among the first femora from this area to be described outside of the temporally-mixed (latest Cretaceous-earliest Paleocene) fossil assemblages of the Bug Creek Anthills in McCone County, Montana. Based on an intertrochanteric fossa divided into the more proximal trochanteric fossa and more distal posttrochanteric fossa, and the presence of a subtrochanteric tubercle in nearly all specimens, the femora are attributable to Multituberculata. A preliminary analysis of functional morphology suggests the specimens tend towards terrestriality. Body mass was inferred from cortical cross-sectional area for specimens preserving diaphyses, and results suggest body masses of < 2 kg.

Poster Session I (Wednesday, November 2)

A SECOND, NEW SPECIES OF TREMATOPID AMPHIBIAN FROM THE LOWER PERMIAN BROMACKER LOCALITY OF CENTRAL GERMANY

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Until recently the amphibian Trematopidae was represented at the well-known Lower Permian Bromacker locality of central Germany by a single species, *Tambachia trogallas*, based on a large portion of the skeleton, including the skull. A second, new species, based on the greater portion of the skull with attached mandibles and associated, loosely articulated postcranial elements has been discovered from the same locality. Both species represent the only trematopid occurrences known outside of North America.

The Bromacker specimen is unique among trematopids in having the entire length of the nasolacrimal canal exposed as a smooth, uniform channel in which the anterior half coincides with maxillary-lacrimal suture. A combination of cranial synapomorphies distinguishes it also from all other well-known members of the family. A cladistic analysis of Trematopidae utilizing only cranial characters of those members of the family well represented in this field of inquiry resolves the Bromacker specimen and the North American Upper Pennsylvanian *Fedexia* as sister taxa of a terminal dichotomy of a clade containing the successively more basal *Tambachia* and the North American Upper Pennsylvanian *Anconastes*. This in turn forms the sister clade to that consisting of the sister taxa *Phonerpeton* and *Acheloma* from the North American Lower Permian. The cladogram conforms to previous analyses in recognizing the same two basal sister clades. The Bromacker specimen, however, is interesting in possessing a couple of characters that represent parallel acquisitions to those defining the *Phonerpeton-Acheloma* clade.

Technical Session IV (Wednesday, November 2, 3:45 pm)

HIGHER-LEVEL OF EARLY CAVIOMORPHA (RODENTIA: HYSTRICOGNATHI), PALEOGEOGRAPHY, AND EVOLUTION OF HYPSONDONTY

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The origin and initial diversification of Caviomorpha, South America's "original" rodents, are debated. Given that the closest relatives of Caviomorpha are African phiomorphs (Hystricognathi) and South America was an island for most of the Cenozoic, mid-Cenozoic arrival via "rafting" from Africa is widely assumed. Study of the oldest reported caviomorphs, from the Tinguiririca Fauna of Chile (earliest Oligocene, 33-31 Ma), prompted our broader investigation of early caviomorph phylogeny. We carried out an extensive morphological phylogenetic analysis of fossil and living taxa from all 4 major caviomorph subclades. We analyzed 222 craniodental characters: 129 dental (79 lower, 46 upper, 4 general), 7 enamel, and 86 cranial. These were coded for 102 taxa: 20 Old World (4 extant,16 extinct) and 82 New World (18 extant, 64 extinct).

Our analysis confirms that the Tinguiririca taxa are a dasyproctid and a chinchilloid. Most taxa traditionally classified as erethizontoids form one of the two basal clades within Caviomorpha. Caviids, †eocardiids and octodontids are monophyletic, while 7 other "families" are not (e.g., fossils traditionally assigned to one group instead ally with another, although support for their placement or for non-monophyly is weak in some cases). Cavioidea is monophyletic, but Octodontoidea and Chinchilloidea, as traditionally conceived, are unnatural. Indeed, three †cephalomyids, usually considered chinchilloids, are instead allied with various octodontoids; a dinomyid is placed among cavioids; and five taxa widely considered octodontoids instead group with chinchilloids. The monophyly of crown clade Caviomorpha, Erethizontoidea, and Cavioidea are confirmed in our analysis, consistent with molecular results. Cavioids form the outgroup to a clade encompassing "octodontoids" plus "chinchilloids." These results indicate a single dispersal event of hystricognaths from Africa to South America, probably during the mid-late Eocene (judging from early Oligocene caviomorph diversity). Hypsodonty originated at least three times independently in Caviomorpha (among chinchillids, caviids, and octodontoids), probably in response to environmental changes.