Abstracts for the Ninth North American Paleontological Covention (NAPC 2009)

University of Cincinnati; June 2009 21-26, 2009

Arrangement of abstracts in this volume

The abstracts are arranged sequentially within each session; sessions are numbered and ordered to reflect their order of occurrence throughout the meeting. Each abstract is preceded with a code that lists the session number, followed by the time of the presentation for oral presentations or the booth number for poster presentations (i.e., *session number: time of presentation/booth number*). An author index is provided at the end of the volume with locations of abstracts in the volume keyed to these codes.

Key to session numbers

1: Plenary Session P1: *What Darwin Didn't Know: Evolution in the 21st Century*
2: Topical Session T1: *Biotic response to paleoenvironmental and paleoclimatological Transitions*
3: Topical Session T2: *Biotic Interactions/ Educational Initiatives*
4: Symposium S1: *Molecular Paleobiology*
5: Symposium S2: *Size Matters: Pursuing General Laws in Body-Size Evolution and Ecology*
6: Symposium S3: *Rapid Evolution of Terrestrial Ecosystems and Their Influence on Marine Realms - Land-sea interactions in the Devonian*
7: Symposium S4: *Paleobiology and Paleontology of Mammals During the Uintan North American Land Mammal Age*
8: Poster session PS 1: *Morphology, Systematics, Diversity, and Extinction*
9: Topical Session T3: *Morphology, Function, Growth, and Unusual Preservation*
10: Symposium S5: *Fossilized Development*
11: Symposium S6: *Through the End of the Cretaceous in the type locality of the Hell Creek Formation and Adjacent Areas*
12: Symposium S7: *Taphonomic Fidelity and Infidelity in Modern and Ancient Communities*
13: Symposium S8: *IGCP 503: Ordovician-Silurian Oceanic/Climatic Events and Biotic Response*
14: Topical Session T4: *Phanerozoic Diversity Dynamics and Biostratigraphy*
15: Topical Session T5: *Paleobiogeography and Systematics*
16: Symposium S9: *Experimental Taphonomy*
17: Poster Session PS2: *Biostratigraphy, Education, Palebiogeography, and Paleoclimatology*
18: Plenary Session P2: *Evolution and Society*
19: Topical Session T6: *Dynamics of Extinction and Radiation in the Phanerozoic*
20: Symposium S10: *The Nature of Science and Public-Science Literacy*

Session No. 1, 8:30 AM; Monday, 22 June 2009
Plenary Session P1. What Darwin Didn't Know: Evolution in the 21st Century

1: 9:00 AM-9:30 AM
Presenter: DONOGHUE, MICHAEL J.

CHARLES DARWIN, THE TREE OF LIFE, AND THE FUTURE OF BIODIVERSITY

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Darwin supposed that one day we would comprehend the entire tree of life, and that this would be highly enlightening. But, only in the last few decades have we had the power to seriously tackle this enormous problem, and we are still struggling to incorporate phylogenetic thinking and methods into biology. Using examples from plants, I will highlight some emerging generalities about past episodes of diversification and movement, and reflect on the use of these findings in making predictions about the future of biodiversity in the face of global change.

1: 9:30 AM-10:00 AM
Presenter: LOSOS, JONATHAN

SYNTHESIZING ECOLOGY AND EVOLUTIONARY BIOLOGY

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Charles Darwin was possibly the first evolutionary ecologist. His ecological insights on the factors regulating interactions among species and the structure of communities are strikingly prescient, and his role in the development of evolutionary science needs no mention. For much of the last century, however, the fields of ecology and evolutionary biology were separate and evolutionary ecology has traditionally been studied in two ways. Ecologists study the processes going on in extant communities to investigate the ways in which ecological processes drive evolutionary change. Conversely, paleontologists and evolutionary biologists study the way in which historical events have shaped current ecological diversity. Synthesis of these perspectives is difficult because they operate on vastly different time scales. Nonetheless, the realization that when natural selection is strong, evolutionary change can occur rapidly and over observable timescales has led researchers to increasingly take experimental approaches to study the nexus of ecology and evolution. In conjunction with paleontological and phylogenetic data, such integrative, multidisciplinary approaches can shed great light on the origin and maintenance of biological diversity.

1: 10:30 AM-11:00 AM
Presenter: STANLEY, STEVEN M.

THE PUNCTUATIONAL MODEL OF EVOLUTION: WHERE DOES IT STAND?

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The punctuational model of evolution asserts that most evolutionary change is associated with speciation events (with major changes presumably occurring rapidly within small, local populations, as suggested in 1954 by Ernst Mayr). During the 1970's, after the punctuational model of evolution was proposed, it was defended on the basis of (1) great longevities for species (approximate stasis) in relation to rapid rates of evolutionary radiation (morphological innovation), (2) relatively little evolutionary change for extant taxa with good fossil records that have experienced little speciation (they are living fossils), and (3) biological evidence for rapid, markedly divergent speciation events in the recent past. Subsequently, several kinds of evidence have greatly strengthened the case for the punctuational model: (1) Comprehensive assessments of phyletic evolution (anagenesis) in particular taxa have shown it to produce relatively little change. (2) It has been shown that an unusual echinoid family, the Dendrasteridae, characterized by an unusual acentric test and unique mode of life, arose

abruptly in the Miocene by way of a simple neotenic change and then diversified after spreading geographically from a point source in waters adjacent to California. (3) Biologists have documented rapid adaptive radiations entailing dramatically divergent speciation events. For example, radiations of cichlid fishes in Africa were even more rapid than previously believed; highly divergent jellyfish species have evolved within inland marine lakes on the island of Palau within the past 12,000 years; and hundreds of distinctive species of gastropods of the family Conidae have evolved within the last 2-3 million years. (4) Applications of molecular phylogenetics and the molecular clock have elucidated the rapid diversification of many taxa whose individual species have survived for long intervals of time. (5) The advent of "evo-devo" research, has demonstrated how easily simple genetic changes can produce profound developmental restructuring of morphologies.

1: 11:00 AM-11:30 AM
Presenter: CARROLL, SEAN B.

ENDLESS FORMS MOST BEAUTIFUL: EVO-DEVO AND AN EXPANDING EVOLUTIONARY SYNTHESIS

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Which genes and what kinds of changes in their sequences are responsible for the evolution of morphological diversity? The answers to these fundamental questions eluded biologists for more than a half-century following the Modern Synthesis of evolutionary theory. I will describe major principles derived from molecular and evolutionary developmental biology (evo-devo") that have pointed away from protein sequence changes and gene duplication as necessary contributors to the evolution of animal form. I will analyze why form evolves largely by altering the expression of functionally conserved proteins; and how such changes largely occur through mutations in the cis-regulatory sequences of complex regulatory loci and of the target genes within the vast networks they control. I will discuss why evo-devo constitutes a major addition to an expanding evolutionary synthesis.

1: 11:30 AM-12:00 AM
Presenter: ERWIN, DOUGLAS H.

EVOLUTIONARY UNIFORMITARIANISM

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The development of evolutionary theory from the publication of The Origin of Species through the late 1800s was heavily influenced by the example Newton's laws of physics, which established the importance of identifying universals that did not vary through time or space of physics, and the debate between catastrophism and uniformitarianism. The geological uniformitarianism of Hutton and Lyell rejected catastrophism. Lyell's influence on Darwin's views on geology is widely known. Less appreciated is the extent to which Darwin and later evolutionary biologists adopted a sort of evolutionary uniformitarianism. To win acceptance of evolution, they implicitly assumed that the rates and processes of evolution operating today were sufficient to explain the history of life; no additional mechanisms, or extraordinary rates were required. There were good reasons for this assumption: it allowed experimental investigation of evolutionary processes, particularly with the advent of genetics after 1900, and led to the elimination of untestable and non-uniformitarian hypotheses such as orthogenesis. Additional mechanisms (e.g. drift) have been added to our views of evolutionary change, and we appreciate that evolution encompasses a spectrum of evolutionary rates. The hierarchical expansion of evolution by macroevolution and levels of selection arguments have also expanded the range of evolutionary mechanisms, yet all have been essentially uniformitarian: the range of evolutionary mechanisms, but the underlying assumption remains that there has been no temporal asymmetry to the operation of different mechanisms. Studies of major evolutionary transitions have broken down this barrier, however, describing a series of mechanisms that repackage genetic information as new evolutionary entities are created. They reflect a more general pattern in which the nature of variation exposed to selection has itself evolved over time. While these patterns can be revealed by comparative studies, they are not directly accessible to experiment, violating an assumption of evolutionary uniformitarianism.

Session No. 2, 1:30 PM; Monday, 22 June 2009
Topical Session T1. Biotic response to paleoenvironmental and paleoclimatological transitions

2: 1:30 PM-1:45 PM
Presenter: TUITE, MICHAEL L., JR.

LINKING TERRESTRIAL BIOGEOCHEMISTRY TO DECLINING RATES OF ORIGINATION IN MIDDLE AND LATE DEVONIAN SEAS

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The biogeochemical transition to a more modern relationship between land and sea during the Middle and Late Devonian is evinced in the geochemical record of nutrient dynamics and the pattern of marine faunal diversity loss. The expanding areal extent of Devonian lowland forests, facilitated by periodic transgressive events, generated an increasing outwelling flux of organic matter and reactive nitrogen from rivers and estuaries as well as higher rates of wet and dry atmospheric reactive N deposition that resulted in elevated primary productivity and episodic high organic content black shale deposition in epeiric basins. Conversely, progressively deeper and more mature tropical soils may have retarded the weathering flux of phosphorus. Composition and isotope analyses of sediments at the Frasnian/Famennian boundary within the Appalachian Basin suggest that reactive N and terrestrial organic matter were abundant during the interval of elevated primary productivity corresponding to the globally-correlated dysoxic Upper Kellwasser horizon and that the P necessary to sustain high levels of productivity was remobilized from organic matter in anoxic sediments. However, while episodes of global oceanic dysoxia, such as the Upper Kellwasser, may have precipitated discrete episodes of widespread extinction, two-thirds of Devonian diversity loss was a function of diminished rates of origination. This pattern of diversity loss is best explained by the frequently observed unimodal relationship between diversity and productivity. The abundance of trophic resources in Middle and Late Devonian seas caused populations to increase and served to diminish origination rates because large populations are inherently more resistant to evolutionary innovation and consequent speciation.

2: 1:45 PM-2:00 PM
Presenter: HUNDA, BRENDA R.

THE ROLE OF PHENOTYPIC PLASTICITY IN THE INTERPRETATION OF STRATOPHENETIC PATTERNS IN THE PALEOZOIC

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Phenotypic variation is the raw material acted upon by natural selection. Nearly all traits will show some plasticity because phenotypes result from the interaction of genetics with environment, yet the response of phenotypic plasticity to variable environmental conditions still requires further understanding. The fossil record allows us to measure morphological change within a species over longer time scales and can be utilized to understand how phenotypic plasticity within a species translates into stratophenetic patterns. There are two primary steps in achieving this goal:(1) The geographic distribution of phenotypic variability within a species and how it corresponds to spatial environmental gradients (known as a

reaction norm) must be accurately documented. (2) The reaction norm for a species must then be evaluated over time. The primary goal of this research is to quantify the relationship between phenotypic plasticity and environment to interpret stratophenetic patterns in the trilobite species *Flexicalymene granulosa* from a 2 million year interval within the Upper Ordovician Cincinnatian Series. In this study, morphology is measured using geometric morphometrics. A characterization of environmental change is acquired through gradient analysis, which numerically evaluates the distribution and abundance of fossil remains to identify environmental gradients in faunal datasets. Initial research has shown that *Flexicalymene granulosa* exhibits phenotypic plasticity along a spatial environmental gradient as a result of environmental heterogeneity in the Kope Formation. This geographic morphocline provides us with an expected norm of reaction where the expression of certain morphologies can be expected under specific environmental conditions in the study interval. Regression of total morphology onto DCA axis 1 scores has revealed a statistically significant relationship between morphology and environment. Congruency between morphological patterns in space and time leads us to hypothesize that stratophenetic patterns observed in *Flexicalymene* over the 2 million interval is the result of clinal translocation.

2: 2:00 PM-2:15 PM
Presenter: HANNISDAL, BJARTE

CENOZOIC CLIMATIC FORCING ON ALGAL CELL SIZE

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Marine phytoplankton play a key role in ecosystem function and biogeochemical cycling on a global scale. Predicting future impact of climate change thus depends on a better understanding of how marine phytoplankton may respond and adapt to global change. Here we explore how different taxa have responded differently to environmental change on geological time scales, using examples from the coccolithophores, a prominent group of calcifying unicellular algae. We target groups ancestral to extant taxa that have shown contrasting physiological responses to environmental parameters in culture experiments: (1) the *Reticulofenestra* lineage (the ancestry of today's most prolific bloomer, *Emiliania huxleyi*), and (2) the *Coccolithus* lineage (the ancestry of *Coccolithus pelagicus* and *C. braarudii*). We use time series of coccolith size (a robust proxy for cell size) ranging through the Cenozoic, and employ a model-free information-theoretic technique to investigate the influence of different climatic parameters on macroevolutionary changes in cell size. In a multivariate case, this analysis detects the significance and relative strength of influence of multiple climatic parameters on algal cell size. The technique is sensitive to non-linear relationships and corrects for interactions among the forcing parameters. In bivariate comparisons, we explore

the possibility of correctly inferring the directionality of causal interactions, to distinguish between forcing and response variables. Our analyses suggest that the macroevolutionary size decrease within the *Reticulofenestra* lineage was primarily a response to a decrease in pCO_2, possibly reflecting physiological adaptation to CO_2 limitation. In contrast, cell size variability within the *Coccolithus* lineage, while influenced by long-term trends in ocean temperature, was not affected by secular changes in CO_2. Improved understanding of such heterogeneity within ecosystem functional groups, including taxon-specific climatic adaptation strategies, will be of fundamental importance to the assessment of future climate change impact and mitigation.

2: 2:15 PM-2:30 PM
Presenter: LIOW, LEE HSIANG

INFERRING CLIMATIC AND BIOTIC FORCING OF DIVERSITY AND THE GLOBAL RISE OF SPECIES

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Speciation plays a crucial role in creating diversity. Considerable effort has been made to identify periods of higher speciation rates, partly with the goal of inferring possible drivers of speciation. However, estimation of the exact time of speciation or global first appearances in the fossil record is hampered by the shape of the temporal trajectory of species occurrence frequencies (long tailed distributions). The time of rise is more accurately estimated than time of global first appearances, and gives insight into conditions conducive for population growth, dispersal and establishment in new localities. Hence, we focus on studying interactions between environmental change, standing diversity, and the global rises of species in the plankton using time series of climate proxies from Zachos et al. (2001), and the latter two time series as derived from the NEPTUNE microfossil occurrence database. We employ a model-free information-theoretic technique to investigate the significance and relative strength of dependence among climatic parameters, standing diversity and the frequency of species rise. We also explore the possibility of correctly inferring the directionality of causal interactions, to distinguish between forcing and response variables. Our analyses suggest that changes in ocean temperature are a main driver of changes in standing diversity in several planktonic groups, including diatoms, radiolarians and calcareous nannoplankton. In addition, we detect significant biotic interactions, including cases where standing diversity of one group (e.g., diatoms) affect diversity and the rise of species in other groups (e.g., nannoplankton). Instead of attributing changes in diversity to driving forces that are either abiotic or biotic, we are able to estimate the relative strength and directionality of both, which will be critical to the development of mechanistic models of global diversity changes.

2: 2:30 PM-2:45 PM
Presenter: HEAD, JASON J.

BODY SIZE EVOLUTION IN CENOZIC REPTILES AS PALEOCLIMATIC PROXY DATA

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Combining the relationship of physiology to environment in modern reptiles with patterns of body size evolution in fossil taxa provides a novel method for paleothermometric reconstruction from a previously unexplored dataset. The ultimate regulator of body size among extant poikilothermic reptiles is ambient temperature; for a given mass-specific metabolic rate, external temperatures provide a critical minimum below which metabolism cannot be efficiently maintained for a given body size. The relationship between body size and external temperature is observable across different latitudes in extant reptiles, and can be used to calculate paleotemperature based on comparisons of body size and temperature in living taxa with body size estimates in fossil taxa. Fundamental assumptions of this method are: 1) body sizes in extant taxa are maxima at a given temperature for a given ecology; 2) mass-specific metabolic rates are appropriate model values for fossils. These assumptions are minimized through isotaphonomic and ecological comparisons, phylogenetic constraint, and by sampling multiple taxa within extinct herpetofaunas. Comparisons of body sizes in extant neotropical squamates, turtles, and crocodilians from aquatic habitats at measured mass-specific metabolic rates at modern Mean Annual Temperatures (MATs) with Paleogene and Neogene herpetofaunas from fluvial depositional environments in northern South America estimate high equatorial MATs during the Paleogene greenhouse and middle-late Miocene. These values are not consistent with climatic thermostat hypotheses, which propose cooler equatorial temperatures during warm phases, but instead suggest that all latitudes experience temperature increases during globally warm episodes.

2: 2:45 PM-3:00 PM
Presenter: BELANGER, CHRISTINA L.

EVALUATING NEARSHORE BIOTIC RESPONSES TO CLIMATE CHANGE USING A COASTAL BENTHIC FORAMINIFERAL PALEOCLIMATE RECORD (EARLY MIOCENE ASTORIA FORMATION, OREGON)

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Coastal paleoclimate reconstructions coupled with faunal collections provide an important record of how nearshore environments and biotas are affected by global climate changes. Here a benthic foraminiferal record from the Astoria Formation is used to evaluate environmental changes in a nearshore setting during the period of global warming leading into the Middle Miocene Climate Optimum. This paleoenvironmental record is then used to examine the roles temperature and commonly linked environmental factors, such as oxygenation and productivity, play in the occurrence, abundance, and physiological health of coastal marine bivalves. Two benthic foraminifera species, *Pseudononion costiferum* and *Buccella mansfieldi*, are used in $\delta^{18}O$ and $\delta^{13}C$ analyses to examine changes in temperature and productivity. These species represent an infaunal and epifaunal species respectively. Using two species serves as a check for post-depositional alteration; both species have similar $\delta^{18}O$ values, but the infaunal species, which resides in pore waters where organic decay releases light carbon, will have lower $\delta^{13}C$ values if unaltered. The magnitude of the difference between the $\delta^{13}C$ values in any given sample also allows assessment of changes in oxygenation and in the relative amount of organic carbon on the seafloor, both of which can have a strong effect on faunal compositions. Taxonomic identity and composition of the entire foraminiferal community are also used to evaluate changes in paleoenvironment. Preliminary $\delta^{18}O$ results indicate a warming of ~4°C from ~20 to 18 mya and an increase in the $\delta^{13}C$ difference between the species suggests an increase in sedimentary organic matter over time. Trace element analysis (i.e., Mg/Ca, Cd/Ca) of foraminifera will be used to further evaluate the paleoenvironment. Concurrent changes in the molluscan taxa suggest that both temperature and productivity drove the changes in community structure and composition. Future analyses will determine the relative roles of these drivers in the observed biotic responses.

2: 3:00 PM-3:15 PM
Presenter: FLUEGEMAN, RICHARD H.

FORAMINIFERAL PALEOECOLOGY ACROSS THE EARLY-MIDDLE EOCENE TRANSITION (EMET) IN WESTERN CUBA

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The early to middle Eocene transition (EMET) represents a time between 50 and 48 mybp when the Earth had a warm, but not extreme, climate. It follows a significant hyperthermal event, the Early Eocene Thermal Maximum, at approximately 55 mybp and precedes the development of the first Antarctic glaciation at approximately 40 mybp. The EMET, however, does not represent a simple transition from “greenhouse” to “icehouse” climate modes.

The Calle G (Avenida de los Presidentes) section in northwestern Cuba consists of early to middle Eocene age chalks of the Universidad Group. Biostratigraphy of radiolaria, foraminifera, and nannofossils shows the section spans the EMET. The Universidad Group contains a diverse foraminiferal assemblage dominated by planktonics. The planktonic foraminiferal fauna is characterized by quantitatively abundant subbotinids and acarininids. The benthic foraminiferal assemblage throughout is characterized by species of *Chrysalogonium*, *Siphononodosaria*, *Nutallides*, *Gyroidinoides*, and *Cibicidoides*. Oxygen isotopes were obtained from the planktonic foraminiferan *Acarinina collactea* across the EMET. The resultant curve shows widely fluctuating values during the early portion of the EMET with more stable values occurring in the middle Eocene. The presence of fluctuating values of oxygen isotopes followed by stable values across the EMET may be related to a change in circulation patterns through the Caribbean. Foraminiferal records from piston cores on Beata Ridge during this interval show a transition from a pelagic to a neritic environment. It seems likely that Beata Ridge developed as a positive feature during the EMET and may have functioned as an oceanic gateway into the late Eocene. The widely fluctuating oxygen isotope values in the latest Ypresian may also be related to an influx of freshwater in the North Atlantic associated with the coeval Azolla event in the Arctic Ocean. On-going studies in the Caribbean may resolve the origin of this signal.

2: 3:15 PM-3:30 PM
Presenter: JANIS, CHRISTINE M.

HORSES, HYPSODONTY, AND GRASSLANDS: ADAPTIVE LAG OR CLADOGENETIC LAG?

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The story of horse evolution in North America famously involves the issue of evolution of hypsodonty and how this reflected the spread of grasslands. For many years the argument was somewhat circular: little paleobotanical evidence existed, but the radiation of the first equine horses (genus *Merychippus*) in the late early Miocene (around 17 Ma) was assumed to reflect a change in habitat. More recent work with phytoliths has shown that grasslands likely first spread some 5 million years earlier, at the start of the Miocene. This apparent disjunct between hypsodont horses and grassland evolution has led to speculation that there was somehow an “adaptive lag” in the horses, or that hypsodonty does not accurately reflect dietary habits and the environmental conditions of the hypsodont animals. A closer look at the fossil record provides a resolution to this problem, but also invokes a second problem. The (paraphyletic) anchitheriine genus *Parahippus*, ancestral to *Merychippus*, is usually considered to be brachydont, but it clearly shows an increased tooth crown height. The first appearance of *Parahippus*, at around 23 Ma, thus shows a response to environmental change in at least one lineage of horses. The “*Merychippus* event” at around 17 Ma is actually an episode of rapid cladogenesis at the base of the subfamily Equinae, not the sudden appearance of

hypsodont forms. Indeed, early species of *Merychippus* are barely more hypsodont than derived species of *Parahippus*. It is not clear what caused this cladogenesis, but interestingly a similar event also took place at the same time among the persistently brachydont anchitheriine horses, with the appearance and diversification of the large, specialized (presumed) browsers *Hypohippus* and *Megahippus*. Simultaneous cladogenesis among both anchitheriine and equine horses does not rule out environmental influence, but makes it unlikely to be related to the grassland habitat alone.

2: 4:00 PM-4:15 PM
Presenter: POLLY, P. DAVID

ENVIRONMENTAL SORTING OF VERTEBRATE FAUNAS: IS LOCOMOTOR ECOMORPHOLOGY AN INDICATOR OF PALAEOENVIRONMENT

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How do communities and species respond to environmental change? The answer is related to what species are found in a community, how they respond to changing environments, and how we can better determine past environments from assemblages of fossils. This study looked at how mean locomotion in terrestrial carnivoran guilds (Carnivora, Mammalia) is associated with environmental factors at a continental scale to determine the extent to which climate determines the geographic distribution of locomotor specializations and whether past environments can be inferred from the locomotor morphology of fossil communities. Ankle posture in Carnivora is correlated with substrate -- species from open settings are often digitigrade, those from closed settings are often plantigrade or semidigitigrade. Three indices for digitigrady were evaluated using 129 terrestrial carnivoran species. A simple ratio of two measurements from a single ankle bone, the calcaneum (distance of the sustentacular facet from the proximal end of the calcaneum proportional to the total length of the calcaneum), was chosen because it was a good proxy for locomotor posture and is likely to be measurable on fragmentary fossil specimens. The ratio was used to estimate mean digitigrady in 38 out of 49 North American carnivoran species at points spaced 50 km apart across the whole continent. The correlation between mean digitigrady and several environmental factors was then tested. Mean digitigrady in carnivorans was highly correlated with ecological province (the latter explained 71% of the geographic variance in digitgrady), mean annual temperature (which explained 59% of variance), and vegetation cover (51% of variance). Mean digitigrady was not correlated with number of carnivoran species (which explained 10% of variance), elevation (6% of variance), or mean annual precipitation (5% of variance). The potential for average digitigrady in carnivorans to be a proxy for ecological province, vegetation cover, or palaeotemperature is good.

2: 4:15 PM-4:30 PM
Presenter: MILLER, JUSTIN M.

AN UNDERUSED METRIC TO DISTINGUISH WARM WATER VS. COOLER WATER SPECIES OF MODERN SAND DOLLARS

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Numerous studies have indicated that echinoid growth can be controlled by varying external conditions including temperature, competition, and sediment composition. It has also been suggested that the number of respiratory pore pairs added to the petal of an echinoid can be altered by sediment grain size but whether pore pairs differ by water temperature conditions (i.e., cold vs. warm water) is unknown especially in regard to near shore sand dollars. Specimens of *Mellita quinquiesperforata* (cool water), *Echinarchinus parma* (cool water) and *Leodia sexiesperforata* (warm water) were measured for three morphological characters: length, width, and length of ambulacrum I (amb 1) and the number of pore pairs in amb I were counted. Best-fit lines on bivariate plots that include the number of pore pairs in the first ambulacrum clearly show that the tropical species has significantly fewer pore pairs ($p=0.0006$) per unit length in comparison to the two cooler water species. Two explanations readily present themselves. First, to a certain degree echinoids can incorporate oxygen through the test wall and diffusion occurs at a higher rate in warmer waters. Thus the tropical species would require fewer pore pairs, relying more on direct oxygen diffusion through the test than the cooler water species. Second, sediment grain sizes amongst all three localities are similar (coarse grained) and only differ in that carbonate is present at the tropical locality. It has not been shown conclusively that pore pair addition is controlled by presence or absence of carbonate sediments but the possibility exists.I found that by counting the number of respiratory pore pairs in ambulacrum I of sand dollars, warm water inhabiting species could be differentiated from species occupying cooler waters suggesting that temperature in addition to sedimentary environment needs to be taken into account in paleoenvironmental analysis of sand dollars.

2: 4:30 PM-4:45 PM
Presenter: MOORE, BRUCE ROGER

EOCENE LEAF REMAINS RECORD A SYNCHRONOUS INCREASE IN ATMOSPHERIC CO2 CONCENTRATION AND PRONOUNCED DRYING TREND IN SOUTHEAST NORTH AMERICA

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The unequivocal relationship between change in atmospheric carbon dioxide as a greenhouse forcing gas and climate remains elusive. Combined analysis of Smilax sp. leaf fossils from three clay lenses in Western Tennessee and Kentucky for stomatal frequency to determine paleo - CO_2 level and hydrological conditions preserved by anatomical epidermal features clearly establishes that atmospheric carbon dioxide concentration increased from lower-mid Eocene to middle Eocene (372 to 411 ± 16 parts per million volume {ppmv} respectively) concommitant with changing moisture regimes from mesic to that of pronounced drought. A modern stomatal frequency index using herbarium leaves from Florida *Smilax laurifolia* covering the post-industrial period from 1894 to 2006 is significantly correlated (r^2 = .6029 $P<0.002$) to anthropogenically increased atmospheric CO_2 concentration from 294 to 381ppmv. Applying the training set to calibrate fossil stomatal ratios, it shows that variability in stomatal frequency was in response to long term change in paleoatmospheric carbon dioxide concentration during leaf development. Drought stress signals on fossil leaves include xeromorphic characters such as thickened epidermal tissue, decrease in epidermal cell size and straightening of anticlinal cell walls. Subsequently, morphological adjustment seen in leaves as moisture signals can be interpreted in terms of paleoprecipatation fluctuations and leaf stomatal frequency for paleoatmospheric carbon dioxide values are robust methods to relate past climate - greenhouse CO_2 dynamics.

Session No. 3, 1:30 PM; Monday, 22 June 2009
Topical Session T2. Biotic Interactions/Educational Initiatives

3: 1:30 PM-1:45 PM
Presenter: WHITE, STEPHANIE D.

EFFECTS OF DRILLING PREDATION ON GLOBAL TURRITELLID DIVERSITY AND ABUNDANCE: A POTENTIAL CATALYST FOR EVOLUTION

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Predation is considered by some to be a major agent of natural selection, and therefore testing hypotheses about how organisms respond evolutionarily to stresses from predators is critical for understanding the vehicles of evolution. The fossil record of drilling predation has been used extensively to infer predator-prey relationships and to test hypotheses about evolutionary paleoecology. Of primary concern is how drilling predation affects species

diversity, as it can potentially affect both speciation rate and extinction rate. A previous study by Kelley et al. (2005) suggests that diversity inversely tracks drilling predation through time; predation apparently caused a decrease in diversity, either by increasing extinction or suppressing speciation. In that study, U.S. Coastal Plain drilling frequency was used as a proxy for global drilling frequencies in correlating drilling with global species diversity. However, it is not clear whether Coastal Plain drilling frequencies are representative of those occurring elsewhere. Bulk samples from Austria, Italy, Northern Adriatic Sea localities, and the Red Sea containing turritelline gastropods were examined to gain a better idea of global drilling frequencies to compare with global species diversity. More than 2910 specimens from eight middle Miocene to Recent formations were examined for data on turritelline prey drilling frequency, and diversity and abundance. Drilling frequencies as high as 77 percent were found for the Recent samples from the Adriatic, and the older material had significantly lower drilling frequencies of 10 to 18 percent. Samples had low turritelline gastropod diversity. Frequency data of naticid (predator) drilling on turritellines (favored prey) will be analyzed for statistical relationships and compared to results from previous studies conducted on bulk samples from the United States Gulf and Coastal Plain. Though still in progress, the results of this study will help to understand the global effects of biotic interaction on extinction, speciation, and ultimately, evolution.

3: 1:45 PM-2:00 PM
Presenter: CHATTOPADHYAY, DEVAPRIYA

HISTORY OF CENOZOIC DRILLING PREDATION: A MULTI-TAXON APPROACH

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Predation is considered as an important agent of natural selection, and studying predator-prey interactions in the fossil record allows evaluation of its evolutionary impact. Predator-prey systems involving drilling predators are especially relevant because the fossil evidence of predation can be analyzed quantitatively. Frequency of complete and incomplete bivalve and gastropod drillholes has been used to evaluate success of predators relative to prey. Conventionally, drilling predation has been studied from a two taxon perspective, the driller and the prey. However, experimental evidence suggests that in the presence of the secondary predator (crab), the success rate of the drilling predator (snail) decreased (frequencies of incomplete holes increased; drilling frequencies decreased). Using the frequency of repair marks as a proxy for secondary predators, a similar pattern was detected in a Plio-Pleistocene molluscan assemblages: with increasing frequency of crab predation marks (a proxy for activities of secondary predators), frequency of complete drillholes decreased and frequency of incomplete drillholes increased. Cenozoic drilling frequency data were used to evaluate whether a similar relationship is detectable over broader temporal and geographic scales.

These revealed an inverse relationship between gastropod drilling and repair scar frequencies. Although it has been argued that the late Cretaceous rise in diversity of drilling predators might have led to increase in drilling frequency, no correlation was detected between diversity of drilling predatory gastropods and drilling frequency. The same is true when only naticid drilling frequencies and naticid diversities are compared. However, decapod diversity is directly correlated with repair scar frequency. These results suggest that the temporal fluctuations in drilling frequency could have been affected by the activity of secondary, durophagous predators.

3: 2:00 PM-2:15 PM
Presenter: SAWYER, JENNIFER A.

COMPARISON OF EOCENE TO RECENT PATTERNS OF DRILLING PREDATION FROM MOLLUSCAN ASSEMBLAGES OF CENTRAL EUROPE: PRELIMINARY RESULTS

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Predatory drilling may be the most studied biotic interaction in fossil assemblages. Its most complete Cenozoic record is geographically restricted to the North American coastal and Gulf plains and the patchy nature of drilling predation at fine temporal and spatial scales is often only tangentially explored. Here we examine preliminary data from the first lengthy time-series on drill frequencies (DF) for bivalve and gastropod assemblages of Central Europe. Recent data consist of > 47,330 molluscs collected from 2 mud flat and 6 sublittoral samples along a transect in the Gulf of Trieste (Northern Adriatic Sea). Sublittoral samples represent delta beds, mud and sand environments, allowing for the analysis of patchiness on several scales. Miocene data consist of ~ 17,600 individuals collected from 104 samples (7 localities) from Paratethys deposits in Austria and represent near shore- to- intertidal and shelf environments. In contrast, all preliminary samples from the Pliocene and Eocene are sublittoral. Pliocene data consist of 685 individuals from three samples (1 locality) in Italy and represent proto-Mediterranean deposits. Eocene data consist of 702 individuals from 3 samples (3 localities) in the subtropical Paris Basin. Overall, DF from fossil assemblages are similar in the Eocene (15.0%) and the Pliocene (16.8%), but are comparatively low in the Miocene (9.8%). Recent DF is by far the highest (21.2 %) and varies considerably between intertidal (1.9 %) and sublittoral settings (28.6 %), as well as between and within pelitic and sandy substrates. Considering that the Paratethys-shell beds were deposited during the Miocene climate optimum, their DFs are low. In contrast to the Recent, DF in the Miocene is similar between near shore (9.4 %) and shelf (10.3 %) samples. Further analysis will contribute to the knowledge of global patterns of drilling predation and the effects of spatial and temporal patchiness on its expression.

3: 2:15 PM-2:30 PM
Presenter: SCHIFFBAUER, JAMES D.

TESTING THE MICROSTRUCTURAL RECORD OF PREDATION: AN EXPERIMENTAL APPROACH TO EXAMINE THE RELIABILITY OF PREDATORY MICROTRACES

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Drill holes in prey skeletons are the most common source of data for quantifying predator-prey interactions in the fossil record. To be useful, however, such drill holes need to be identified correctly. From Schiffbauer et al. (2008, Palaios), field emission and environmental scanning electron microscopy were applied to describe and quantify microstructural characteristics of drill holes from feeding experiment prey shells and Miocene specimens. The microstructures that we observed are interpreted as *Radulichnus*-like micro-rasping marks, or predatory microtraces, made by the radula of the drilling gastropod predators. The range of organisms examined illustrates the utility of scanning electron microscopy imaging for identifying micro-rasping marks associated with predatory drill holes in both modern and fossil specimens. The mean adjacent spacing of these microtraces is notably denser than the maximum width of muricid radular teeth determined by measurements taken from published literature. However, because the radular marks typically overlie or crosscut each other, the denser spacing of predatory microtraces possibly reflects superimposition of scratches from repeated passes of the radula. As a second hypothesis, the radular cusps are triangular in cross-section, and thus denser microtrace spacing may reflect variable pressure of radular passes. That is, radular passes with less pressure should produce more narrowly spaced rasping microtraces, as only the tip of the radular cusps would penetrate the shell material; conversely, deeply penetrating radular passes should be nearer to the basal width of the radular cusps. In an effort to resolve such questions, we have utilized an experimental approach in an attempt to mimic these microtraces with actual radulae collected from live *Nucella lamellosa* using an integrated micromanipulator within a focused ion beam electron microscope. These distinct microtraces offer promise for augmenting our ability to identify drill holes in the fossil record and to distinguish them from holes produced by non-predatory means.

3: 2:30 PM-2:45 PM

Presenter: SCHIMMEL, MAJKEN K.

BIOTIC INTERACTIONS RECORDED IN EOCENE ECHINOIDS AND BRACHIOPODS FROM THE CASTLE HAYNE LIMESTONE, NORTH CAROLINA

SCHIMMEL, MAJKEN K., Geosciences, Virginia Tech, 900 Houndschase Lane, Apt. D, Blacksburg, VA, 24060, United States, majken5@vt.edu; COFFEY, BRIAN, Department of Geological Sciences, University of North Carolina at Chapel Hill,104 South Road, Mitchell Hall, Campus Box No. 3315, Chapel Hill, NC 27599-3315; BARBOUR WOOD, SUSAN, Department of Geosciences and Natural Resources, Western Carolina University,331 Stillwell Building, Cullowhee, NC 28723; KOWALEWSKI, MICHAL J., Department of Geosciences, Virginia Tech, 4044 Derring Hall (0420), Blacksburg, VA 24061

The Castle Hayne Limestone (Middle Eocene) in coastal North Carolina is noted for its diverse macro-invertebrate fauna, including abundant, well-preserved echinoid tests and brachiopod shells. Some of these echinoids and brachiopods display trace fossils suggestive of biotic interactions, including drill holes and repair scars. These traces may record a wide spectrum of biotic interactions including successful predation, unsuccessful predation, and parasitism. These traces may also potentially provide quantifiable data on intensity of predation/parasitism and behavioral stereotypy of trace makers (site-, taxon-, and size-specific interactions). Using systematic field collections acquired recently from the Castle Hayne and Rocky Point quarries, trace fossils were recorded and analyzed for data grouped by species, genera, and the entire sampled echinoid and brachiopod assemblage. Placement of drillholes found in the echinoid tests and brachiopod shells was recorded by dividing the test (or shell) into anatomically-defined sectors in order to determine which part of the echinoid or brachiopod was affected by traces and to assess if the distribution of traces suggests any anatomical correlatives (e.g., in case of echinoids, drill holes of parasitic or predatory origin may be expected to concentrate around gonads). Common echinoids also were analyzed at the species level in terms of distribution of traces, in relation to the size of the drilled echinoid. This study demonstrates that fossil echinoids and brachiopods can provide a wealth of paleoecological information about biotic interactions. Echinoids, in particular, represent an important, if understudied, fossil system for testing the Escalation Hypothesis and, more generally, for evaluating evolutionary importance of ecological interactions. While the ecological interplay between echinoids and their enemies (e.g., drilling predators such as cassid gastropods and drilling parasites such as eulimid gastropods) is an important process in modern benthic ecosystems, a few workers have investigated such interactions in the fossil record.

3: 2:45 PM-3:00 PM
Presenter: CURRANO, ELLEN

HIGHLY SPECIALIZED INSECT HERBIVORY FROM THE LATE OLIGOCENE GUANG RIVER FLORA, CHILGA, NORTHWESTERN ETHIOPIA

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There is a common assumption in modern ecology that insect herbivores are more specialized in the tropics than in the temperate zone (Coley and Barone 1996). Is this pattern of specialization a recent development, or has it existed for millions of years? To begin to answer this question, we performed an insect damage census on the 27-28 Ma Guang River flora from the Chilga region of northwestern Ethiopia. Based on leaf physiognomic and nearest living relative analyses, mean annual temperature was 21-27oC and precipitation of at least 1300 mm/yr. Four sublocalities were excavated along 60 meters of a single stratigraphic horizon, and 433 identifiable angiosperm fossils were collected. Leaves were identified using a combination of leaf architectural and cuticular features, and insect damage was quantified using the damage morphotype system of Labandeira et al. (2008). This study is the first analysis of insect herbivory in the Cenozoic of Africa, and just the second in the tropics. The Guang River flora contains three palm, two other monocot, and 36 dicot species, and species composition and abundances vary considerably among sublocalities. This high diversity and heterogeneity is consistent with modern tropical moist forests. Legumes dominate the diversity and biomass of the flora. Thirty-one percent of leaves have insect damage, which is comparable to damage frequencies reported on temperate Cenozoic floras. However, while most damage on temperate floras is external foliage feeding, insect damage at Chilga is dominated by specialized feeding types, particularly galls. There are at least eight gall types, found on twelve plant species, and 10.6% of the leaves have galls. Over 63% of *Sapoteae* sp. (Sapotaceae) leaves have cecidomyiid-like (gall midge) galls, some of which are three-dimensionally preserved. These results suggest that although the Chilga plants were well-defended against generalist herbivores, they were susceptible to specialized herbivores.

3: 3:00 PM-3:15 PM
Presenter: KENDRICK, DAVID

DID UINTACRINUS HAVE PHOTOSYMBIONTS?

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Since its discovery, the Cretaceous crinoid *Uintacrinus socialis* has puzzled workers with its unusual morphology and gregarious habits. The large, globular calyx, extremely long arms (>

100 cm) and free-living habit make for a unique combination unlike any modern or extinct crinoid. *Uintacrinus* has been variously interpreted as wriggling across the sea floor, elevating itself off the bottom with its arms, floating just above the sea bed dragging its arms along the bottom, and floating at the sea surface. This study proposes to test another possibility - the hypothesis that *Uintacrinus* harbored photosymbionts in its tissues. Photosynthetic products derived from photosymbionts have distinct negative carbon isotope values relative to more conventional heterotrophic organisms. If bulk organic carbon analysis of *Uintacrinus* produces carbon isotope values similar to the photosynthetic signature, this would be consistent with the hypothesis. A negative signature would also be consistent with a phytoplanktonic diet; however, modern crinoids are not specialists and ingest everything they catch within the size limitations of the food grooves on the arms, making it unlikely that a strongly negative signal results only from heterotrophy.

3: 3:15 PM-3:30 PM
Presenter: LENTS, NATHAN H

TEACHING THE PROCESS OF SCIENCE IN EVOLUTION, PHYLOGENY, AND NATURAL SELECTION

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A growing number of studies point to the effectiveness of explicitly teaching the nature and process of science, as many college students have little understanding of science beyond methodical procedure (Dagher, 1997; Moss, 2001; Bell, 2003). This presentation will detail a process-driven method of teaching phylogeny and natural selection that is currently under experimental implementation in a majors-level introductory biology course. First, students are given a series of readings available through Vision learning (http://www.visionlearning.com), which detail the scientific process and scientific data analysis. Then, students are given a corresponding lecture on the philosophy and methods of the scientific process. Next, students engage a process-driven lab exercise in which they examine real data from six primates (humans, *afarensis*, chimpanzee, orangutan, gorilla, and macaque) in the form of a pseudogene DNA sequence, a protein sequence, schematics of chromosome ultra-structure, and pictures/measurements from skull specimens. Each type of data is given as a distinct activity and students are not told the species' identities. Their challenge is to generate a tentative phylogenetic tree for each activity, based on the provided data. Each activity involves debate among groups regarding the evidence for their hypotheses, and the identities of the species are finally revealed. Students then generate a final phylogenetic tree that takes into account all of the analyses. Simultaneously, we have refined an instrument for assessing attitudes and beliefs regarding evolution and natural selection, as well as the impact of course material on those beliefs. This instrument was given as a pre- and post-test to students in a targeted section of Biology-104, as well as a control

group which did not receive the newly developed teaching materials described above. In this presentation, we will detail the activities, student work and responses, and the results of our assessment measuring student attitudes toward modern evolutionary theory.

3: 4:00 PM-4:15 PM
Presenter: YACOBUCCI, MARGARET M

CIVIC ENGAGEMENT FOR THE 21ST CENTURY PALEONTOLOGY STUDENT

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The National Research Council, National Science Foundation, and AAAS have placed the development of an informed citizenry, emphasizing ethical and social issues and sound decision-making, solidly within their criteria for scientific literacy. Research has shown that civic-oriented activities within science courses promote student learning of basic science concepts, boost student confidence, and improve retention. Traditionally, however, college-level paleontology courses (whether for non-majors or majors) have focused solely on what is often misleadingly labeled as “content” - the myriad of names, terms, dates, and basic geological and paleontological concepts that make up the core knowledge set in our field. General education students often perceive such courses as exercises in rote memorization and rarely develop an appreciation of the contributions of paleontology to modern science or to society at large. Majors are also underserved by the traditional approach, missing opportunities for professional development that may be critical to their retention in the field. Civic engagement goes beyond merely informing students about issues of public concern; engagement requires students to actively consider problems about which they, as consumers, taxpayers, parents, teachers, elected officials, or scientists, might have to make decisions. In my introductory non-majors course, students wrestle with creationism, global warming, the commercialization of fossils, fossil collection on public lands, and the decision-making process in setting federally-funded research priorities. Science majors taking upper-level paleontology courses can be challenged to explore the roles scientists play as public advocates. Should a professor agree to a public debate with a proponent of Intelligent Design? How can paleontologists best leverage influence on Capitol Hill into additional research funding? How can the students themselves help local K-12 teachers provide learning opportunities for their kids? Future paleontologists need training in these aspects of professional life as much as they need training in fossil systematics or paleoecology.

3: 4:15 PM-4:30 PM
Presenter: RINDSBERG, ANDREW K.

TAKE CONTINENTAL ICHNOLOGY TO THE MASSES!

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Ichnology is now taught as a part of any introductory sedimentology or paleontology course, and even as a separate course in many geology departments. Some biology departments also teach courses in bioturbation. These courses, however, are nearly all aimed at majors in geology. How can we teach ichnology to non-geology students? It turns out this challenge is not so difficult. Ichnology is a more basic science than most, though it does require observation and communication skills for students to interact with peers and instructors. In fact, non-geologists can sharpen their ability to observe using ichnologic techniques. Teaching these skills is largely a matter of reminding students to look more closely at phenomena they see every day, such as: canine and human footprints in concrete sidewalks; dig marks and tree nests made by squirrels; arthropod traces (incisions, leaf mines, galls) left on plants; trails made by earthworms in mud puddles, accompanied by tracks of songbirds seeking water (and worms); or insect nests, both solitary and eusocial, subterranean and arboreal. In this sense, continental ichnology is far easier to teach than marine ichnology: after all, modern traces made by a wide variety of taxa already surround students, enabling them to discern and study traces on a daily basis. Sketching, mapping, measuring, describing, and analyzing ordinary traces give students a pragmatic understanding of the scientific method. In our experience, once students are trained to look for continental traces and become aware of their ubiquity, they become better observers, more easily understand the concept of multiple, testable hypotheses, and see how inference works as a tool when guided by actualism. We will provide lesson plans developed in our classes for non-geology majors that use some aspects (covert and overt) of continental ichnology, while giving insights on successes and failures in teaching continental ichnology.

3: 4:30 PM-4:45 PM
Presenter: MCCORMICK, TIM

PALAEOSAURUS: A PALEONTOLOGICAL COLLECTIONS RESOURCE IN THE WEB 2.0 ERA

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Over the last 8 years the British Geological Survey has undertaken an ambitious initiative to build a digital index to its paleontological collection. Comprising an estimated three million specimens, this collection is the most comprehensive biostratigraphic resource relating to Great Britain and its continental shelf found anywhere, and is the second largest fossil

collection in the United Kingdom. “PalaeoSaurus” (www.bgs.ac.uk/palaeosaurus/home.cfm) currently holds data on some 2.3 million specimens in the BGS collection, ranging in age from Neoproterozoic to Quaternary, and offers a formidable curatorial and research resource. The time is right to take stock of this highly successful enterprise and consider its future development. BGS is at the forefront in utilising and adapting web service technologies to enhance the visibility and usefulness of its diverse data sets. Ongoing developments in xml data interchange formats such as GeoSciML, as used by the “OneGeology” initiative www.onegeology.org, and “Access to Biological Collections Data” format developed by the Taxonomic Data Working Group www.tdwg.org, offer the promise of greatly increased flexibility in accessing, searching, visualising and utilising paleontological collections data. Exploiting these capabilities will enable PalaeoSaurus, among other things: to participate in distributed data searches alongside collections data from other institutions; to export data in a way that can be used in “mashup” applications; and to provide a web-based validation service against which other data sets can be constrained. In addition, we intend to enhance the experience of visitors to the PalaeoSaurus website by linking it to BGS’ extensive collection of geoscientific images, and to encourage web visitors to add value to our data by annotating records with their own information, which ultimately can be verified and fed back into the database.

Session No. 4, 1:30 PM; Monday, 22 June 2009
Symposium S1. Molecular Paleobiology

4: 1:30 PM-2:00 PM
Presenter: SMITH, ANDREW B

WHEN MORPHOLOGY AND MOLECULES AGREE: ENHANCED PERSPECTIVES ON ECHINODERM EVOLUTION (KEYNOTE)

SMITH, ANDREW B, Department of Palaeontology, The Natural History Museum, Cromwell Road, London, Middlesex, SW7 5NBD, United Kingdom, a.smith@nhm.ac.uk

Integrating paleontological with genomic data allows us to explore questions in ways that go beyond that achieved by either on its own, but only when the two approaches are largely in accord, as in the case of echinoids. Because molecular and morphology-based phylogenies of the post-Palaeozoic crown group are largely congruent there is a single tree on which to study and compare evolutionary rates and patterns of character acquisition. There are also two independent estimates of divergence times from which to explore how the nature of the fossil record varies over geological time. Molecular and paleontological data can also provide complementary perspectives on the origins of novelty. A more complete understanding of body plan evolution in echinoderms is gained through integrating molecular, developmental and paleontological observations. Whereas molecular genetics and developmental biology suggest mechanisms by which the unique echinoderm body plan may have arisen, the fossil

record of stem group members allows us to visualize and put into sequence the stages of these processes.

4: 2:00 PM-2:15 PM
Presenter: GILLIS, ANDREW

SHARED DEVELOPMENTAL MECHANISMS PATTERN THE GNATHOSTOME GILL ARCH AND PAIRED FIN SKELETONS

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One of the most prominent hypotheses of 19th Century comparative anatomy was Gegenbaur's Gill Arch Theory of the origin of paired appendages. Gegenbaur noted anatomical parallels between the gill arch skeleton of chondrichthyans (cartilaginous fishes - sharks, skates, rays and holocephalans) and the paired fin skeleton of gnathostomes, and hypothesized a transformational homology: the fin girdle with the proximal branchial arch, and the endoskeleton of the paired fin proper with the distal branchial rays. To date, however, the Gill Arch Theory has lacked supporting experimental, developmental or molecular data. We describe, for the first time, the molecular patterning of chondrichthyan branchial rays (gill rays) in the little skate, *Leucoraja erinacea*, and reveal profound developmental similarities between gill rays and vertebrate paired appendages. Sonic hedgehog (Shh) and Fibroblast growth factor 8 (Fgf8) regulate the outgrowth and patterning of the chondrichthyan gill arch skeleton, in an interdependent manner similar to their roles in gnathostome paired appendages. We demonstrate that paired appendages and branchial rays share a number of conserved developmental features, including Shh-mediated mirror-image duplications of the endoskeleton following exposure to all-trans retinoic acid, endoskeletal outgrowth directed by a Fgf8-expressing pseudo-stratified distal epithelial ridge, and truncation or deletion of branchial rays following local inhibition of Shh or Fgf8 signaling. When considered in light of comparative anatomical and fossil data, these findings suggest that the skeletal patterning role of the retinoic acid/Shh/Fgf8 regulatory circuit has a deep evolutionary origin - predating vertebrate paired appendages - and may have functioned initially in patterning pharyngeal structures in a deuterostome ancestor of vertebrates.

4: 2:15 PM-2:30 PM
Presenter: TAYLOR, DAVID WINSHIP

EVIDENCE FROM LIVING PLANTS THAT THE JURASSIC/CRETACEOUS TO TERTIARY MOLECULAR FOSSIL OLEANANE IS ANCESTRAL IN ANGIOSPERMS

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Oleanane is a triterpenoid which is common and abundant in many Late Cretaceous and Tertiary sediments, but rare in older sediments. The observed spatial and temporal distribution of this biomarker (and the widespread occurrence of functionalized oleanoids in living monocots and eudicots) has led to oleanane's use as a qualitative indicator of angiosperm input in sediments. However, more precise interpretations of oleanane occurrence are limited by incomplete taxonomic surveys for oleanoid natural products in living angiosperms and other seed plants. In particular, basal-most angiosperms have yet to be sampled. To examine oleanoid distribution in the base of the angiosperm tree, we sample species from the three most basal orders, Amborellales, Nymphaeales and Austrobaileyales, as well as Chloranthales, Magnoliales, Laurales, Piperales, Acorales, Alismatales, Ceratophyllales and Ranunculales. Living material was collected, identified and air dried. Half the sample was mounted as a voucher and the other half was crushed and cut into small fragments for analysis. The samples were then subjected to hydrous pyrolysis, extracted, hydrogenated using an ionic reduction procedure, and separated into saturate and aromatic fractions. The presence of oleanoids was tested using GCMS and GC-MRM-MS techniques. The procedure was designed to mimic conditions of diagenesis and burial which transform diverse functionalized oleanoid natural products into a limited number of identifiable triterpanes, nortriterpanes, and aromatic triterpenoids in sediments. Oleanoids were found in the most basal orders. A MacClade reconstruction supports the hypothesis that oleanane is ancestral in angiosperms. Together with previous data from fossil seed plants, these results suggest that the angiosperm lineage is monophyletic and separate from other living seed plants, and related to a small group of extinct fossil seed plants.

4: 2:30 PM-3:00 PM
Presenter: WELCH, JOHN J.

USING FOSSILS IN MOLECULAR DATING: COPE'S RULE AND THE ORDINAL-LEVEL RADIATION OF MAMMALS (KEYNOTE)

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The temporal information in DNA sequences is limited in two major ways. First, external data are required to convert relative branch lengths into absolute dates. This means that molecular dating typically relies on a detailed interpretation of the fossil record, and this prevents us from comparing molecular and palaeontological estimates without circularity. Second, systematic changes in the substitution rate across a phylogeny are not detectable from molecular data. We address both problems by treating fossils as non-contemporaneous tips, as is common in microbial dating, but with phenotypic measurements used in place of DNA. If phenotype predicts molecular rate, then systematic changes in trait - inferable from the fossil record - can be used to infer systematic changes in rate. Applying this approach to the radiation of the mammalian orders, we show how an increase in body mass over time, combined with a negative correlation between body mass and substitution rate, could explain the continued disagreement between rocks and clocks.

4: 3:00 PM-3:15 PM
Presenter: SPERLING, ERIK A.

MOLECULAR DIVERGENCE ESTIMATES SUGGEST A 150 MILLION YEAR LATE PROTEROZOIC SPONGE SPICULE GAP

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Central to understanding the Cambrian 'explosion' is whether animals have a long and cryptic Precambrian history hidden from the fossil record. Molecular divergence estimates, which offer an independent record from fossil data, have recently confirmed a roughly literal reading of the fossil record, with most phylum-level divergences closely predating the Precambrian/Cambrian boundary. However, some studies have revealed at least one area where molecular estimates clashed with the fossil record, namely the origin of the spiculate demosponges, whose origination based on molecular clock estimates was considerably deeper than the first accepted appearances of spicules a few million years prior to the Precambrian/Cambrian boundary. Here we have applied a molecular clock to an extensive new dataset consisting of seven nuclear housekeeping genes from 71 taxa, including 29 sponges. Our analysis suggests that the spiculate demosponges diverged 655 Ma, and crown-group Demospongia diverged 693 Ma. Since spicules must have appeared between the origin of crown-group demosponges and the origin of the spiculate demosponges, there is a 150-107 million year missing spicule record from these estimates to the first accepted sponge spicules

in the fossil record, with an additional 20-25 million years to the first accepted demosponge spicules. The concordance of our molecular clock results with the Phanerozoic sponge and bilaterian fossil record indicates this spicule gap is unlikely to be widely overestimated. Possible explanations for the spicule gap include independent acquisition of spicules within demosponges, small spicule sizes, or ocean conditions that led to the dissolution of spicules. This study highlights the importance of molecular clocks in providing an independent test of the fossil record, as it suggests that animals began to biomineralize well before the fossil record indicates, and opens new avenues of investigation into the paleoecology, paleoceanography and taphonomy of the late Proterozoic world that may have otherwise gone unnoticed.

4: 3:15 PM-3:30 PM
Presenter: TARVER, JAMES E.

DATING THE ORIGIN OF VERTEBRATES USING GEOLOGICALLY CONSTRAINED MOLECULAR CLOCKS

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Ever since Zuckerkandl and Pauling first proposed the molecular clock people have made efforts to refine it. Much of this work has focused on trying to more accurately model various aspects of molecular evolution. The use of 'strict' global clocks has been superseded by 'relaxed' local clocks that take into account rate heterogeneity between lineages. The sequence data itself has received considerable attention with the models used to understand substitution rates moving away from the theoretical such as Nei's model of protein evolution to the empirical WAG model of Whelan and Goldman. One area that has received relatively little attention is that of the calibrating fossils and how this data should be incorporated into the analyses. Although workers agree that you need to include numerous fossils for cross calibration, there is still one vital aspect that has received relatively little attention; prior probability distributions. The two most widely used programs today BEAST and MULTIDIVTIME use a Bayesian MCMC approach to date internal nodes. By using this approach, it's possible to set different prior probability distributions for each calibration point. These distributions can be uniformly distributed between two dates, normally distributed around one date or have either gamma or lognormal distributions. However, these distributions are purely arbitrary in design and do not reflect either the quality of the calibrating fossil or the availability of rock for a particular stratigraphic period. Here we use a new method recently implemented in mcmctree using a Cauchy distribution that allows variation in prior probability to more accurately reflect both palaeontological and geological information. We present results

obtained from an original dataset, which includes all nine extant classes of chordates, with original sequences from the hagfish (*Myxine glutinosa*), the lamprey (*Lampetra planeri*) and the catshark (*Scyliorhinus canicula*) to date the origin of major vertebrate clades.

4: 4:00 PM-4:30 PM
Presenter: WORHEIDE, GERT

EVOLUTION AND PHYLOGENY OF NON-BILATERIAN METAZOANS (KEYNOTE)

WORHEIDE, GERT, Earth & Environmental Sciences, Palaeontology, Ludwig-Maximilians-Universitaet Muenchen, Richard-Wagner-Strasse 10, Munich, Bavaria, 80333, Germany, woerheide@lmu.de

Deep level metazoan relationships have long been controversial issues for the field of systematic biology and palaeobiology, and especially a well resolved and supported phylogeny of non-bilaterian animals is needed to provide a robust framework for reconstructing early metazoan evolution in the Neoproterozoic. Expanding molecular datasets and continuing advances in phylogenomic methods are increasingly being used, aiming to unravel these relationships. However, important nodes remain notoriuosly difficult to resolve. For example, some recent large-scale metazoan phylogenomic analyses – contrary to classical conceptions – found ctenophores to be the earliest branching metazoan taxon and favoured a sister-group relationship between sponges and cnidarians, while other analyses suggest that the Placozoa diverged first or that sponges are a paraphyletic assemblage that share a grade of construction rather than common ancestry. Several new large phylogenomic analyses, based on datasets with different gene- and increased taxon-sampling of non-bilaterians, will be presented. A strongly supported monophyletic Porifera is always recovered, regardless of outgroup choice and evolutionary model. Most analyses favour a sister-group relationship of Ctenophora+Cnidaria, reviving the “Coelenterata” concept. However, Placozoa relationships remain unstable as they are highly dependent on taxon sampling, evolutionary model selection and outgroup choice. We suggest that additional data, especially from deeply diverging lineages within Placozoa, and more critical data analyses are required before the branching order of all non-bilaterian groups is robustly supported. However, results so far allow insights into the evolution of some key traits of the Metazoa.

4: 4:30 PM-4:45 PM
Presenter: QUENTAL, TIAGO B.

EXTINCTION DURING EVOLUTIONARY RADIATIONS: RECONCILING THE FOSSIL RECORD WITH MOLECULAR PHYLOGENIES

QUENTAL, TIAGO B., Invertebrate Paleontology, Harvard University, 26 Oxford St., MCZ, Cambridge, MA, 02138, United States, tquental@oeb.harvard.edu; MARSHALL, CHARLES, R., Invertebrate Paleontology, Harvard University, 26 Oxford St, MCZ, Cambridge, MA, USA, 02138

Recently, likelihood methods have been developed to tease out whether decreasing diversification rates commonly observed in molecular phylogenies are due to decreases in speciation rates, increases in extinction rates, or a combination of both. Unexpectedly, it has been concluded that a decreasing diversification rate can only be explained by a decreasing speciation rate with no extinction. The explanation is that substantial extinction would have eliminated the early history of clades, erasing the evidence of the observed decreasing rate of diversification. However, from a paleontological perspective, zero extinction rates during evolutionary radiations seem unreasonable. But perhaps, despite the ubiquity of extinction seen in the fossil record, the initial stages of evolutionary radiations are, in fact, extinction free. Here we determine whether the conclusion of zero extinction during evolutionary radiations is necessarily true. Using computer simulations we explored different density-dependent models of diversification. In agreement with the previous work, we find that decreases in diversification rates can only be observed with decreasing speciation rates. But we also show that substantial extinction can occur without erasing the signal of decreasing diversification rates; it appears the initial conclusion of zero extinction rates during evolutionary radiations was the result of running simulations with insufficient speciation rates. Further, we find that the ratio between the initial speciation rate and the extinction rate at equilibrium, and not the diversification rate per se, determines whether the signal of decreasing diversification will be eroded from a molecular phylogeny. This ratio can thus be used to quantify the relative magnitude of extinction for any given empirical phylogeny. We also show that if the equilibrium extinction rate can be estimated from the fossil record, that the initial speciation rate of the evolutionary radiation can be estimated, a parameter which can seldom, if ever, be measured directly from the fossil record.

4: 4:45 PM-5:00 PM
Presenter: LLOYD, GRAEME T.

PROTEIN STRUCTURAL DOMAINS, THE TREE OF LIFE AND THE EVOLUTION OF COMPLEXITY

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Identifying appropriate characters to compare very distantly related taxa, both in terms of phylogenetic relationships and organismal complexity, is problematic when limited to the

morphological features preserved in the fossil record. Molecular biology offers an alternative approach to resolving phylogeny, but sequence data can be confounded by accumulated mutations when extremely deeply diverging relationships are targeted. In addition, sequence data does not fit the binary presence-absence role required to assign synapomorphies to clades or allow the counting of parts as a proxy for organismic complexity. Here the alternative data source of protein structural domains (discrete units of the folded protein) that can be automatically identified as presence-absence characters in genome-sequenced organisms are used to tackle these problems. This data already resides in the freely-available online resource, SUPERFAMILY (http://supfam.mrc-lmb.cam.ac.uk/). Not only are many of these characters extremely ancient, and hence ideal for comparative studies across the three domains of life, but they also fit well the role of ancient synapomorphy and organismic complexity proxy. Results are presented for phylogenetic, principal coordinate and other numerical analyses of presence-absence matrices for domains (grouped at family and superfamily levels) and architectures (the sequence of domains in the whole protein) in over 700 genome-sequenced organisms. These suggest that most novel domains evolved in the Precambrian, and that Phanerozoic protein evolution shifted towards shuffling and recombining these domains in order to make novel proteins: protein architecture evolution became increasingly more prominent. As a proxy for organismic complexity these results suggest a ranking of increasing complexity with Archaea at the base and vertebrates at the top. Both the promise and limitations of this approach are discussed with particular reference made to the potential complexity of the last universal common ancestor and the problem of horizontal evolution.

4: 5:00 PM-5:15 PM
Presenter: VINTHER, JAKOB

HARD EVIDENCE FOR SOFT QUESTIONS: TRACING THE EVOLUTION OF CHITONS AND APLACOPHORANS WITH MOLECULAR PALEOBIOLOGY

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Chitons (Polyplacophora) and aplacophorans are a group of mollusks which have been regarded as crucial in understanding the early evolution of the phylum. Aplacophorans have been regarded by many as the basalmost mollusks, whereas others have been regarding them as a sistergroup to the chitons in the clade Aculifera/ Amphineura. The fossil record leaves no evidence for an early appearance of aplacophorans, whereas other groups, like gastropod and bivalve stem lineages are present by the end of the Early Cambrian. Chiton-like stem groups

are known from the Late Cambrian, whereas the putative stem aplacophoran *Acaenoplax* is from the Early Silurian. This fossil suggests, along with embryological data, a plesiomorphic state of possesing a row of seven dorsal shell plates for the aplacophorans along with a foot, which indicates a chiton-like ancestor for the aplacophorans and also that the chitons should be the sistergroup in the clade Aculifera. This group should, given the fossil record, have diverged prior to the Late Ordovician and presumably after the Late Cambrian appearance of chiton-like fossils that seem to be stem aculiferan fossils. In order to test this we have been sequencing seven nuclear housekeeping genes from a number of chitons and aplacophorans comprising the crown groups of both along with a representative selection of bivalves, gastropods and cephalopods in order to obtain a phylogeny of the mollusks and in order to estimate the timing of divergence of the Aculifera. This analysis confirms the fact that aplacophorans are not basal mollusks and that the Aculifera appeared much after the Cambrian explosion, which indicates that the morphology of the simple aplacophorans have little significance for reconstructing the ancestral morphology of mollusks.

4: Poster
Presenter: ANDERSON, BRENDAN

ESTIMATING THE DIVERGENCE TIMES OF "MISSING" OPEN-OCEAN TAXA OF THE PALEOZOIC: A MOLECULAR CLOCK APPROACH. For full abstract, see *25: 2:00 PM, Booth 1*

Session No. 5, 1:30 PM; Monday, 22 June 2009
Symposium S2. Size Matters: Pursuing General Laws in Body-Size Evolution and Ecology

5: 1:30 PM-1:45 PM
Presenter: BELL, MARK A.

A HISTORY OF TRILOBITE BODY SIZE EVOLUTION

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As one of the most diverse clades within the fossil record, trilobites provide excellent candidates for macroevolutionary investigations. Despite an average length of 100 mm, individuals or entire populations are known to have well exceeded this length. In order to properly quantify the distribution and evolution of body size within the group a database was

constructed consisting of measurements from 13,000 individuals designed to cover the taxonomic, temporal and geographic range of the Class. Here, online databases of diversity (i.e. Sepkoski and the PaleoDB) and environmental proxies are used to correlate body size against environmental and ecological fluctuations. Trilobites are shown to have a body size evolution similar to their overall diversity; following a peak in the Cambrian and Early Ordovician they decreased in size until the end Permian with a secondary peak in the Middle Devonian. Spearman rank correlations for the entire Paleozoic suggests that while trilobite body size positively correlates with diversity and temperature it negatively correlates with weathering and productivity. The support of these trends are discussed though the use of several resampling techniques. Finally, the effects on body size of the Ordovician glaciation are noted here. The Lilliput effect, where post-extinction faunas generally consist of small sized forms, is recognised here both within the global dataset as well as regional subsets. However, by comparing taxa that became extinct against those which survived it appears that no size selectivity occurred.

5: 1:45 PM-2:00 PM
Presenter: LOCKWOOD, ROWAN

CLIMATE CHANGE AND BODY SIZE EVOLUTION: PATTERNS IN VENERICARD BIVALVES DURING THE PALEOGENE OF THE GULF COASTAL PLAIN

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Body size is one of a number of ecological attributes thought to vary in response to temperature in modern bivalves, but the influence of climate change on size in fossil organisms remains poorly understood. The Paleogene of the U.S. Gulf Coastal Plain is an ideal study system for assessing the potential link between temperature and body size in benthic mollusks. In particular, the record of venericard bivalves (Bivalvia: Venericardia), which are well-preserved and abundant throughout the Paleogene, makes it possible to document trends in body size across two intervals of climate change - the Paleocene-Eocene Thermal Maximum and the Early Eocene Climatic Optimum. Body size was quantified in 952 specimens representing 35 species of venericard bivalves, spanning the early Paleocene to the early Oligocene along the Gulf Coastal Plain. Specimens from museum collections and field samples were examined, re-identified, and photographed in two orientations - lateral and cross-sectional. Landmark coordinates were used to quantify morphology - 13 in the lateral and 6 in the cross-sectional orientation. Homologous landmarks included the position of hinge teeth and adductor muscles and pseudo-homologous landmarks included the position of maximum

shell height and length. Size was quantified using centroid size metrics in both orientations, combined using the geometric mean of both measures. Data on grain size and paleoenvironment at sample sites were also collected to qualitatively control for the effects of environment on these data. Size changes were quantified through time and compared explicitly with global and regional climate change data (derived from microsampling of venericard shell bands), within a phylogenetic framework. Preliminary results fail to show a statistically significant relationship between temperature and body size, but suggest that body size may be weakly tracking patterns of climate change.

5: 2:00 PM-2:15 PM
Presenter: ALLMON, WARREN D.

SIZE IN TURRITELLINE GASTROPODS ACROSS THE PLIO-PLEISTOCENE BOUNDARY IN THE ATLANTIC COASTAL PLAIN

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Turritellines (family Turritellidae) are mainly suspension-feeding marine gastropods. Previous work suggests that turritelline abundance and species diversity are at least sometimes linked to primary productivity. Size - affected by rates and/or duration of growth -- has been less studied, but growth rates in some living and fossil species appear to be relatively high. Over their geological range (Lower Cretaceous-Recent) they vary in size from ~2 to >20 cm. Turritellines in the Plio-Pleistocene of the U.S. Atlantic Coastal Plain (ACP) include 10-15 species (systematic revision in progress), and ranging from 2 to 10 cm. They also changed in abundance and diversity across this interval, and therefore may offer a good test case of the role of productivity in affecting these variables. Preliminary data on size and abundance, as well as growth (determined by O-isotope sclerochronology) of fossil and Recent turritellines from the ACP suggest that mean size, species diversity, and abundance of all turritelline species declined - roughly coincidentally -- over the past 5 million years in this region. These changes appear to have occurred in at least two steps: between the Pinecrest/Duplin and Caloosahatchee/lower Waccamaw formations (middle to Late Pliocene), and between the Caloosahatchee/ lower Waccamaw and upper Waccamaw/Bermont formations (Late Pliocene - Early to middle Pleistocene). Preliminary results (based on isotopic profiles from five species from Florida and North Carolina) suggest that size decrease was due to decrease in growth duration after the middle Pliocene, followed by decrease in growth rates across the Plio-Pleistocene boundary. These patterns may be consistent with previously estimated decreases in primary productivity across this interval. They may also, however, point to multiple causal

mechanisms. Work in progress aims to expand the isotopic data to all species, and to determine to what degree these size changes were accomplished within lineages or by immigration.

5: 2:15 PM-2:30 PM
Presenter: ALROY, JOHN

THE LATEST WORD ON BODY MASS EVOLUTION IN NORTH AMERICAN MAMMALS

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North American fossil mammals have long served as a convenient system for studying body mass evolution, but most aspects of earlier studies leave room for improvement. First, mass estimates have most often been based on the area of the first lower molar. However, because its size scales variably with mass in different extant groups it is not a reliable estimator in the deep Cenozoic record. Based on measurements of complete cheek tooth dentitions in extant Old World mammals, a more reliable approach is to ignore tooth position and focus on the size of the second largest lower tooth, whatever that might be. A variety of related and equally simple equations perform about as well. Second, an early demonstration that Cope's rule applies most strongly to mid-size mammals rested on comparisons of older and younger species in the same genera, which might or might not be closely related. A new data set of more than 300 comparisons between putative ancestor and descendant species suggests that the trend is even stronger than had been thought. Third, recent speculations (including mine) about a correlation between body mass and extinction rate are not supported by new analyses of observed age range durations. No relationships are seen regardless of whether or how the data are binned, whether species falling below a minimum duration are excluded, or what statistics are used. Finally, speciation rates remain problematic because they are not a simple function of a single variable such as duration, unlike extinction rates. Nonetheless, the relationships between species richness, age of first appearance, occurrence frequency, and body mass for extant genera do not imply that speciation rate is size-dependent. Together, the data suggest that a nonlinear Cope's rule is the main factor that has imposed the rigid limits on mammalian body size throughout the Cenozoic.

5: 2:30 PM-2:45 PM
Presenter: ORCUTT, JOHN D.

CLIMATIC AND BIOTIC INFLUENCES ON EQUID BODY SIZE EVOLUTION

ORCUTT, JOHN D., Geological Sciences, University of Oregon, 1272 University of Oregon, Eugene, OR, 97403, United States, jorcutt@uoregon.edu

A long-standing question in ecology is whether biotic change is more strongly controlled by climate or biotic interactions. Because fossil data allow ecosystem change to be observed over time, paleontology provides a unique and useful perspective on this debate. A particularly interesting case study is mammal body size; though latitudinal body mass gradients were observed as early as 1847, the processes underlying these patterns remain unclear. The hypothesis originally proposed to explain these gradients is now know as Bergmann's rule which, in its original formulation, holds that temperature is the driving force behind body size evolution: large individuals have low surface area to volume ratios, making them more efficient at retaining heat and giving them a selective advantage in cold climates. Since the publication of Bergmann's rule, several alternative hypotheses have been presented proposing mechanisms both climatic (e.g. temperature, seasonality) and biotic (e.g. competition, food availability) in nature. Due to its well-resolved fossil and climate records, the North American Oligo-Miocene represents an excellent natural laboratory in which to apply a paleontological test to these competing hypotheses. Using dental measurements, I have reconstructed Arikareean-Hemphillian (30-5 Ma) body mass trends for equids, one of the most completely sampled groups of fossil mammals, at several taxonomic levels. Data were collected along two transects (one north-south and one west-east) for each land mammal age subdivision, as well as along chronoclines within biogeographic regions. Counter to Bergmann's rule sensu stricto, equid body mass is not strongly correlated with mean annual temperature, though some taxa do track seasonality and precipitation. However, given the variability in patterns between taxa and regions, it is likely that body mass is governed by a complex interaction between climatic and biotic factors.

5: 2:45 PM-3:00 PM
Presenter: HENDY, AUSTIN J.W.

TAPHONOMIC OVERPRINTS ON PHANEROZOIC TRENDS IN BODY-SIZE AND MORPHOLOGY

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A number of taphonomic processes have the ability to degrade as well as enhance the relative quality of fossil material, therefore introducing bias into analyses of taxonomic diversity, morphological complexity, and trends in body-size. Complicating this, these taphonomic biases have varied over time, both as a result of changes in the physical environment or in the production or concentration of fossil organisms themselves. Additionally these taphonomic biases vary significantly between major groups of taxa due to changes in the presence and robustness of hard parts, hard part mineralogy, and variations in life-habit. Phosphatisation, for instance, plays an important role in enhancing the fossil record of Cambrian life,

preferentially preserving thin and small-shelled metazoans. Silicification of fossil material through the Paleozoic, but especially the Permian, also enhances the preservation and abundance of fossils at the small end of the size spectrum. Lithification and aragonite dissolution, however, tend to bias against the preservation of small specimens and result in greatly depleted community composition in rocks of Paleozoic and early Mesozoic age. These biases are presented using two datasets: 1) specimen-derived (museum-reposited) data of preservational quality and body-size characteristics for a range of long-lived gastropod, bivalve, echinoid, and decapod clades; and 2) occurrence-based data, supported by ancillary taphonomic information for a range of Phanerozoic marine organisms from the Paleobiology Database. These data reveal that the above-mentioned taphonomic processes do act to skew the representation of particular size-classes in the fossil record, influencing broad-scale characterization of body-size trends groups. Additionally, these biases severely affect the preservation of diagnostic morphological characters, the basic criteria for which taxonomic units are defined from in the fossil record. The taphonomic condition of the fossil record therefore plays an important if not somewhat under-appreciated role in perceptions of biodiversity and interpretation of evolutionary trends.

5: 3:00 PM-3:15 PM
Presenter: MCCLAIN, CRAIG R.

BIODIVERSITY AND BODY SIZE ARE LINKED ACROSS METAZOANS

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Body size variation across Modern Metazoa is immense, encompassing 17 orders of magnitude in biovolume. Factors driving this extreme diversification in size and the consequences of size variation for biological processes remain poorly resolved. Species diversity is invoked as both a predictor and a result of size variation, and theory predicts a strong correlation between the two. However, evidence has been presented both supporting and contradicting such a relationship. Here, we use a new comprehensive dataset for maximum and minimum body size across all modern metazoan phyla to show that species diversity is strongly correlated with minimum size, maximum size, and consequently intra-phylum variation. Similar patterns are also observed within birds and mammals. The observations point to several fundamental linkages between species diversification and body size variation through the evolution of animal life.

5: 3:15 PM-3:30 PM

Presenter: LAFLAMME, MARC

MODULAR CONSTRUCTION IN THE GROWTH AND FEEDING OF THE EDIACARA BIOTA

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Ediacaran rangeomorphs and erniettomorphs consist of macroscopic, soft-bodied and structurally complex organisms/colonies which utilize repeatable modular units as building blocks to form several different species all occupying different epifaunal trophic guilds. Rangeomorphs and erniettomorphs lacked any discernable feeding appendages or external openings and presumably fed via direct nutrient absorption of dissolved organic carbon (DOC) from the water column. Erniettomorph modular units consist of tubular branches or segments with minimal external ornamentation. Modeling of shape variations attributed to growth demonstrates a need to limit the internal, biologically active component of the erniettomorph module by constructing metabolically inactive vacuoles, which would have significantly reduced the volume of metabolically active tissue and allowed for effective surficial diffusion. Analogous volume reduction is common among modern giant osmotrophic bacteria. Rangeomorph modular units consisted of fractal branches which resulted in morphologically similar units at several branching orders. Each order of branching significantly increased the surface-area in contact with the surrounding medium, while having negligible effect on total volume, and therefore allowed for effective absorption-based feeding through fractal branching alone. The growth strategies of rangeomorphs and erniettomorphs were strongly influenced by the need to keep a high surface-area to volume ratio, which resulted in two distinct growth strategies. Erniettomorph growth was characterized by the addition of new tubular modular units with growth rather than inflation of these units which would drastically reduce the surface-area to volume ratio. In contrast, rangeomorphs were able to grow by inflation but their growth was accompanied by fractal branching in order to maintain physiologically viable surface-area to volume ratios. Passive osmotrophy of macroscopic Ediacara biota offers an alternative to self-powered filter feeding of sponges and cnidarians, and may represent a failed Ediacara trophic strategy due to direct competition with more efficient crown-group metazoans.

5: 4:00 PM-4:15 PM
Presenter: HUNTLEY, JOHN WARREN

BODY SIZE DISTRIBUTIONS AS A MEANS TO TEST FOR THE EVOLUTIONARY IMPORTANCE OF COMPETITION AMONG TERRESTRIAL GASTROPOD SPECIES

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Limiting similarity postulates that morphologically (and by extension ecologically) similar species will differ enough in size or shape to minimize the effects of competition. This hypothesis has been controversial amongst ecologists and paleoecologists whose studies have demonstrated its occurrence among modern organisms and in time-averaged fossil deposits, respectively. However, high-resolution time series demonstrating limiting similarity sustained over longer time scales are lacking. Here we test the hypothesis of limiting similarity in Pleistocene-Holocene land snails from the Canary Islands over a period of 42,500 years by integrating radiocarbon-calibrated amino acid dating techniques, stable isotope estimates, and morphometric data. We tested for ecological character displacement between the two most abundant species and for the existence and persistence of community wide character displacement among the entire gastropod fauna. Two proxies of body size show that the two most abundant species (*Theba geminata* and *T. arinagae*) maintained a difference in size from 42,500 B.P. through the last occurrence of *T. arinagae* 14,900 B.P., with a concomitant trend of a decreasing body size. *Theba geminata* body size did not converge on that of *T. arinagae*. Moreover, the coefficient of variation in *T. geminata* body size did not increase significantly following the extinction of *T. arinagae*. Therefore, ecological character displacement and release did not occur. Community-wide character displacement, as suggested by the over-dispersion of body sizes, was found in only one time bin over the last 42,500 years. Our results suggest that limiting similarity is a transient ecological phenomenon rather than a long-term evolutionary process. Moreover, our study not only demonstrates the problems inherent in biological snapshot studies and geological studies of time-averaged deposits to test limiting similarity adequately, but it also presents a more adequate research protocol to test the importance of interspecific competition in the history of life.

5: 4:15 PM-4:30 PM
Presenter: KRAUSE, RICHARD A., JR.

DISCORDANT SHAPE OF SIZE DISTRIBUTIONS OF EPIFAUNAL AND INFAUNAL JURASSIC BIVALVE SPECIES

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Whereas the prevalence of right-skewed size distributions for mammal and bird species has been well documented, the pattern for marine invertebrates is less clear. Modern Pacific bivalve species have been shown to have slightly left-skewed distributions but much less is known about fossil taxa. Using the taxonomic literature and measurements of specimens in museum collections, we have compiled a database of sizes for over 1200 nominal Jurassic bivalve species. We find that they tend to have left-skewed distributions, but there are significant differences in distribution shape between ecological groups. Epifaunal species are commonly right-skewed, while infaunal species are almost always left-skewed. This apparent dichotomy persists in most Jurassic stages and in many regional collections, where sample size is sufficient to investigate this pattern. Understanding of the underlying causes of species' size distributions is not straightforward as there are a myriad of potentially influential factors. Energetic models are difficult to apply to fossil taxa that have no living representative. Thus, we have evaluated the tendency for species or genera to evolve toward the modal size class during the Jurassic. The vast majority of species and genera in our dataset show no such tendency. In fact, taxa larger than the modal size in one stage are equally likely to be smaller than the modal size in the next stage as they are to remain at the same size or evolve toward the mode. Furthermore, epifaunal and infaunal bivalves show no substantial difference in their propensity to evolve toward the modal size. These results agree with similar studies of Cretaceous and modern bivalves and may suggest species sorting (differential origination and extinction within and among size classes) as a mechanism for maintaining the shape of size distributions in time and space.

5: 4:30 PM-4:45 PM
Presenter: NOVACK-GOTTSHALL, PHILIP M.

VARIATION IN LOCAL BODY SIZE DISTRIBUTIONS OF FOSSIL AND MODERN TAXONOMIC GROUPS MAY REFLECT HABITAT AND LIFE-HISTORY DIFFERENCES

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The shape of body size distributions (BSDs) across species within local assemblages may reflect local controls during community assembly or the local expression of global species' spatial distributions. Modern mammal assemblages remain the best documented, and tend to be

more dispersed than the global pool of mammals. However, it remains unclear whether similar distributions persist across taxa, time, or environments. Here we evaluate the controls on local BSDs using a large compilation of BSDs for modern and ancient assemblages from a diverse range of habitats and taxa, including mammals, mollusks, brachiopods, trilobites, and freshwater diatoms and fishes. To standardize comparisons across diverse taxa, size was measured as body volume, using a single size estimate for each taxon within local assemblages. BSDs were evaluated using skewness, kurtosis, and model-fitting techniques. Within clades from a single habitat, BSDs are invariant throughout the Phanerozoic. Moreover, fossil assemblages are statistically indistinguishable from their modern counterparts, despite differing in age by as much as 400 million years. In contrast, there exist significant differences in the shape of BSDs among taxonomic groups and among habitats. Consistent with prior studies, terrestrial mammals and most shallow subtidal gastropods and bivalves display uniform-to-normal BSDs with negligible-to-slightly-negative kurtosis. Brachiopods and trilobites display more negatively skewed distributions with positive kurtosis. Freshwater fishes, diatoms, and both terrestrial and deep sea gastropods display BSDs with highly positive skew and positive kurtosis. Although these groupings share little in terms of phylogeny and habitats, they may reflect similarities in geographic dispersal. For example, the freshwater and deep sea taxa all live in patchily distributed microhabitats that require passive, opportunistic dispersal. Taken together, these results suggest that BSDs may reflect ecological and/or physiological properties that vary among higher taxa and habitats but that have been conserved over vast stretches of geological time within them.

5: 4:45 PM-5:00 PM
Presenter: BOYER, ALISON G.

AN UPPER LIMIT TO MAXIMUM ANIMAL BODY SIZE THROUGH THE PHANEROZOIC

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Maximum body size has increased enormously over the Phanerozoic, but the pattern and timing of this size increase is poorly known. Consequently, the limits to body size and the extent to which size evolution is passive or driven have been difficult to evaluate. Our compilation of the largest known fossil Arthropods, Chordates and Molluscs in each Epoch demonstrates that size increased rapidly following the appearance of multicellular animal life, reaching 9.8 log10 biovolume units (BV; approx. 6300kg) during the Middle Ordovician . Since that time, however, maximum size has been maintained at approximately 10-11 BV, while global animal diversity has continued to increase. The apparent upper bound to global maximum body size is conserved across both time and animal phyla. Many clades have

attained this maximum size independently, including cephalopods, reptiles, fishes, and mammals. In each class, maximum size was reached quickly from a substantially smaller ancestor. In the oceans the largest animals were habitually motile predators or filter feeders, whereas on land herbivores have out-sized predators since the Triassic. Correlation of maximum size patterns to motility, habitat, and trophic level indicate that primary productivity and trophic efficiency may provide clues to the limit of maximum size on earth.

5: 5:00 PM-5:15 PM
Presenter: FINNEGAN, SETH

SIZE INVARIANT EXTINCTION RISK IN THE MARINE FOSSIL RECORD

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Large body size is a frequently-cited risk factor for extinction, but published studies provide only mixed support for this hypothesis, primarily among terrestrial vertebrates. Here we conduct a comprehensive examination of the association between body size and extinction risk for a phylogenetically and ecologically broad range of benthic invertebrate and planktonic groups through the Phanerozoic. In none of the groups examined do we find a consistent positive relationship between size and extinction risk (e.g., larger species experience higher extinction risk), either for the clade as a whole or for subtaxa within clades. Two of the groups (gastropods and diatoms) exhibit a weak but marginally significant inverse relationship between size and extinction risk. Although this is consistent with findings from some previous studies, it is difficult to rule out taphonomic or collection biases as the source of the inverse association in these data sets. The absence of a consistent relationship between body size and extinction risk in marine invertebrates may reflect differences between these groups and terrestrial vertebrates in the allometric scaling of relevant macroecological and life-history attributes, but also may be related to the absence of an anthropogenic extinction signal in our Phanerozoic-scale datasets.

Session No. 6, 1:30 PM; Monday, 22 June 2009
Symposium S3. Rapid Evolution of Terrestrial Ecosystems and Their Influence on Marine Realms - Land-sea interactions in the Devonian

6: 1:30 PM-1:45 PM
Presenter: ALGEO, THOMAS

NEW INSIGHTS ON THE FRASNIAN/FAMENNIAN MASS EXTINCTION: A ROLE FOR SOIL EROSION?

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The Frasnian/Famennian (F/F) mass extinction was the most severe marine biotic crisis of the middle Paleozoic. The present study examines the geochemistry of a 28-m-thick F/F boundary section from western New York State, comprising bioturbated shales of the Hanover Formation and mostly laminated shales of the overlying Dunkirk Formation. Paleoredox proxies (DOP, FeT/Al, δ^{98}Mo) indicate an increase in the frequency and intensity of anoxia at the F/F boundary. Trace-metal proxies suggest an episode of deepwater restriction, possibly as a consequence of eustatic fall. The boundary is characterized by a large decrease in Zr/Al, indicating lower silt:clay ratios, and by a large decrease in excess Ba (i.e., total Ba-detrital Ba), implying reduced levels of primary productivity. Organic C- and N-isotopic data provide evidence of a major change in organic matter fluxes commencing ~7 meters below the boundary and persisting ~10 m above it. Kerogen and total organic carbon δ^{13}C exhibit shifts of +5‰ and +15‰, respectively, in organic-poor beds within this interval, suggesting a large input of highly weathered, soil-derived organic matter. Organic δ^{15}N values decrease from +2 to -1‰ at the boundary, possibly as a result of cyanobacterial N fixation. Biomarker analysis, still in progress, may provide additional clues concerning changes in organic matter sources. The existing data are consistent with a model of enhanced terrigenous siliciclastic flux to the northern Appalachian Basin at the F/F boundary linked to climatic cooling, eustatic regression, and soil erosion. The rapid development of soils as a consequence of the expansion of terrestrial ecosystems during the Middle and Late Devonian (Algeo et al., 1995, Late Devonian oceanic anoxic events and biotic crises: “Rooted” in the evolution of vascular land plants? GSA Today, v. 5(5), p. 45, 64-66) may have created the potential for precipitating marine ecological crises through soil erosion events.

6: 1:45 PM-2:00 PM
Presenter: MARSHALL, JOHN E. A.

THE TERRESTRIAL FRASNIAN

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Truly terrestrial Frasnian sections that also contain a record of the biota are extremely rare. These sections are crucial as they provide the missing terrestrial component of the Devonian Earth System. In other parts of the Devonian record these terrestrial records have added very significantly to our understanding of the extinction processes that operated in the marine realm. Here we can report on a long (> 1km) terrestrial section from Ymer Ø, East Greenland that gives a high resolution integrated record of spores and palaeoclimate through much of the Frasnian interval. Productive palynological samples are quite rare but contain similar spore assemblages to those recorded from the Timan in Russia. These spores assemblages from the Timan are significant in that they occur in well studied sections that also contain conodonts and goniatites. The East Greenland section shows a number of distinctive climatic events such as thin 'coals' and two intervals which are defined by palaeosols and mark sustained episodes of aridity. In the latest Frasnian these palaeosols are associated with a progressive and significant down-step in the diversity and complexity of terrestrial vegetation. Therefore any mechanisms that are proposed to explain the Frasnian-Famennian event must act on the entire Devonian Earth System rather than simply within the marine realm.

6: 2:00 PM-2:15 PM
Presenter: RETALLACK, GREGORY J.

PEDOSTRATIGRAPHIC CORRELATION OF MISSISSIPPIAN AND DEVONIAN RED BEDS

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Most Middle Devonian to Mississippian paleosols of the Catskill, Mauch Chunk and other formations of New York and Pennsylvania have calcareous nodules close to their rooted surfaces (<50 cm) as in soils (Aridisols) of desert shrubland. Some paleosols however have deeper calcic horizons (Bk), more deeply weathered horizons (Bw and Bt) and larger root traces and stump casts, as in soils (Vertisols, Alfisols) of dry woodland. Deep-calcic paleosols occur in sequences of few (1-5) paleosols within long sequences of hundreds of shallow-calcic paleosols, and reflect short-term events of climate and vegetation change. Deep-calcic paleosols are found at stratigraphic levels correlative with marine black shale events: Genundewa, Middlesex, Lower and Upper Rhinestreet, Lower and Upper Kellwasser, Nehden, Condroz, Enkeberg, Annulata, Hangenberg, Ivorian, Asbian, Brigantian and Chokierian. Deep-

calcic paleosols are not spaced at regular intervals of time: frequent Middle Devonian events contrast with less frequent Late Devonian and few Mississippian events. Middle Cambrian and Early Triassic were also times of frequent deep-calcic events in calcareous redbeds, in contrast with Early and Late Cambrian, Middle Triassic and Late Permian. Devonian deep-calcic events may have been global, because comparable Devonian deep-calcic paleosols are found in sequences of shallow-calcic paleosols in the Cloghnan Shale near Bunduburrah, New South Wales, and Aztec Siltstone of Mt Lashly, Victoria Land, Antarctica. Such short-lived episodes of deep-calcic paleosols during the Permian, Mesozoic and Cenozoic have been attributed to global greenhouse spikes during which wetter climate and woody vegetation displaced desert shrubland, and oceanic eutrophication led to marine anoxia. Global distribution of deep calcic paleosols with comparable spacing within sections allows pedostratigraphic correlation of non-marine red beds in a manner comparable with paleomagnetic stratigraphy.

6: 2:15 PM-2:30 PM
Presenter: WAN, ZHENZHU

STOMATAL PARAMETERS OF MIDDLE DEVONIAN-EARLY CARBONIFEROUS LAND PLANTS

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The concentration of atmospheric CO_2, the most important greenhouse gas in the Earth's climate system, changed from as much as 12 PAL (present atmospheric level) in the Middle Devonian to ~1 PAL by the mid-Carboniferous, as inferred from modeling and carbon isotopic studies (Berner, 2004). However, the timing and rate of the decline in atmospheric CO_2 during this interval remain poorly known. The present study attempts to refine the record of changes in atmospheric CO_2 through analysis of fossil plant stomata. Fossil plant cuticle preserved as coalified compressions was recovered for long-ranging Devono-Carboniferous morphospecies morphospecies (e.g., *Archaeopteris*, *Drepanophycus*, *Elkinsia*, *Lepidodendropsis*, *Psilophyton*, and *Rhacophyton*) from multiple locales of varying ages. By tracking changes in several plant clades, the influence of local factors such as altitude, latitude, incident radiation, and atmospheric humidity can be controlled for, and broad trends in stomatal parameters may be imputed to a global environmental control such as atmospheric CO_2. To date, only a handful of studies have attempted to recover fossil plant cuticle from Paleozoic formations (McElwain and Chaloner, 1995; Edwards et al., 1998). Maceration of fossil plants collected for the present study has yielded abundant fossil plant cuticle, including many specimens containing stomata. Work currently under way will determine the stomatal density and index of these specimens and the delineation of secular patterns that comment on changes in atmospheric pCO_2 through time. Berner, R. A., 2004. The Phanerozoic carbon cycle; CO_2 and O_2: Oxford University Press, Oxford, 150. Edwards, D., Kerp, H., Hass, H., 1998. Stomata in early land plants: an anatomical and ecophysiological approach. J. Exp. Bot. 49, 255-278.McElwain, J. C.,

Chaloner, W. G., 1995. Stomatal density and index of fossil plants track atmospheric carbon dioxide in the Palaeozoic. Ann. Bot. 76, 389-395.

6: 2:30 PM-2:45 PM
Presenter: VECOLI, MARCO

THE EFFECTS OF TERRESTRIALIZATION ON MARINE ECOSYSTEMS: THE FALL OF CO_2

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The rise of land plants during the earliest Palaeozoic had profound effects upon subsequent Earth history and evolution. Through the sequestration of standing carbon biomass and carbon burial, there was a primary shift in the distribution of active carbon within the biosphere and surficial earth systems. This manifested itself in a dynamic decline in pCO_2 during Silurian -Devonian time, which affected both terrestrial and marine ecosystems. We examined first order correlations between terrestrialization and pCO_2 by comparing the GEOCARB III data with time constrained fossil events in the early evolution of land plants. Next we compared the same GEOCARB III data with the species/genus richness of lower Palaeozoic acritarchs derived from the Palynodata database. Stepwise decline in the pCO_2 model data appears to be closely correlated in time with major evolutionary punctuations in the plant kingdom. The decline of the acritarchs, however shows a highly correlated lag of about 10 m.y. with respect to the pCO_2 decline. While the correlation between the rise of terrestrial land plants and CO_2 decline is widely known, the relation between pCO_2 and acritarch species richness suggests a very tight coupling between the evolution of the marine phytoplankton and atmospheric pCO_2. Declining pCO_2 was a significant causal factor in the near extinction of acritarchs by the end of the Devonian.

6: 2:45 PM-3:00 PM
Presenter: BROCKE, RAINER

MARINE-TERRESTRIAL SEQUENCES IN THE LOWER DEVONIAN OF GERMANY- A PALAEOBOTANICAL AND PALYNOLOGICAL APPROACH

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The Lower Emsian in the Rheinisches Schiefergebirge (Germany) is characterized mainly by siliciclastic sediments which have been deposited in the southern front of the Old-Red-Continent. The palaeo-relief was highly differentiated, indicated by a large number of small basins partly developed on a delta top position with occasional gentle marine ingressions. In such local basins or coastal shoreline environments, accumulation of coals or coaly sediments (so-called Brandschiefer) became frequent, in contrast to older strata. The Heimbacher Schichten which are probably an equivalent of the Middle Emsian Klerf Formation have been studied in detail. They are less coalified than typically developed in neighbouring areas. Thus, the maturity of the organic matter is comparably low and allows the preparation and analysis of cuticles and miospores. The studied section of the abandoned quarry “Linderjahn” near Bad Münstereifel (Western Germany) is a typical example of a mixed sequence of terrestrial and marine sediments. Based on macrofossils, the marine influence seems to be restricted to a well defined horizon around 70 cm above a so-called “coal seam”. This “coal” serving as tectonic slide surface is in fact a clayey siltstone with very thin coal layers. Micro , meso and macrofossils have been analysed to show the transition from terrestrial to marine facies which is not obvious from a general overview of the sedimentary succession.

6: 3:00 PM-3:15 PM
Presenter: SCHINDLER, EBERHARD

SILICICLASTIC MICROFACIES AND TAPHONOMY OF A LOWER DEVONIAN MARINE-TERRESTRIAL TRANSITIONAL ENVIRONMENT (NELLENKÖPFCHEN FORMATION, RHEINISCHES SCHIEFERGEBIRGE, GERMANY): IMPLICATIONS FOR SMALL-SCALE FLUCTUATIONS IN A COMPLEX SETTING

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The homogeneous succession of high-energy intertidal, predominantly sandy deposits in the Lower Devonian (Emsian) Nellenköpfchen Formation near Alken (Mosel area, Germany) is interrupted by two finer-grained fossiliferous units, the 'Lower Alken Fossiliferous Unit' (LAFU)

and the 'Upper Alken Fossiliferous Unit' (UAFU). They are famous because of an exceptional taphocoenosis, including early land plants, terrestrial spiders, eurypterids and scorpions. Siliciclastic microfacies analysis has successfully been applied for the recognition of trends throughout the individual fossiliferous units. The LAFU is composed of nine subunits which are characterized by continuous trends in grain size and sedimentary structures as well as the degree and kind of bioturbation. They are separated by distinct boundaries. Except for a basal twofold silting-up cycle rich in autochthonous to parautochthonous plant material, no superimposed trend is obvious in the LAFU. In contrast, the UAFU is formed by five distinct subunits, in general showing a fining-upward trend starting with rhythmic high-energy pulses at the base. Towards the top, organic(plant)-rich sediments have been deposited reflecting a repeated silting-up situation. In contrast to previous single-event interpretations, these sets of distinct subunits now prove a much more complex origin. This is due to the combination and interaction of small-scale sea-level change, lateral shift of depositional facies, synsedimentary tectonics and meteorological events. It can be shown that both units are the result of sedimentary processes in a distal deltaic setting comprising a number of different depositional sub-environments as occurring in interdistributary areas of the lower delta plain. The delta system of the Indus River may serve for comparison.

6: 3:15 PM-3:30 PM
Presenter: BERRY, CHRISTOPHER M.

THE FIRST FORESTS - TOWARDS THE DOMINANCE OF ARCHAEOPTERIS

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Cladoxylopsida are the first forest trees in the fossil record. Large in situ rooted casts at Gilboa plus compressions at South Mountain, NY (Givetian-Frasnian boundary) reveal strange trees with tapering trunks and highly ramified leafless branches. *Archaeopteris* (Progymnospermopsida) is widely regarded as the dominant forest tree of later Frasnian to Famennian age. Although pteridophytic, these plants are more familiar, often interpreted as conifer-like trees with multiple features recognized in later seed plants. They have eustelic vascular architecture, extensive wood, excurrent habit, and many-times ramified plagiotropic lateral branches. Ultimate branchlets are either simple or compound, depending on interpretation, and include the first record of laminar leaves (or leaflets). Based on megafossils and spores, *Archaeopteris* (or close relative) extends back at least to the mid Givetian, perhaps earlier. At South Mountain, narrow (ca. 45mm) stems are abundant at the outcrop. Several are permineralized, showing eustelic architecture and extensive secondary

xylem. Some compression specimens, up to 3m long, have apparent abscission scars and may therefore represent trunks or major lateral branches bearing branchlets. One specimen shows apparent attachment of lateral branches, or branchlets, to a narrow trunk suggesting monocauline habit. This specimen also provides the best, if still somewhat equivocal, evidence to date for attachment of isolated fimbriate-to-leafy *Archaeopteris macilenta* sterile and fertile branchlets also found at the locality. In all examples so far, we see no indication of greater complexity for this plant. Total size attained by *Archaeopteris macilenta* at South Mountain is uncertain, but likely much smaller than contemporaneous cladoxylopsids. With changeover in dominance from cladoxylopsids to more complex *Archaeopteris* in the Late Devonian we may be observing the emergence of woody forest structure in a much more modern sense. Prior to that, global dynamics related to forest ecosystems may have been very different.

6: 3:30 PM-3:45 PM
Presenter: STEIN, WILLIAM E.

SIZING UP THE FIRST FORESTS

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The Silurian-Devonian fossil record shows rapid diversification with increased size of vascular plants culminating with trees, and extensive forests, by the Carboniferous. Although the record provides useful benchmarks for important structural features, ecological interpretations of early plant communities and their influence on geochemical cycles remain mostly unconstrained. Cladoxylopsids are the oldest trees known. In Gaspé, Quebec (lower Eifelian) plants were pole-like with 3-5 cm diameter trunk and at least 3 m height. They occur in parallel orientation on a bedding plane as if they comprised stands of similar-sized individuals. At the top was a crown of regularly abscised branches bearing highly ramified branchlets, with branches likely serving as modular photosynthetic units. Base of the plant was tapered and enveloped by robust apparently unbranched prop-like roots. Slightly later cladoxylopsids, of the order Pseudosporochnales, occur worldwide. Near Gilboa, NY (lower Frasnian), upright in situ sandstone casts of bases up to a 1m in diameter show sizeable trees with distinctive basal flaring and flat bottom, covered by dense, radiating unbranched roots. Recent work provides evidence of vascular anatomy for trunk, base, and root. Nearby specimens shows tree(s) ca. 8m in height with gently tapering trunk, and crown with digitately

ramified flattened branches that bore branchlets with terminal reflexed sporangia. One likely juvenile specimen shows extensive ground parenchyma and a complex vascular system. Given available evidence, multiple ecological interpretations of cladoxylopsid trees remain possible. Although possessing limited secondary growth, it is clear that these plants were not woody in the standard sense. Instead, they were lightly built, likely fibrous, perhaps reed-like in overall habit. Detritus produced by these plants would likely have been extensive but not refractory. The trees grew by means of a single shoot apical meristem, as do modern tree-ferns or palms, with no evidence of clonal growth by vegetative propagation.

Session No. 7, 1:30 PM; Monday, 22 June 2009
Symposium S4. Paleobiology and Paleontology of Mammals During the Uintan North American Land Mammal Age

7: 1:45 PM-2:00 PM
Presenter: WESTGATE, JAMES

PALEOECOLOGY OF A GULF COAST UINTAN-AGE TROPICAL RAIN FOREST/MANGROVE SWAMP COMMUNITY FROM LAREDO, TEXAS

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The Casa Blanca fossil flora and fauna was a diverse tropical rain forest/mangrove swamp dwelling community. It was recovered from the middle Eocene Laredo Formation, Claiborne Group, of Webb County, Texas. Only one other Paleogene land mammal community is known from the North American Coastal Plains. Fifteen tons of estuarine oyster-shell “hash” excavated at Laredo were screen-washed and treated with acetic acid to recover the fossil remains. Thirty-two mammal species include four new omomyine primate species, two marsupials, two insectivores, a bat, a large mesonychid, carnivores, a horse, two rhinos, a titanothere, six artiodactyls, a sirenian and at least eight rodent species. Paleoecological analyses of non-mammalian vertebrate, invertebrate, and floral remains indicate that the community lived in or near a tropical, *Nypa* mangrove-estuarine complex. Vertebrae from the giant estuarine snake *Pterosphus schucherti* marks its first record in middle Eocene strata of North America. The presence of cf. *Allaeochelys*, *Galeocerdo eaglesomei*, *Diaphyodus wilsoni*, *Pterosphenus schcherti* and a megalopid indicate a Tethyan influence on the community. Although more than a third of the mammalian taxa are new and endemic, others allow correlation with non-marine mammalian communities in the North American interior. Remains of *Epihippus gracilis* (horse), *Amynodon advenus* (rhino), and *Mytonomys* new sp. (rodent), indicate that the middle Laredo Formation is Uintan in age, while *P. petersoni* and *Procynodictis* cf. *P. vulpiceps* suggest it is a Uinta C correlate. The presence of *Notiotitanops mississippiensis* provides a westward range extension of this coastal brontothere which

formerly was known only from the Cook Mountain Formation of Mississippi. The gastropod *Turritella cortezi* allows correlation of the paralic middle Laredo Formation with the open marine Hurricane Lentil in the Cook Mountain Formation of east Texas. Cook Mountain Formation plankton are correlated with lower Bartonian strata of western Europe.

7: 2:00 PM-2:15 PM
Presenter: HARSH, SUSAN L.

FIELD AND LAB TECHNIQUES FOR RECOVERING MICRO-MAMMAL REMAINS FROM LOW YIELDING UINTA FORMATION FACIES

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Fossil micro-mammal localities are often missed when field test samples are small and specimens are scarce. Although Uinta Formation outcrops have been prospected for nearly 140 years, the Uinta C micro-mammal fauna is poorly known. This has biased past speculations on local climate change during Uintan time. In 2007, a 900 kg (1 ton) test sample was collected from clays at the Uinta C, Uinta Formation, WU-26 “Pond site” from surface exposures bearing numerous *Amia* vertebrae in weathering lag concentrations. The 2007 sample yielded 30 micro-mammal teeth (Westgate and others, 2008). In 2008, 4500 kg (5 tons) of red and green mudstones were collected and screen-washed in four days. Screen-washing in the Green River using 0.5 mm mesh bags reduced the samples to 90 kg (98% primary reduction). River-washed samples (41 kg red clay & 24 kg green clay) were reprocessed in the Lamar University Paleontology Lab. Varsol and H_20_2 were tested for their effectiveness as clay dispersants. Varsol was the better dispersing agent with visually effective results and a 76% vs. 58% weight reduction. By soaking samples in varsol the red clay was reduced to 1.7 kg (96% secondary reduction) and the green clay to 5.3 kg (78% secondary reduction with a large pebble fraction). Primary and secondary processing generated a 99.9+% sample-weight reduction. Sample fractions from sieves with 0.6->1.6 mm mesh were inspected using binocular microscopes. Thirty-five mammal cheek teeth identifiable at the generic or species level were recovered from the green clay. These include 25 cheek teeth from mostly mouse-size rodents (1-2 mm APL), and 10 marsupial, insectivore, carnivore, horse and artiodactyl teeth. The recovered mammal remains collectively weigh about 1 gm or one three-millionth of the original 3000 kg reprocessed sample, and a specimen yield of 0.00003%.

7: 2:15 PM-2:30 PM

Presenter: DUNN, RACHEL H.

POSTCRANIAL MORPHOLOGY OF ZIONODON, A NEW GENUS OF INSECTIVORE FROM THE UINTA FORMATION, UTAH

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Zionodon is a new genus consisting of two species of large-bodied insectivore from the Uinta B member of the Uinta Formation, Utah. Both species are notable for their large body size and for the presence of associated postcrania. The new taxa are larger than North American erinaceomorphs from the earlier Wasatchian and Bridgerian and are matched or exceeded in size only by the Uintan and Duchesnean erinaceomorphs known from southern California. Postcranially, the new genus is primitive in lacking many specializations of the ankle seen in extant erinaceids and other Eocene insectivores such as an unreduced fibula that is separate from the tibia, an unreduced medial malleolus and the retention of a superior astragalar foramen. *Zionodon* shares some tarsal features with the enigmatic Wasatchian genus *Creotarsus*. The morphology of the forelimb suggests some digging behavior in having an expanded entepicondyle and the presence of distinct tubercles for insertion of the extensor carpi radialis on the bases of MC II and III. The hindlimb exhibits a mosaic of features typical of terrestrial runners, such as an anteroposteriorly deep distal femur and a deep patellar groove, along with features seen in arboreal climbers, such as a medially and plantarly inflected calcaneal heel. The majority of the evidence suggests that new genus was terrestrial but it could probably dig and climb as well.

7: 2:30 PM-2:45 PM
Presenter: LUDTKE, JOSHUA A.

UINTAN SPECIES DIVERSITY, BIOGEOGRAPHY, AND BIOCHRONOLOGY OF THREE GENERA OF SELENODONT CETARTIODACTYLS

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Cetartiodactyls represent a major component of the Uintan fossil record. This record is a mix of primitive bunodont and bunoselenodont groups that had appeared earlier in the Eocene of North America and mostly bunoselenodont and selenodont groups that were either new endemic forms or immigrants from the Old World. This latter set of cetartiodactyls includes camelids, oreodonts, protoceratids, oromerycids, praetragulids, and leptomerycids. Three of the genera within two of these groups (oreodonts and protoceratids) have recently had species-level systematic investigations performed that increase their utility in discerning Uintan biochronology. *Leptoreodon* is an early member of the Protoceratidae, with seven

discernable species. Three of these species are known from middle Uintan localities, while all seven are known from late Uintan localities. The most diverse area for *Leptoreodon* appears to be southern California, with two endemic species and two other species mainly known from this area. The western interior appears to be relatively lacking in species diversity for *Leptoreodon*, possibly as a result of competition from the early protoceratid Leptotragulus, which is similar in morphology to *Leptoreodon*. *Protoreodon* and *Diplobunops* are early members of the oreodont group Agriochoeridae. Only one and two species of *Protoreodon* are known, respectively, from the early and middle Uintan. The late Uintan is much more diverse, with six species of *Protoreodon* and two species of *Diplobunops* known. The distribution of these early oreodonts show very little endemism: most species are fairly well-spread, however one species is known only from western Texas and one from southern California. The most taxonomically diverse area for early oreodonts appears to be the western interior, with six species known from this area. A few species turnovers show a potential unrecognized biochronological horizon within the late Uintan, although this would need to be confirmed with a larger study incorporating more genera.

7: 2:45 PM-3:00 PM
Presenter: MURPHEY, PAUL C.

AN OVERVIEW OF THE BIOCHRONOLOGY, BIOSTRATIGRAPHY AND CORRELATION OF UINTAN AGE MAMMAL FAUNAS

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The Uinta Formation is the nominal stratotype of the Uintan NALMA, although it is both pre- and post-dated by Uintan age faunas. Three biochronological zones have been formally defined for the Uintan, and stratotypes for each of these zones, Ui1a, Ui2, and Ui3, have been assigned. A fourth zone, Ui1b, has been informally recognized but not formally defined due lack of sufficient information. The stratotype of Ui1a is the Turtle Bluff Member of the Bridger Formation in Wyoming; the stratotypes of Ui2 and Ui3 include the upper portion of the Wagonhound Member and the Myton Member of the Uinta Formation, and the lower part of the Brennan Basin Member of the Duchesne River Formation in Utah. Potential candidates for Ui1b stratotypes include portions of the Friars and Santiago formations in San Diego County, California, and the middle unit of the Adobe Town Member of the Washakie Formation in Wyoming or correlative strata in Colorado. The Ui1b biochron is approximately correlative with the controversial Shoshonian subage. The faunal characterization and correlation of the Bridgerian-Uintan and Uintan-Duchesnean transitional intervals remain problematic issues of Eocene biochronology because few continuous fossiliferous sequences are known, and all are sparsely fossiliferous and/or poorly sampled. Furthermore, significant regional endemicity

exists between Uintan mammalian assemblages of the Pacific coast and the continental interior. A major challenge remains in the teasing apart of actual continental scale paleobiogeographic distribution patterns from taphonomic factors that are specific to the depositional environments in which these animals lived, died and were preserved; from taphonomic patterns created as a result of collection biases. Future screen-washing efforts in the Uinta Formation, as well as the lower part of the Duchesne River Formation, will provide additional data that will increase our understanding of Uintan endemism, and facilitate precise correlations between coastal and interior faunas.

7: 3:00 PM-3:15 PM
Presenter: BROCHU, CHRISTOPHER

CLOSING THE GATOR GAP: CROCODYLIANS FROM THE UINTAN OF THE WESTERN NORTH AMERICAN INTERIOR

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At least two new crocodylian species are known from units of Uintan age in the Vernal Basin of eastern Utah. The first is an alligatorine and appears to be the sister taxon to Alligator. Although it has a relatively short snout, it lacks the enlarged cheek teeth that characterized earlier alligatorines such as *Allognathosuchus* and *Navajosuchus*, reinforcing suggestions that the American alligator, an ecological generalist, evolved from more specialized ancestors. The second is a large crocodyloid similar to *"Crocodylus" affinis*, known from abundant remains of Bridgerian age, but having morphological features (e.g. long mandibular symphysis including the splenial) typical of more distantly-related slender-snouted forms. Unlike Uintan units elsewhere in western North America, hoofed crocodiles (pristichampsines) have not been recorded from the Vernal Basin. Neither has *Borealosuchus*, which is known from the Uintan of western Texas. Nevertheless, crocodylian faunas of Uintan age in North America (with two or three species recorded) are typically intermediate in diversity between the Bridgerian (during which four or five species may be found in a horizon) and the Chadronian, in which only Alligator is encountered. They thus help fill a gap in our understanding of how crocodylian diversity changed in response to widespread climatic changes during the Eocene.

7: 3:15 PM-3:30 PM
Presenter: COPE, DANA A.

BIOGEOGRAPHY, CLIMATIC CHANGE AND TEMPORAL DIVERSITY IN UINTAN PRIMATES: A FOCUS ON THE CASA BLANCA FAUNA FROM LAREDO, TEXAS AND THE NORTHEAST UINTA BASIN, UTAH

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Comparison of primates from the Uinta Basin and the Laredo Formation's Casa Blanca community provides insight into Uintan primate diversity. Past workers have linked decreasing diversity in the intermountain basins of western North America with a "retreat" to southern refugia as tropical/ subtropical climates became more temperate through Uintan time. Recent research suggests that Uintan biogeographic changes were more complex than previously thought. This is complicated by taxonomic confusion over the identity of the upper dentition of some Uintan omomyids. Beginning in the 1990's, more than a decade of intensive fieldwork in the Uinta Basin yielded a diverse Uinta B primate fauna, with *Trogolemur*, *O. uintensis*, *Chipetia*, and *Macrotarsius*, but only *Mytonius hopsoni* was discovered in Uinta C deposits. Micro-mammals are rare in the Uinta Formation's Uinta C facies apparently because of a shift away from Uinta B depositional environments associated with wetter hydraulic conditions. However, recent screen-washing of six tons of material from the Uinta C "Pond Site" has yielded additional primate taxa including teeth from a new genus of a tiny omomyid, an *Omomys*-sized omomyid, as well as *Ourayia* or *Mytonius*. An additional tiny omomyid species was discovered while surface collecting at another Uinta C locality. This new evidence indicates that a more diverse primate fauna prevailed and adapted to climatic change in the Uinta Basin than previously was thought. The Casa Blanca primates include a new endemic genus and species and two new species of *Mytonius*. This coastal plain, mangrove/tropical forest primate community displays both diversity and endemism. Employing new collection methods has allowed us to better understand local primate diversity throughout the Uintan NALMA.

7: 4:00 PM-4:15 PM
Presenter: TOMIYA, SUSUMU

DIFFERENTIAL PATTERNS OF TAXONOMIC AND MORPHOLOGICAL SUCCESSION OF CARNIVOROUS AND NON-CARNIVOROUS MAMMALS FROM THE UINTAN TO THE DUCHESNEAN IN SOUTHERN CALIFORNIA

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The middle Eocene vertebrate localities of southern California provide a rich record of mammalian faunal succession at a regional scale during a period of substantial climate change. This time period also coincides with the estimated time of origin of the crown-clade Carnivora and its early evolution in North America among a diverse array of other carnivorous mammals such as mesonychids, hyaenodontid creodonts, and derived non-carnivoran

carnivoramorphans. The ecological context of this critical phase in mammalian carnivore evolution was investigated by tracking changes through time in the broadly-defined guilds of carnivores and non-carnivores. Quantitative analyses of the taxonomic composition of assemblages and the dental ecomorphology of carnivores show that, in southern California: (1) compositional changes of carnivores and non-carnivores are asynchronous from the early Uintan to the Duchesnean North American Land Mammal Ages, (2) the dental morphospace occupied by carnivores remains stable across the Uintan-Duchesnean boundary despite significant compositional change within the guild at the same time, and (3) the compositional change of non-carnivores from the early Uintan to the late Uintan is more pronounced than that across the Uintan-Duchesnean boundary. The different patterns of taxonomic and morphological succession of carnivorous and non-carnivorous mammals suggest trophic disequilibrium in taxonomic evolution and structural stability in community evolution at the regional scale over several million years.

7: 4:15 PM-4:30 PM
Presenter: TOWNSEND, BETH

REGIONAL TRENDS IN MAMMALIAN PALEOECOLOGY DURING THE UINTAN (MIDDLE EOCENE) NORTH AMERICAN LAND MAMMAL AGE

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During the Uintan North American Land Mammal Age (NALMA), mammalian communities underwent substantial changes in ecologic and taxonomic composition as closed habitats were replaced by more open ones across the western interior. In order to document these changes, we examined four Uintan mammalian assemblages representing both early (Ui2) and late (Ui3) faunas from four separate regions (Southern California, Texas, Central Rockies, Northern Rockies). For each assemblage we recorded taxonomic (generic presence-absence) and paleoecological (diet, body size, and substrate preference) information, basing our ecological assessments on standard skeletal proxies. We assessed (1) how these assemblages differed ecologically from earlier Eocene faunas, (2) regional differences in ecological diversity, (3) taxonomic differences within and between ecological categories, and (4) temporal trends within the Uintan NALMA. Preliminary results indicate that medium size mammals (1-10 kg) are represented mostly by larger carnivores and a diversity of terrestrial rodents and artiodactyls in the Uintan. This differs from the earlier Eocene, when carnivores, creodonts, and some primates dominate this size range with many of them being arboreal taxa. Regional analyses suggest that assemblages from the Northern Rockies (Saskatchewan, Montana) are more ecologically similar to those from Southern California than the Central Rockies (Wyoming, Utah, Colorado). The Northern Rockies assemblages have a small mammal

community (<1 kg) that is as ecologically diverse as Southern California. Additionally, in both assemblages arboreal/scansorial taxa encompass almost 60% of the fauna, and similar patterns are seen in dietary adaptations as well. The Central Rockies assemblages display the most stability of paleoecological parameters through time while the Southern Californian and Texas assemblages exhibit more fluctuations. Taphonomic and collecting biases likely play some role in the differences among assemblages. However, our results indicate that previous suggestions of the existence of a tropical refugium in Southern California during the later Uintan should be re-evaluated.

Session No. 8, 2:00 PM; Monday, 22 June 2009
Poster Session PS 1. Morphology, Systematics, Diversity, and Extinction

8: 2:00 PM, Booth 1
Presenter: KAUFFMAN, ERLE G.

THE FIRST DIVERSIFICATION OF METAZOAN LIFE: BIOGEOCHEMISTRY AND COMPARATIVE MORPHOLOGY OF 1.9 – 2.5 BILLION YEAR OLD TRACE FOSSILS TO PHANEROZOIC COUNTERPARTS

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The origin of metazoans is currently 800 to 600 million years ago, after oxygenation of the Earth. Discovery of 1.9-2.5 billion year old metazoan-like burrows in the Snowy Range in southern Wyoming, associated with a protracted oxygenation event, was investigated. The importance of the work lies in both the evolution of life and in the investigation of an oxygenated biosphere in our climate system. In southern Wyoming, the Precambrian Snowy Pass Supergroup consists of the basal Medicine Peak Metaquartzite, Lookout Schist, Sugarloaf Quartzite, and Nash Fork Formation – a cap carbonate. These are marine shoreface to shallow water deposits consisting of two quartzite units, separated by a mixed phyllite and quartzite facies, and capped by a limestone/marble with massive stromatolites. We found evidence for trace fossils, and preliminarily described five new genera. Twenty-one samples from the shale adjacent to the quartzite bearing the structures of probable biogenic origin were analyzed for major oxides and trace element geochemistry. Two distinct populations of samples emerged in plots of metal concentrations against bulk C_{org}. Powdered rinsed samples of representative black and gray shales with variable C_{org} concentrations (0.005 to 0.27%) and one quartzite

sample were extracted using established methods. A homologous series of C20-C26 n-alkanes, albeit in low concentrations, was identified by GC-MS analysis of a 10 g sample with 0.07% C_{org}. The preliminary results suggest that biomarker constituents may be extractable from larger samples of the shales, and potentially, also from the quartzites that bear structures of probable biogenic origin. Biodepositional features within the stratigraphic complex of the Snowy Pass Supergroup were investigated, as were the Phanerozoic counterparts of the proposed metazoan trace fossils.

8: 2:00 PM, Booth 2
Presenter: AUSICH, WILLIAM I.

PARAFAC TO ISOLATE COMPONENTS OF PALEOZOIC CRINOID BIOMARKERS

O MALLEY, CHRISTINA E., School of Earth Sciences, The Ohio State University, 3078 Melva Ave, Columbus, OH, 43225, United States, omalley.47@osu.edu; AUSICH, WILLIAM I., School of Earth Sciences, The Ohio State University, 125 S. Oval Mall, Columbus, Ohio 43210; CHIN, YU-PING, School of Earth Sciences, The Ohio State University, 125 S. Oval Mall, Columbus, Ohio 43224

Crinoids have been observed to have taxon-specific coloration through time and in different localities, and organic molecules have been extracted directly from Paleozoic crinoids. Biomarker molecules have been isolated from Paleozoic crinoids that have retained some color differentiation as fossilized remains. A diverse collection of specimens (n=51) was chosen to represent many taxonomic groups of the Crinoidea in order to investigate the relationships of the occurrence of these biomarker molecules at many taxonomic levels. Similarity between chemical extracts was measured by using PARAFAC (Parallel Factor Analysis) on Fluorescence Excitation Emission Matrices (EEMS) to identify individual components of the extracts, and their distribution across taxa as well as their relative abundance within a specimen. The occurrence of these components has potential to be developed into characters for use in phylogenetic analysis. Such characters are interesting in the study of crinoids as a source of phylogenetic information independent from morphology.

8: 2:00 PM, Booth 3
Presenter: PACHUT, JOSEPH F.

MOST PALEOZOIC BRYOZOANS HAD POLYEMBRYONIC LECITHOTROPHIC LARVAE: A STATISTICAL ANALYSIS OF LARVAL AND ANCESTRULAR SIZES

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Larvae of living marine invertebrates are approximately the same size as the initial post-larval organism potentially permitting the recognition of larval type in extinct organisms. Planktotrophic larvae typically have a prolonged existence and potentially broad geographic distribution whereas lecithotrophic larvae often settle quickly after release resulting in more restricted distributional patterns. However, some lecithotrophic bryozoans undergo embryonic fission forming multiple, small, polyembryonic larvae. The relationship between post-larval size and larval type was evaluated in bryozoans by comparing the size of the founding individual of a colony, the ancestrula, to the sizes of extant planktotrophic, lecithotrophic, and polyembryonic lecithotrophic larvae and ancestrulae. The sizes of larvae and ancestrulae of extant lecithotrophic and planktotrophic cheilostome species are statistically the same. They are, however, statistically larger than polyembryonic larvae of extant cyclostomes (stenolaemates). The sizes of cyclostome larvae are indistinguishable from the ancestrulae of extant and fossil cyclostomes, the ancestrulae of other fossil stenolaemate species measured from the literature, and the ancestrulae of three of four Cincinnatian genera. Ancestrulae of a fourth genus, *Dekayia*, are the same size as cyclostome larvae but are statistically smaller than the ancestrulae of all other stenolaemates. With few exceptions, stenolaemates have statistically smaller larvae and ancestrulae than both lecithotrophic and planktotrophic cheilostomes. It appears that the sizes of fossil ancestrulae permit the discrimination of taxa that had polyembryonic lecithotrophic larvae from those possessing other larval types. This inference is strengthened, in some cases, by the co-occurrence of brood chambers and restricted paleogeographic species distributions. The presence of cyclostomes in Early Ordovician strata suggests that polyembryony may have been acquired during the initial radiation of the phylum. Polyembryony appears to be a monophyletic trait but confirmation may require the demonstration that species of several stenolaemate suborders, lacking skeletally expressed brood chambers, also had polyembryonic larvae.

8: 2:00 PM, Booth 4
Presenter: AHN, SOO-YEUN

TRACE FOSSILS FROM THE EDIACARAN-CAMBRIAN TRANSITION IN WESTERN NEVADA: BEHAVIORAL HOLDOVERS FROM THE TERMINAL NEOPROTEROZOIC

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Small assemblages of trace fossils occur in the Deep Spring Formation (Ediacaran-Cambrian) and the Harkless Formation (Cambrian: Series 2) of Esmeralda County, Nevada. Traces preserved in the Ediacaran part of the Deep Spring Formation (Middle Member) include *Bergaueria*, *Palaeophycus*, *Planolites* and other resting, dwelling, and perhaps foraging traces. Trace fossil diversity in the Harkless Formation is greater and, includes *Bergaueria*, *Cruziana*, *Monomorphichnus*, *Palaeophycus*, *Planolites*, *Trichophycus pedum*, and other traces. The most common traces in the Harkless Formation are tubular burrows having diameters of 0.3 to 0.7 cm. Unbranching open burrows having wall linings, and either collapse features or sediment fill of the same type of sediment as the host rock, are classified as *Palaeophycus*. These tubes show diverse preservation types, from full relief to papery impressions with little relief. Some tubes are coated with limonite. When *Palaeophycus* co-occurs with a microbial mat structure, gas bubbles are commonly observed on the mat surface directly overlying the *Palaeophycus* tube. These mineral coatings and gas bubbles indicate the former presence of decaying matter in the burrows. Short, unbranched shallow burrows preserved in hyporelief, perhaps *Palaeophycus* or *Planolites*, are present in the Harkless Formation and the Deep Spring Formation. Sediment infill is observed in some burrows, but there is no clear evidence of passive or active sediment filling. It is uncertain if the individual tubes represent feeding/sediment processing or dwelling behaviors, or both. The presence of traces such as *Palaeophycus*/ *Planolites* and *Bergaueria* (a saclike dwelling trace) in the Deep Spring and Harkless formations indicates the continuation of certain behavioral activities by animals across the Ediacaran-Cambrian transition. The greater diversity of traces in the Harkless Formation signifies an expansion of behavioral activities paralleling an increase in taxic diversity through the early half of the Cambrian.

8: 2:00 PM, Booth 5
Presenter: BABCOCK, LOREN E.

A POSSIBLE SPRIGGINID FOSSIL FROM THE CAMBRIAN OF CHINA

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The family Sprigginidae, which embraces *Spriggina* and *Marywadea*, comprises a clade of elongate, multisegmented, bilaterian organisms of Ediacaran age and disputed phylogenetic affinity. Suggested affinities are with annelidan polychaetes, rangeomorph fronds, and trilobitomorph arthropods. Factors hampering a clear understanding of their relationships include lack of preserved appendages and other important features of nonbiomineralized anatomy, incomplete preservation of dorso-ventral anatomy, and lack of closely comparable

fossils in Phanerozoic strata. Similar issues limit an understanding of the relationships of other Edicaran organisms. A new specimen of an elongate multisegmented animal from the Chengjiang Biota (Cambrian: Series 2) of Yunnan, China, shows close similarity with *Spriggina*. Its significance lies not only in its possible relationship with Ediacaran sprigginids, but also in the fact that it preserves a combination of dorsal, ventral, and internal anatomy. The head shield is smooth and rounded dorsally, and has a U-shaped rim ventrally. Approximately 36 narrow post-cephalic segments are followed by a small semicircular tail shield. Right and left sides of the segments meet at a midline. In places, slight offset seems to be present but it appears to be related to differential compaction along the length of an undulose trunk. The midline of the trunk is flanked by a paired elongate row of dark spots forming a "gut trace." Extending from under the ventral surface is an array of appendages interpreted to be chaetae. The new specimen differs from *Spriggina floundersi*, only in minor characters such as segment number, a slightly smaller head shield, and a larger tail shield. Assuming the new specimen to be a Cambrian sprigginid, the presence of chaetae and general features of the head and tail shields strengthen the interpretation that sprigginids are polychaete annelids.

8: 2:00 PM, Booth 6
Presenter: FAN, JUNXUAN

CARBON ISOTOPES AND EVENT STRATIGRAPHY NEAR THE ORDOVICIAN-SILURIAN BOUNDARY, YICHANG, SOUTH CHINA

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The organic carbon isotope data through the unweathered Ordovician-Silurian boundary strata at the Wangjiawan Riverside section, which is c. 180 m southeast of the Wangjiawan North section, the GSSP for the base of the Hirnantian Stage (Upper Ordovician), show that a positive $\delta^{13}C_{org}$ excursion begins just below the base of the Hirnantian Stage and peaks in the lower part of the N. extraordinarius Biozone. This is followed by an interval of slightly reduced $\delta^{13}C$ values and a second peak of 2‰ above pre-Hirnantian values, which occurs in the lower part of the *N. persculptus* Biozone (upper Hirnantian).The peaks in $\delta^{13}C_{org}$ values can be correlated well with episodes of glacial expansion described from Africa and peri-Gondwanan Europe. Evidence from sedimentological, faunal, and geochemical data from South China, as well as the evidence of glacial sediments in North Africa, all suggests a short-lived glaciation of approximately 1 Ma in the Ordovician South Pole region, consisting of at least two major pulses. The first phase of gradual glacial expansion began just before the Hirnantian Epoch and the second phase ended with rapid melting in the late Hirnantian (early *N. persculptus* Biozone).

8: 2:00 PM, Booth 7
Presenter: HISTON, KATHLEEN

SILURIAN MIGRATIONAL SEAWAYS: COMPARISON OF NAUTILOID FAUNAS FROM PERI-GONDWANA, AVALONIA AND LAURENTIA

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The study of the distribution and biodiversity of environmentally sensitive groups is an important element for a detailed reconstruction of regional paleogeography. It cannot be excluded that faunal gradients from Baltica and Avalonia, across Peri-Gondwanan Europe, to North African shelf basins have probably been controlled chiefly by marine water temperature gradient and, consequently, the surface current system. The accurate documentation of palaeobiodiversity in some northern Gondwana areas (e.g. Sardinia, Carnic Alps and Bohemia) represents an important and taxonomically consistent database however, the knowledge to date in this regard is still quite limited. A multidisciplinary study of prevalently pelagic organisms, the main victims of the Late Ordovician extinction events and therefore more sensitive markers for verifying faunal recovery, from the Silurian successions of the Carnic Alps documents the exchange of faunas between adjacent North Gondwana derived areas such as Sardinia, Bohemia and the Montagne Noire. In recent years there has been an increase in systematic studies of Silurian nautiloids from the British Isles, Sardinia and Bohemia and the observed temporal and spatial data from these faunas may now be considered a reliable tool for paleogeographic reconstruction. Recent studies on nautiloid faunas from Anticosti Island now allow a comparison across three palaeocontinents, examination of faunal affinities between the areas in question and discussion of their possible migrational pathways. Particular emphasis is given to establishing the response of the nautiloid faunas to oscillations in sea-level and to the oceanic variations recorded during this time interval in diverse areas of North Gondwana. This data will be correlated with the adjacent paleogeographic areas to obtain a global response signal of the nautiloid faunas to the fluctuations in sea-level and oceanic processes.

8: 2:00 PM, Booth 8
Presenter: PARK, TAE-YOON

MIDDLE CAMBRIAN OCTAGONAL CUP-SHAPED FOSSILS FROM SHANDONG PROVINCE, CHINA

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Fossils of a mysterious octagonal cup-shaped organism (OCO) have been discovered from the middle Cambrian Changhia (Zhangxia) Formation at three stratigraphically equivalent localities in Shandong Province, China. Specimens from the northernmost Mantoushan section seem to retain the original calcareous exoskeleton, whereas those from the Jiulongshan section and the southernmost Xintai section are moderately and heavily silicified. Serial thin sections were prepared for the specimens from the Mantoushan section, while silicified fossils from the other two localities were dissolved out by hydrochloric acid and acetic acid. This organism is characterized by eight-sided cup with or without a holdfast in the narrow end. An interesting fact is that some of dissolved specimens show a protuberance inside the cone. The wall is perforated, making the organism resemble a solitary archaeocyath to some aspects. However, OCO is single-walled and displays an octagonal radial symmetry. Paired lamellar septa are projected inward from eight corners of the cup. The phylogenetic affinity of OCO is currently indeterminable. OCO occurs within thrombolitic, decimeter- to meter-scale bioherms or is attached to the flanks of bioherms. OCOs at the flanks of the bioherms are often associated with thrombolitic/dendrolitic microbes and small sponges which form a cryptic community. Growth direction is somewhat irregular, but there is a trend of growing downward and/or laterally, suggesting that the organism was pendent in life. This organism (OCO) might have dwelled in shaded or possible cryptic habitats out of direct sunlight in life.

8: 2:00 PM, Booth 9
Presenter: ZACHOS, LOUIS G.

FROM WHENCE COMETH THE PLATES: THE OCULAR PLATE RULE AND PALEOZOIC ECHINOIDS

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The echinoid coronal skeleton is constructed from hundreds to thousands of individual calcite plates. The corona is dynamic in the sense that not only do the plates grow individually, but new plates are added throughout the life of the animal. The Ocular Plate Rule (OPR) states that (1) all coronal plates originate at the apical system from the adoral edge of five ocular plates, and (2) the corona is divided into five growth zones. For modern echinoids each growth zone consists of a paired ambulacral column and the adjacent half-column of

interambulacral plates. This rule works for all modern echinoids, which have five biserial ambulacral and five biserial interambulacral columns (for a total of 20 columns). However, a problem arises when Paleozoic echinoids are considered. With only a few exceptions, Paleozoic echinoids had pluriserial columns of plates either in the ambulacra, the interambulacra, or both. Earlier work has attempted to map the lineage of plates in each column, but this procedure fails because of the changes in column number towards the ambitus. We shift viewpoint and attempt to associate plates by cohort or sets that encircle the apex of the test. This permits a reconstruction of the corona during ontogeny and a redefinition of growth zones in a manner applicable to pluriserial forms. The results demonstrate that the OPR is valid for Paleozoic echinoids and is a synapomorphy of the Echinoidea.

8: 2:00 PM, Booth 10
Presenter: REICH, MIKE

A CRITICAL REVIEW OF THE FOSSIL RECORD OF OCTOCORALLIA (CNIDARIA: ANTHOZOA)

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Octocorals have a rather disjunct record throughout the geological column. The earliest possibly date back to Ediacaran faunas and are widely represented and diversified today as soft and horny corals (Alcyonacea and Gorgonacea), sea pens (Pennatulacea), as well as blue corals and stoloniferans (Helioporacea and Stolonifera) and some other small groups. As they are generally characterised by a lightly chitinised exoskeleton (e.g. Gorgonacea) or endoskeletons with microscopic calcareous sclerites or axial rods (e.g. Alcyonacea, Pennatulacea) and poor preservation potential, which is clearly the principal reason for their rarity and occasionally absence in the fossil record. Despite this, over the decades a number of Palaeozoic octocorallian fossils have been described. In many of these, precise attributions to understand higher-level taxa have not been possible, largely as a result of indifferent preservation of the microstructure. After detection of skeletal carbonate hydroxylapatite in recent gorgonaceous octocorals, heretofore unknown in modern coelenterates, several Cambrian phosphatic 'problematica' have occurred regarding relationships to octocorals appear now in another light. Similarly, fossils of the Ediacaran leaf-like presumed pennatulids have been described from Cambrian rocks - the earliest of these is *Priscapennamarina* from the Early Cambrian of eastern Yunnan, China. The Middle Cambrian Burgess Shale taxon *Thaumaptilon* is also presumed to be a pennatulid, while another Burgess Shale fossil - *Echmatocrinus* - originally described as a crinoid, was later interpreted as a probable octocoral. Some Neoproterozoic phosphatised embryos have been attributed to cnidarians, but interpretations of the Ediacarian and Cambrian pennatulid-like fossils and probable octocorals are not always accepted with regard to the further Phanerozoic fossil record. The early fossil record, evolution and phylogeny of Octocorallia and Anthozoa, including recent

molecular analyses, is still in a state of confusion and more palaeontologic work must definitively be done accepting or rejecting of the one or other hypothesis.

8: 2:00 PM, Booth 11
Presenter: ELIAS, ROBERT J.

AFFINITY OF PROBLEMATIC ORDOVICIAN CORALLINE FOSSIL *AMSASSIA* FROM SHAANXI, NORTH-CENTRAL CHINA

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Coral-like fossils are one of the most common components in Ordovician reefs of Shaanxi Province, situated on the western margin of the North China Block. These reef-builders superficially resemble small-corallite favositoid tabulate corals, both in the field and in thin sections. This study reveals that most, if not all, of the specimens from this area that were previously identified as the tabulate *Lichenaria* are actually *Amsassia*. This poorly known, problematic genus has been assigned by various authors to the tabulate corals, tetradiids (considered to be corals), or chaetetid sponges. *Amsassia* has some morphologic features that are consistent with each of these groups. The phacelocerioid type of modular organization in *Amsassia* also occurs in some tabulates and tetradiids, but not in chaetetids. The cross-sectional shape of modules in *Amsassia* resembles that of some tabulates, but differs from the typically quadrate form in tetradiids; shapes resulting from the separation of modules do not occur in chaetetids. The diameter of modules in *Amsassia* is comparable with that in tetradiids and is at the low end of the range in tabulates, but is generally larger than in chaetetids. Septa are absent in *Amsassia*, chaetetids, and some tabulates, but are well developed in tetradiids. This study focuses on a fundamental character, module increase, using serial transverse peels of Shaanxi specimens. Three types of longitudinal fission have been observed in *Amsassia*. Bipartite fission is the most common among these types, and is a typical mode of increase in chaetetids. Tripartite and quadripartite fission are uncommon in *Amsassia*. Some of the forms of quadripartite fission are comparable with the distinctive mode of increase in tetradiids. Lateral or coenenchymal increase, characteristic of tabulates, has not been recognized in *Amsassia*. The affinity of *Amsassia* remains unresolved, but we conclude that this genus is not a tabulate coral.

8: 2:00 PM, Booth 12

Presenter: CRÔNIER, CATHERINE

DEVELOPMENTAL PATTERN OF THE THORACO-PYGIDIAL EXOSKELETON OF THREE RELATED DEVONIAN PHACOPID TRILOBITES

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In arthropods, the ontogeny of the trunk forms a complex part of development. Recent discoveries of fossil ontogeny provide an additional source of data and a broader evolutionary significance of body patterning (Hughes et al. 2006). The developmental study of the thoraco-pygidial exoskeleton of three related phacopine trilobites according to the integrated ontogenetic scheme proposed by Hughes et al., 2006 has been conducted. Pygidial shields assigned to three ontogenetic series belonging to *Trimerocephalus lelievei* Crônier and Feist, 1997, *Weyerites ensae* (Richter and Richter, 1926) and *Nephranops incisus incisus* (Roemer, 1866) species from the Upper Devonian (Famennian), gave us the opportunity to understand better the evolutionary pattern of the trilobite segmentation. The analysis showed a different mode of development and thus revealed a degree of variability between the related taxa. The comparison of the boundaries of the different aspects of ontogenesis ratifies the diversity of the segmentation process among trilobites, and even among related phacopine species. The most interesting points seem to be (i) the apparently 'meraspid transition' of the trunk segmentation to get a synarthromeric development, and (ii) two mode, i.e. hypoprotomeric development and synarthromeric development, that occur in the same time window. Crônier, C., and Feist, R. 1997. Morphologie et évolution ontogénétique de *Trimerocephalus lelievrei* nov. sp., premier trilobite phacopidé aveugle du Famennien nord-africain. Geobios, Mémoire Spécial 20: 161-170. Hughes, N. C., Minelli, A., and Fusco, G. 2006. The ontogeny of trilobite segmentation: a comparative approach. Paleobiology 32: 602-627.Richter, R., and Richter, E. 1926. Die Trilobiten des Oberdevons. Beiträge zur Kenntnis devonischer Trilobiten IV. Abhandlungen der preussischen geologischen. Landesanstalt 99: 1-314. Roemer, F. A. 1866. Beiträge zur geologischen Kenntnis des nordwestlichen Harzgebirges. Fünfte Abtheilung. Palaeontographica 13: 201-235.

8: 2:00 PM, Booth 13
Presenter: CRÔNIER, CATHERINE

MORPHOLOGY AND ONTOGENY OF A MIDDLE DEVONIAN PROETID TRILOBITE FROM THE ARDENNES MASSIF (FRANCE)

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Numerous exoskeletons comprising several growth stages allow the tracing of morphological and morphogenetical features of a new species of proetid *Dechenella* from the Middle Devonian of the Ardennes Massif, France. For the accurate description of cephalic and pygidial features, a landmark-based approach was adopted in order to recognize ontogenetic instars and to establish the pattern of size increase and shape change during ontogenetic development. Thus, the quantitative analysis permitted to characterize the shape change and to compare the timing of size and shape changes. Additionally, despite a wide range of variability, the results suggest the occurrence of three morphotypes which can be ascribed to distinct taxa.

8: 2:00 PM, Booth 14
Presenter: HUBERT, BENOÎT L. M.

METHODS FOR STROMATOPOROIDS STUDIES: WHAT EFFECTS HAVE THE ORIENTATION OF THIN SECTIONS?

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To support the systematic of stromatoporoids at a generic level, the firstly determination results from qualitative analysis (i. e. types of the skeletal elements, relations between them). Then, at a specific level, features mainly correspond to quantitative measurements (i. e. size and density of horizontal and vertical skeletal elements).Thus, the taxonomic studies of stromatoporoids - for the massive forms - are classically based on observations and measurements executed successively on two carefully oriented thin sections, “one (traditionally called a vertical section) perpendicular to the growth surface and the other (traditionally called a tangential section) parallel to it” (Stearn et al. 1999). Making these sections suppose to know exactly the orientation and growth direction of the stromatoporoids. If the growth of the stromatoporoids animal shows small undulations, variations or irregularities, the thin section (vertical section) is generally or partly oblique. Similar problems exist to prepare a well oriented tangential section.In order to estimate the degree of error due to the orientation of the thin sections, some larges specimens of Givetian stromatoporoids, collected in the Ardennes, were cut along successive angular plans (a = 10 degrees between each sections) from horizontal (0°) to vertical (90°) orientation. The genus Actinostroma was chosen relatively to its kind of skeletal structure with well distinct and long pillars and straight laminae. Complementary analyses were made on another genus, Stromatopora with cassiculate skeletal morphology. In every case, when it was possible, the largest thin sections were prepared.Such observations will conduct to be careful with the determination of a lot of stomatoporoid species.

8: 2:00 PM, Booth 15
Presenter: CLAPHAM, MATTHEW E.

OUTLINE MORPHOMETRICS AND ONTOGENETIC SHAPE CHANGE IN *PROMYTILUS*: IMPLICATIONS FOR THE TAXONOMY OF LATE PALEOZOIC MYTILIDS

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The taxonomy of late Paleozoic *Promytilus* species (Bivalvia, Mytilidae) relies heavily on comparison of valve outline shapes, such as curvature of the posterior margin, length and curvature of the hinge line, depth of the byssal sinus, and size of the anterior lobe. Many of the more than 15 named late Paleozoic species have been discriminated by subjective morphological comparison of one or a few specimens, without consideration of potential intraspecific variability. The outline shape of more than 100 *Promytilus* museum specimens and figured individuals, representing 12 species, was quantified using elliptical Fourier analysis to test previous species concepts. Twenty-six individuals of *Mytilus californianus* were also included to assess typical intra-population variability in mytilids. This morphometric technique describes the outline with a series of elliptical Fourier functions, extracting the most important variations with principal component analysis on Fourier coefficients of the harmonics. Nearly 70% of shape variability in *Promytilus* is explained by the overall outline, which varies from broad and relatively ovate to narrow and obliquely elongate. Although several North American species can be discriminated by this parameter, it is not taxonomically useful because of significant ontogenetic shape changes. Both living *Mytilus* and Paleozoic *Promytilus* change from ovate to elongate during ontogeny, with North American *Promytilus* species appearing to fall along a single diffuse trend. Other principal components explain less variation but still describe morphologically important characters such as the concavity of the ventral margin, curvature of the hinge line, and size of the anterior end of the shell. Some existing species may be able to be separated using these characters but consideration of intra-population variation in *Promytilus* and living *Mytilus* suggests that *Promytilus* has been over-split.

8: 2:00 PM, Booth 16
Presenter: SCHEMM-GREGORY, MENA

ECOLOGY OF THE PARASPIRIFER-LIKE MORPHOTYPES (BRACHIOPODA, LOWER AND MIDDLE DEVONIAN)

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A *Paraspirifer*-like morphotype is typical of spiriferid brachiopods characterized by medium to large specimens with a strong dorsibiconvex curvature and strong development of secondary shell material in the apical region. Within the Delthyridoidea these forms are represented mainly by the upper Lower to Middle Devonian *Paraspirifer* in Europe and North America and an Emsian new genus that has been identified in northern Spain as well as in the Siegenian of Morocco. Representatives of the new genus, *Paraspirifer cultrijugatus* and partly the group of *Paraspirifer brownockeri* occur in clear water carbonate facies which was probably poor in nutrients. Accretion of secondary shell material in the apical region of the ventral valve causes the shell to lie at an angle on the seafloor such that the dorsal valve is above the ventral valve. In this position the anterior margin of the sulcus tongue is the highest point of the brachiopod which guarantees the separation of the inhalant current from the exhalant current that is ejected at the tongue. In this way the inhalant current through the lateral commissure assures a maximum influx of nutrients. A 3D reconstruction of the new genus shows that the spiralia were oriented in a posterior direction reaching almost to the hinge line with spirals that were very short in diameter and reaching to half of wing length in transverse cross section. The orientation of the brachidium in *Paraspirifer brownockeri* was in a lateral direction which means that the ecological parameters during the life of *Paraspirifer brownockeri* were different than in the time interval in which the new genus has lived. Due to the mouldic preservation of European late Early Devonian *Paraspirifer* taxa the brachidia of these forms are unknown.

8: 2:00 PM, Booth 17
Presenter: MCKINNEY, MICHAEL

EDRIOASTEROID AMBULACRA INCREASE ALLOMETRICALLY WITH RESPECT TO VOLUME

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The relationship between surface area and volume is fundamentally important to scaling arguments, especially for surface-area-related phenomena such as metabolism. Most processes scale allometrically as a result of decreasing ratios of surface area to volume associated with volumetric increases in body size. Where geometric similarity (shape constancy) is maintained with increasing size, surface area (y) scales to the two-third power of volume (x) according to the allometric equation: $y = b \times k$ and $k = 0.67$. However, most organisms do not maintain geometric similarity as they grow, and therefore the scaling exponents of many surface area-related processes deviate from the predicted value of 0.67.

Metabolism, for example, often scales as k = 0.75. Such deviations can be explained by geometric allometry involving changes in the shape of exchange surfaces; these changes maintain high area:volume ratios and minimize surface area-related constraints. Here we report on some preliminary results comparing area of the feeding apparatus (ambulacra) verses the volume of the theca for a suite of isorophid edrioasteroid species. The species include forms that vary greatly in ambulacral shape including linear, curved and distally meandering ambulacra. For each species, ontogenies from single stratigraphic horizons were measured for total surface area of ambulacra, and thecal diameter. Assuming a constant thecal shape, thecal volume was estimated. Regression of log (ambulacral area) on log (thecal volume) reveals a strikingly consistent pattern whereby all ontogenies of all species fall on or near the same line (r^2 = 0.93, N = 38), with a slope (k) = 0.91, s.e. = 0.034. This indicates an exceptionally high allometric increase for ambulacral area, even above that expected from the 0.75 slope of metabolic requirements. We speculate on the causes of this pattern, e.g., that this allometric increase may be related to increasing competition for food particles with growth.

8: 2:00 PM, Booth 18
Presenter: FORTIER, DANIEL

REDESCRIPTION AND PHYLOGENETIC SYSTEMATICS OF MERIDIOSAURUS VALLISPARADISI, A PHOLIDOSAURID FROM THE LATE JURASSIC-EARLY CRETACEOUS OF URUGUAY

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Based on a fragmented rostral portion found in late 70's, *Meridiosauris vallisparadisi* was tentatively described as a pholidosaurid, a group of long-snouted neosuchians with aquatic and fish-eating adaptations. It was found in the fluvial fine- to medium-grained sandstone facies of the Tacuarembó Formation (Kimmeridgian-Hauterivian), NE Uruguay. In order to access the phylogenetic relationships of this taxon, we tried to perform a cladistic analysis. However, that could not be possible, since a number of misunderstandings and new features were found in the holotype. The anatomical redescription resulted in a great quantity of new characters; the most important are the following ones: external nares dorsally separated by the premaxillary bar; absence of a notch on the ventral edge of rostrum at premaxilla-maxilla contact; nasals do not meet premaxilla dorsally; sculpted region along alveolar margin on lateral surface of maxilla; sinusoidal premaxilla-maxilla suture in palatal view; nasal lateral edges oblique to each other, converging anteriorly; cheek teeth are not constricted at the base of crown; the lateral contour of the snout in dorsal view is sinusoidal; presence of evaginations in the maxillary alveolar edges at each alveoli; 5th premaxillary tooth positioned

laterally to the maxillary toothrow; incisive foramen situated far from the premaxillary toothrow. A cladistic analysis was performed using TNT and the dataset of Turner & Buckley [2008, JVP 28(2):232-408], using a total of 290 characters and 76 taxa. 1000 replications were performed, using heuristic search. The analysis resulted in new clade, formed by *Meridiosaurus* and *Sarcosuchus*+*Terminonaris*. The tree taxa share three synapomorphies, related to the premaxilla shape and position. *Meridiosarus* has three autapomorphies, related to maxilla and snout shape. *Meridiosaurus* is the most complete record of a pholidosaurid from South America. The other record is from Brazil, a few fragments of *Sarcosuchus* from Recôncavo Basin (Early Cretaceous).

8: 2:00 PM Booth 19
Presenter: FORTIER, DANIEL

A NEW SPECIMEN OF *CAIMAN BREVIROSTRIS* FROM THE LATE MIOCENE OF AMAZONAS, BRAZIL

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A new specimen of a juvenile alligatorid was collected in 2003 during a field trip in the Talismã site (Purus River), located in the state of Amazonas, near Acre State. A virtually complete skeleton was collected. The postcranium is articulated, but the skull was completely fragmented during digging out. The remains were assigned to *Caiman brevirostris* by Maciente & Souza-Filho (2007, XX Cong. Bras. Pal., p. 246). This is the first record of a complete crocodylian from the Neogene of south-west Amazon. The postcranium has not been prepared yet. The skull and mandibles are fragmented in more than twenty pieces. Even so, it was possible to identify many bone elements. Although it is very fragmented, the fossil could be assigned to *Caiman brevirostris*, mainly by having a short skull (characteristic for the species) and a nasopremaxillary suture well known for this taxon. Two phylogenetic analysis were performed to test the relationships of this taxon among other caimans, the first using the data from the holotype and the second one using the new osteological data collected from the new specimen. Both analyses used 75 taxa and 166 characters, mainly from Brochu [2004, JVP 24(4):857-873). A heuristic search strategy was used through TNT software. The first analysis resulted in a lack of resolution in the Caimaninae clade, collapsing it. In the second analysis, using data from the new specimen, nine most pacimonious trees were recovered, each one with 494 steps (CI=0.42, RI=0.84). As a main result, all the caimans has been placed together forming a clade, but the position of *Caiman brevirostris* inside the clade is not well defined. The next step of the project is to prepare the postcranium in order refine the

phylogenetic relationship of the species among caimans, and discuss the ontogenetic stage of the specimen.

8: 2:00 PM, Booth 20
Presenter: SCHACHNER, EMMA R.

EVOLUTION OF THE ARCHOSAURIAN RESPIRATORY SYSTEM: EVIDENCE FROM RIB AND VERTEBRAL MORPHOLOGY

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The Extant Phylogenetic Bracket (EPB) method has been used to provide objective reconstructions of theropod pulmonary anatomy with a high degree of confidence. The lung morphology of other dinosaurs and basal archosaurs, which also lie within the same EPB between extant crocodilians and birds, has received considerably less attention. Detailed examination of the thoracic rib and vertebral anatomy of extant archosaurs has indicated a strong relationship between rib morphology and pulmonary anatomy, and therefore respiratory mechanics. Lung ventilation in extant crocodilians is achieved by costal aspiration in association with an hepatic piston pump, a derived mechanism utilizing a novel respiratory muscle, the diaphragmaticus, which shifts the thoracic and abdominal viscera cranially and caudally. The tubercula and capitula of the ribs are on the horizontal plane, forming a smooth thoracic 'ceiling' and facilitating the movement of the lungs and internal organs. The avian respiratory system is composed of small and rigid dorsally attached flow-through lungs, which are unidirectionally ventilated by non-vascularized air sacs. These are associated with strongly bicapitate rib heads that have a capitular articulation on the centra, providing a rigid rib cage with a corrugated ceiling that locks the lungs in place. The highly derived avian and crocodilian pulmonary anatomies are a function of very different evolutionary pressures; it is likely that neither represents the plesiomorphic pulmonary condition for Archosauria. Comparisons between the dorsal vertebral series and adjacent ribs of select fossil specimens with extant archosaurs indicate that there was significant pulmonary variation within the group. Preliminary data reveal that saurischian dinosaurs follow a distinctly avian trend, while ornithischian dinosaurs demonstrate an intermediate morphology. The vertebrae of aetosaurs and phytosaurs appear to be similar to the crocodilian condition, while other pseudosuchians have independently evolved axial skeletons that are more dinosaurian in construction.

8: 2:00 PM, Booth 21
Presenter: MANNING, PHILLIP L.

TRUNK-RECOIL, A NEW MODEL FOR THE EXPLOITATION OF ELASTIC STRAIN ENERGY IN BIPEDAL DINOSAUR LOCOMOTION

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The locomotor capabilities of quadrupedal vertebrates are considerably enhanced by the storage and recoil of elastic energy in the epaxial tendons, providing energy recovery from step to step. However, elastic recoil in extant running bipeds is restricted to the hindlimbs due to a vertical orientation of the torso. Here we use a reverse engineering approach to demonstrate that the unique body shape of a group of extinct animals, bipedal dinosaurs, enabled them to store energy in their horizontally held torso and tail. By tuning the resonant frequency of an elastic back spring in computer simulations of *Allosaurus fragilis*, we were able to produce a significant gain (~30%) in top speed, coupled with a reduction in metabolic cost (~20%). This illustrates both the critical functional significance of these anatomical structures and the danger of relying on extant analogues when reconstructing the locomotor capabilities of extinct animals. Furthermore we predict that a more detailed model of the musculoskeletal system including the elastic storage mechanisms in the legs coupled with contributions from the trunk musculature would lead to even greater performance gains. This allows the intriguing possibility that previous speed calculations may have considerably underestimated the locomotor abilities of many dinosaurs including formidable giant predators such as Tyrannosaurus rex. This may be of particular interest if the cumulative effects of elastic storage prove to be additive in the remaining elements of the musculoskeletal system.

8: 2:00 PM, Booth 22
Presenter: BURTON-KELLY, MATTHEW E.

DELINEATING PALEODRAINAGES USING MORPHOSPACE OCCUPATION OF FRESHWATER MUSSELS

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Although Cretaceous fossil freshwater mussels (Unionoidea) frequently possess distinguishing external features upon which identification can be based, most post-K-Pg mussels have less diagnostic features. Discriminating previously unnamed taxa within an assemblage based on morphology is especially difficult when those taxa occupy similar morphospace and do not preserve key characters. Calculating the size of morphospace occupation is identified here as a possible method for estimating the number of taxa present in a given assemblage, assuming the normal range of this value is known for comparable taxa (modern or fossil). Previous neo- and paleontological morphometric analyses performed on freshwater mussels have identified problematic areas in this model: choice of similar proxy taxa to the organisms under study; ontogenetic, sexually dimorphic, and size variation within taxa; taphonomic deformation; and morphological ecological plasticity and evolutionary convergence. The present study attempts to address these last issues. The shapes of *Anodonta grandis* from two sites in the Red River drainage basin (a North Dakota river and a Minnesota lake, ~190 km apart) were compared using the analysis of 50 pseudolandmarks along the shell outline, anchored on the umbo. Three measures of variation (Foote's disparity, within-group variation, and sum of variance) show that the size of morphospace occupation is not statistically significantly different between the sampled environments, supporting a similarity in the natural amount of variation in each population. Additionally, pseudolandmark analyses show lack of a discernible difference between the shapes of *A. grandis*, suggesting similar habitats and a close phylogenetic relationship. We suggest these techniques provide a potential means to discriminate stable morphological populations (based on morphospace occupation) through space and time. Future studies on additional occurrences within and outside A. grandis watersheds should allow baseline statistics on how morphological variation can be applied to mussels of similar form in paleodrainages.

8: 2:00 PM, Booth 23
Presenter: BUICK, DEVIN

THE KEY IS AUTOMATION! IMPROVEMENTS TO THE PROCESS OF OUTLINE MORPHOMETRICS

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Beyond learning the nuances of shape theory, initial inroads into morphometrics are often accompanied by frustration with the procedural difficulties of capturing and analyzing shape data, which typically involves a convoluted series of computer programs. With the development of digital photography and independently-written freeware, such as NIH programs or the IMP series by David Sheets, the procedural side of quantifying shape has improved significantly. But there is still a long way to go towards developing an efficient, user-friendly, open source process. Studies of morphological disparity can be hampered by inadequate sample sizes, resulting from poor preservation and/or sampling, but also from the

time intensive task of collecting shape data for large collections of specimens. Here, I present methodological improvements using outline morphometrics geared towards both novice and experienced researchers, with particular improvements in efficiency accomplished through automating multiple procedural steps, to increase sample size and thus have more confidence in mean values. Using the bivalve genus *Cucullaea* as an exemplar, this research presents a streamlined workflow for outline morphometrics, from initial photography through to the generation of a morphological framework for identifying differences among individuals or groups in morphospace. While bivalves are particularly well suited for such analyses, this procedure can be tailored by individual researchers to quantify anatomical shapes for many other taxonomic groups. Overall the procedure uses the following steps: 1) Adobe Photoshop batch processing for image enhancement, autotracing and outline exporting; 2) the NIH program ImageJ for automating the collection of XY coordinates and scale factors for each trace; 3) HANGLE programs (Haines and Crampton, 1996) for calculating Fourier coefficients, normalization and reconstruction of traces from synthetic coefficient data; and 4) the programming language R for constructing the backing grid of synthetic outline shapes for morphospace, and for calculating distance, variance and range metrics.

8: 2:00 PM, Booth 24
Presenter: KOLBE, SARAH

MULTI-SCALE GEOGRAPHIC AND ENVIRONMENTAL VARIATION IN THE MORPHOLOGY OF THE BIVALVE GENUS *CHIONE* IN THE GULF OF MEXICO, WESTERN ATLANTIC, AND CARIBBEAN

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Just as diversity can be evaluated at multiple scales (e.g., alpha and beta diversity), the morphological variability of species can be examined within samples (“alpha disparity”) and among samples that are spatially separated (“beta disparity”). Patterns of variability within a hierarchical spatial framework may shed light on how a species' total morphological variability is partitioned throughout its range, and the extent to which gene flow among populations influences the extent of their morphological similarity to one another. Here, we present an investigation of morphological variability in the prolific venerid bivalve *Chione cancellata* and the closely related *C. elevata*, at multiple geographic scales, to quantify the extent of morphological variation in Chione as a function of environment and geography. We examined samples of *Chione* collected during previous investigations from locations in Florida, St. Croix, and the Bahamas, as well as museum specimens from Texas, Cuba, Venezuela, Columbia, the Dominican Republic, and Trinidad and Tobago. Individuals were digitally imaged, and morphological data were collected using landmark points corresponding to key shell features. Multivariate techniques were applied to examine *Chione* morphology. Results demonstrate a strong structure to the morphological data in relation to geographic location. *Chione* samples

have statistically significant differences in morphology at nearly every geographic scale, even among specimens collected from less than 1 km apart in different hydrodynamic regimes. When similarities among samples are considered, samples group together in a predictable order: samples within a bay tend to be more similar than samples from two different bays; samples from two bays on an island tend to be more similar than samples from two different islands; samples from nearby islands tend to be more similar than samples from widely-spaced islands. These results suggest a strong geographic hierarchy on *Chione* morphology that may be related to gene flow among populations.

8: 2:00 PM, Booth 25
Presenter: WILLIAMSON, LAUREN

A MORPHOMETRIC ANALYSIS OF THE HIGHLY VARIABLE CLYPEASTEROID, *PERIARCHUS LYELLI*

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The Late Eocene echinoid, *Periarchus lyelli* (Conrad, 1834), known for its wide geographic range, high abundance, and specific stratigraphic range, is an ideal example of an index fossil. However, due to its highly variable test morphology, many have questioned if this classification is erroneous, and if, in fact, this sand dollar is actually two or three distinct species that have been misclassified as a single species. *P. lyelli*, as a species, is typically described as subcircular (or slightly domed) in cross-sectional outline with a nearly flat oral surface (Kier, 1980). However, numerous examples can be found where the cross-sectional outline is highly domed or bell shaped, sharply pointed, or in some specimens, flattened with little vertical relief. A preliminary study on this subject has been performed on specimens from Mississippi, North Carolina and South Carolina (Williamson, 2006), showing significant separation in test shapes from these three states. Continuing the initial research, this study will analyze the test shapes of *P. lyelli* over its entire North American geographic distribution, along the gulf coast and southern Atlantic coast of the United States. Echinoid test analysis will incorporate multivariate statistical analysis techniques such as Elliptical Fourier Analysis and Procrustes Analysis. An internal examination of the test will be performed in order to determine the importance of differences in support structures inside the sand dollar. In addition to physical examination, substrate analysis will be performed to determine if differences in test shape correlate to differences in lithofacies and paleoenvironmental differences. The correct classification of index fossils is extremely important for accurate stratigraphic and geologic identification. An examination of the highly variable clypeasteroid, *P. lyelli* will not only provide insight to the precise classification of the sand dollar, but also the evolution of new architectures and the difference between interspecies variation and intraspecies variation.

8: 2:00 PM, Booth 26
Presenter: TWITCHETT, RICHARD J.

OPHIUROID PALAEOECOLOGY AND THE MESOZOIC MARINE REVOLUTION

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Ophiuroids are a highly successful group of benthic marine invertebrates, with a long fossil record, that are found in the present day from the shallows to the abyssal depths, from the poles to the tropics. In the modern environment, ophiuroid species may live exposed on the sediment surface, in crevices in abiotic (e.g. rock) or biotic (e.g. coral) substrates, in burrows, as commensal organisms in sponges, or have a wide ranging and variable habit. Morphologically, ophiuroids are fairly conservative and it can be difficult to determine the mode of life from fossil remains. One parameter that is of particular importance is the ratio of arm length (al) to disk diameter (dd). Modern burrowers have the highest al:dd ratio (> 9.0), surface dwellers have the shortest relative arm length (al:dd < 5.7). Ophiuroids with other modes of life have relative arm lengths that fall somewhere between these values, although the ranges do overlap (e.g. in wide-ranging taxa that do not burrow the al:dd ratio is between 3.4 and 13.8). We measured the al:dd ratio in a range of Phanerozoic fossil ophiuroids to determine when burrowing first appeared in the fossil record and whether it was related to the Mesozoic Marine Revolution. The best preserved ophiuroids are typically found in storm deposits, and, for obvious taphonomic reasons, species inferred to be surface dwellers dominate our sample set. Species that we interpret as definite burrowers (al:dd > 13.8) first appear in the Cretaceous (Albian), e.g. *Ophiactis applegatei* (al:dd = 23). A handful of pre-Cretaceous specimens, including examples from the Jurassic, Triassic and Devonian, have relatively long arms (al:dd between 9 and 10), and may have burrowed, but we cannot rule out a crevice-dwelling or a wide-ranging lifestyle for these taxa.

8: 2:00 PM, Booth 27
Presenter: SUMRALL, COLIN D.

FLEXIBLE TO STIFF: A COMMON FUNCTIONAL DESIGN IN ECHINODERM APPENDAGES AND ITS BEARING ON STYLOPHORANS

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Appendages bearing a relatively short, enlarged and highly flexible, proximal region and a longer, thinner but stiffer, distal region are common echinoderm adaptations. This modification has been independently derived in the stem of derived glyptocystitoids, the eocrinoid *Rhopalocystis*, some crinoids, and in the feeding appendages of stylophorans, crinoids, and blastozoans. In stems, typically the flexible proximal portion has a greater diameter than the rest of the appendage with a large number of proportionately shorter but wider skeletal elements resulting in more elements per unit height. Lumens typically are large with extensive soft tissue, but there are exceptions. In some stems, the proximal skeletal elements are highly modified for flexibility including imbricate plating in solutes, and spiraling pivot points in glyptocystitoids. Stiffer distal appendages tend to have a smaller diameter with proportionately higher skeletal elements as compared to the proximal appendage. Lumens are smaller with less soft tissue, and ossicles are more tightly held together with ligaments.In feeding appendages, the proximal portion is more flexible to unfurl and refurl the appendage, and the medial to distal portion is usually stiff and either slightly curved or straight to resist the passing currents. Proximal flexibility is usually produced by aboral gaps in the proximal brachioles of eocrinoids and a few other blastozoans, or hinged sutures in the proximal brachials of some crinoids. Stylophorans have feeding appendages bearing an imbricately plated proximal portion, generally organized into poorly to well-defined rings that are much shorter in height than diameter. The distal portion is stiff with tightly sutured, uniserial, hemispherical elements and biserial, loosely articulated, imbricate, covering plates. This plating is consistent with the construction of an ambulacrum rather than a stem. Although similar in general morphology, based on subsidiary features, stylophoran aulacophores and solute steles are analogous and not homologous structures.

8: 2:00 PM, Booth 28
Presenter: BOARDMAN, GRANT S.

MIO-PLIOCENE SALAMANDER FAUNA FROM THE SOUTHERN APPALACHIANS

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Continued screening efforts at the Gray Fossil Site, Washington County, Tennessee, have yielded a unique and diverse salamander fauna for the southern Appalachian Mio-Pliocene; including at least five taxa (*Ambsytoma* sp.; *Plethodon*-type, Spelerpinae-type, and *Desmognathus*-type plethodontids, and *Notophthalmus* sp.) from three families (Ambystomatidae, Plethodontidae, and Salamandridae respectively) present in the area today and supporting the woodland-pond interpretation of the site. All specimens represent the earliest record of their families in the Appalachians (and the earliest record of Plethodontidae

and Ambystomatidae east of the Mississippi River), with the *Notophthalmus* sp. vertebrae being the only Mio-Pliocene body fossil known for the Salamandridae in North America. The *Desmognathus*-type specimens may help shed light on the evolutionary origins of the supergenus *Desmognathus*, which purportedly has its roots in this region during the Mio-Pliocene. The GFS salamander fauna is predominated by plethodontids; competition is inferred by the presence of several similarly large-sized taxa and is invoked to explain the presence of neotenic individuals of *Ambystoma* in an otherwise amicable terrestrial environment.

8: 2:00 PM, Booth 29
Presenter: HECKERT, ANDREW B.

MICROVERTEBRATE SAMPLING DRAMATICALLY INCREASES THE VERTEBRATE DIVERSITY OF THE UPPER TRIASSIC NEWARK SUPERGROUP, NORTH CAROLINA, USA

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The Moncure microvertebrate locality (NCSM 1904) in the Cumnock Formation, Sanford sub-basin, North Carolina, greatly increases the known Upper Triassic vertebrate fauna from the Newark Supergroup. Recovered microvertebrate fossils include abundant records of osteichthyans, rare amphibians, and numerous amniotes. This tropical paleolatitude locality is now the most diverse Upper Triassic vertebrate locality in the Deep River Basin and in the state of North Carolina, and one of the richest Upper Triassic localities in the Newark Supergroup. Lungfish teeth are abundant, diminutive (3-8 mm long) and possess 6-7 sharp ridges radiating through ~120° from the mesial corner, and are therefore assigned to *Asiatoceratodus* (=*Arganodus*), and are either juveniles or a distinct, dwarfed (?) species. Other osteichthyans include thousands of scales, teeth, skull, and lower jaw fragments of semionotids and, possibly, redfieldiids. Temnospondyls are rare but probably represent metoposaurids, possibly *Apachesaurus*. Poorly preserved but intriguing records include a possible procolophonid as well as acrodont and pleurodont jaw fragments we tentatively assign to lepidosauromorphs. Among the archosauromorph teeth are a Revueltosaurus-like taxon distinct from *R. callenderi* but similar to *Pekinosaurus olseni*; a morphotype best assigned to *Galtonia gibbidens*, and several other archosauriform tooth morphotypes. Particularly noteworthy is an apparently venomous archosauriform similar to *Uatchitodon kroehleri*, albeit with compound denticles, that may represent a new taxon. Synapsids include teeth of traversodontids, *Microconodon* and other cynodonts that represent either extremely advanced dromatheriids or primitive tritheledontids. These new records include both taxa

more typical of non-Newark basins (abundant archosauriforms, temnospondyls, lungfish) as well as more typical Newark synapsid-rich faunal elements. Unlike most localities of this age, the Moncure locality yields both archosauriforms and cynodonts, and therefore may provide additional insight into the dynamics of the Triassic-Jurassic transition of vertebrate faunas from synapsid- to diapsid-dominated assemblages.

8: 2:00 PM, Booth 30
Presenter: TACKETT, LYDIA S.

BIOTIC RESPONSE TO A MAJOR EXTRATERRESTRIAL IMPACT: MARINE PALEOECOLOGY OF THE NORIAN LUNING FORMATION, NORTHWEST NEVADA

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Throughout the Phanerozoic, many bolides have bombarded the Earth, but only the Chicxulub impact of the End-Cretaceous has been attributed to global extinctions. For most impacts, the objects are too small to significantly affect distal environments, but for larger craters, like Manicouagan (214 ±1 Ma) in Quebec, the lack of global effects is somewhat of a conundrum. The massive Manicouagan crater (originally ~100km diameter) indicates an impactor comparable in size and force to that of Chicxulub, and yet no increase in global extinction levels is associated with this impact event. Physical factors (e.g., crystalline shield host material) constrained the impact's effects, but impact models predict that craters = 10-12 km in diameter will create “atmospheric blow-out” - upper atmospheric ejecta that is distributed globally. The ejecta would primarily rain-out westward over areas of precipitation, affecting shallow marine ecosystems. This research involves analysis and correlation of two sites in northwestern Nevada deposited in shallow marine environments throughout the Norian Stage (228.8-204.5Ma) - ideal candidates for reflecting any biotic response to the effects of the Manicouagan impact. A less than expected biotic response to this impact may in part be due to resilient ecological structure characteristic of this time. The paleoecological characteristics of the Luning communities will be assessed to determine how they may have contributed to their resistance to extinction. A combination of previous research on the physical parameters of large impacts and paleoecological analyses of global depositional sequences from the Norian Stage, including this study, will thus provide a more complete understanding of the disparate degree of biotic responses to large impact events.

8: 2:00 PM, Booth 31
Presenter: SHI, YUKUN

DIFFERENCES BETWEEN SUBFAMILIES IN DIVERSIFICATION PROCESS OF THE EARLY AND MIDDLE PERMIAN FUSULINID FAUNA IN SOUTH CHINA

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During the last 30 years, compilation of Phanerozoic fossil records has been successively conducted to disclose the large-scale pattern of diversification of fossil faunas. Meanwhile, much attention has also been paid to taxonomic diversities to uncover evolutionary processes of different faunas through crises, or to pursue the potential constraints of these different processes. As for fusulinid foraminifers, previous research has shown their Permian diversification pattern in South China. And this research indicated that the fusulinid fauna there proliferated twice at generic and specific levels, once in the Early Permian and again in the Middle Permian. Comparative study revealed that the first-occurrence rates of Early Permian fusulinid genera and species are significantly higher than those of Middle Permian. A sustained low rate of speciation could be the immanent factor for the lower species diversity in the Middle Permian. However, the causes of these differences in speciation rate are still not clear. Accordingly, a detailed research is carried out here to reveal these differences. Based on the fusulinid occurrence records from a computerized database of stratigraphic distribution, statistical comparisons have been conducted to disclose the differences among six subfamilies (constituting the major part of the fusulinid fauna) in generic and specific diversities, rates of speciation and extinction, and changes in the rates and others. Our results reveal that: (1) significant differences exist in the diversification patterns of different taxa; (2) the rates of speciation and extinction in Schwagerininae are statistically higher than those in the others. Furthermore, the high rate of speciation in Schwagerininae contributed to the higher rate of diversification of the fusulinid fauna in Early Permian, whereas the lower rate of diversification in the Middle Permian has resulted from the ubiquitous low rates of speciation in all major taxa in the fauna, such as Schwagerininae, Neoschwagerininae, Verbeekininae, Sumatrininae, and Miselllininae.

8: 2:00 PM, Booth 32
Presenter: RITTERBUSH, KATHLEEN A.

CHARACTERIZING PALEOECOLOGICAL CHANGE ACROSS THE END- TRIASSIC MASS EXTINCTION: SURVIVAL AND RECOVERY DURING GLOBAL CRISIS

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Global environmental stresses induced by extensive flood basalt volcanism at the end of the Triassic are suggested as causal mechanisms for one of Earth's most severe mass extinctions. Changes in taxonomic diversity do not sufficiently characterize ecological responses to this environmental stress. Paleoecological studies at this interval are few, and can be complicated by unique regional patterns or by problematic depositional sequences. Characterization of the paleoecology of the western coast of Pangea before, during, and after the end-Triassic crisis will aid in assessment of causal mechanisms and of rates for extinction and recovery. In Nevada, the Triassic/Jurassic boundary is represented by conformable marine mixed siliciclastic and carbonate outcrops in the Gabbs Valley Range and nearby mountain systems. New field research was conducted to elucidate paleoenvironments and paleocommunity structure in Muller Canyon, a candidate GSSP for this interval. The boundary is estimated to lie about 8 m below the Sunrise Formation, and contains very sparse fauna including the mussel *Modiolus*. The significance of this genus as a survivor or disaster taxon is intriguing in light of recent research revealing increased success among mussels under elevated CO2 conditions. Ecologic recovery early in the Jurassic included large gastropods, bivalves, and ammonoids, suggesting high levels of oxygen and carbonate availability within the photic zone. Such observations suggest a relatively rapid ecological recovery of these level-bottom marine ecosystems from the environmental stress that caused the mass extinction.

8: 2:00 PM, Booth 33
Presenter: RIVERA, ALEXEI A.

LIFE POSITION IN AN EXTINCT ECHINODERM CLASS: A BIOMECHANICAL APPROACH

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Appearing during the great Ordovician radiation of marine life, the blastoids became a prominent constituent of the Paleozoic Fauna and persisted until the Middle Permian mass extinction. These stalked, suspension-feeding echinoderms occupied the same adaptive strategy and epifaunal tiering levels as crinoids, anthozoans, and stenolaemate bryozoans, and are traditionally interpreted with the filtration fan of arm-like brachioles directed upward and oriented perpendicular to the substrate (the “collecting bowl” position). Alternatively, it may have been oriented parallel to the substrate with the stalk bent approximately 90° and the oral pole facing either up-current or down-current as in some Recent stalked crinoids. To explore the hydrodynamic behavior of these various postures, water flow was examined around a life-sized model of the spiraculate blastoid *Pentremites pyriformis* from the Mississippian Chester Series of North America at current velocities typical of shallow

carbonate shelf or reef settings (2-10 cm/s). Experimental observations in a flow tank suggest that the “collecting bowl” position is unlikely because of long water residence times (~60-120 s) around the oral pole, which delays waste removal from the spiracles and anus. The up-current facing oral pole experienced shorter residence times, but turbulent wakes emerged downstream of the theca; the resulting backwash of re-circulated water could thus foul upstream feeding and respiratory structures. Dynamic pressure generated from the incoming flow might also potentially force waste into the mouth, spiracles, and anus. The down-current facing oral pole experienced short residence times without any significant backwash, and therefore appears to be the most probable life position. While the application of living taxa in inferring the functional morphology and life habits of fossil taxa is often complicated (for example, *Nautilus* as an uncritical model for ammonoids), at least some Recent crinoids may be posturally analogous to blastoids despite key morphologic and ecologic differences.

8: 2:00 PM, Booth 34
Presenter: RIVERA, ALEXEI A.

MAMMALIAN EVOLUTION AND THE END-CRETACEOUS MASS EXTINCTION

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A classic example of adaptive radiation in the fossil record is the large-scale diversification of mammalian lineages early in the Cenozoic Era. About twenty orders, as anatomically and ecologically divergent as bats, horses, and whales, appeared in a geologic interval lasting only ten or fifteen million years. The brevity of this interval is remarkable because throughout the preceding hundred million years of the Mesozoic Era, mammals remained relatively small and unspecialized. Dominant Mesozoic taxa, such as dinosaurs and other archosaurs, may have suppressed extensive mammalian diversification by predation rather than direct competition. Only after the catastrophic end-Cretaceous mass extinction did mammals have the opportunity to occupy newly vacated adaptive zones and thus begin their dramatic rise to prominence. To explore the plausibility of this scenario, a mathematical model of taxonomic evolution and fossil preservation was used to estimate stratigraphic range extensions (intervals of complete non-preservation) in eleven extant and five extinct placental orders that first appear during the Paleocene and Eocene epochs. Assuming Cenozoic rates of extinction and preservation, range extensions ranged from 3.66 to 7.39 × 10^5 years at the 50% confidence level, though all orders remained confined to their subepoch of first appearance. Assuming much lower Mesozoic rates of extinction and preservation, all orders are estimated to extend backward by at least one subepoch at the 50% confidence level; four (Carnivora, Insectivora, Mesonychia, and Condylarthra) are estimated to extend into the Maastrichtian Age of the Late Cretaceous. The possibility that some ordinal origination occurred in the Late Cretaceous therefore cannot be ruled out. The overall analysis, however, suggests that most

of the actual radiation occurred in the Paleocene soon after the end-Cretaceous asteroid impact. Preliminary calculations also indicate that it was even more rapid than previously thought, thereby supporting the punctuational model of adaptive radiation.

8: 2:00 PM, Booth 35
Presenter: HARRIS, ELISHA B.

A MID-CRETACEOUS ANGIOSPERM-DOMINATED MACROFLORA FROM THE CEDAR MOUNTAIN FORMATION OF UTAH: IMPLICATIONS FOR DIVERSITY AND CLIMATE

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Two bursts of diversification (in the Barremian-Aptian and the Cenomanian) set off the explosive radiation of angiosperms in the mid-Cretaceous. Despite the robustness of this pattern, the details of the taxonomic, geographic and ecological radiation of angiosperms are relatively poorly known because only a small number of macrofloras have been reported. Here we describe an all-angiosperm flora preserved in a limy, lacustrine, mudstone deposit from the Cedar Mountain Formation of Emery County, Utah. Similar deposits nearby have been radiosiotopically dated to 98 Ma, the Aptian-Cenomanian transition. Among 76 specimens, we recognize 16 morphotypes, all of which are dicot angiosperms. From this we infer that a moderate-diversity angiosperm community completely dominated the lakeside. This result is surprising given the early date of this material. Preliminary palynological analyses have been unproductive, yielding little information about landscape-scale vegetation. Leaf s margin and leaf size analyses were used to estimate mean annual temperature (MAT) and mean annual precipitation (MAP) respectively. MAT was 25-27°C and the MAP was 70.4 cm. The reconstructed high MAT and low rainfall are consistent with the high carbonate content of the lake sediments. Early angiosperm dominance in a hot, arid climate may be yet another example of angiosperms finding an initial ecological roothold in otherwise marginal environments.

8: 2:00 PM, Booth 36
Presenter: POLTENOVAGE, MICHAEL A.

PALEOASYS: AN APPLICATION FOR HIGH-RESOLUTION TRACKING, REPORTING, AND ANALYZING PALEONTOLOGICAL RESEARCH ACTIVITIES WITHIN THE HELL CREEK STUDY SYSTEM

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An increasing wealth of published and unpublished paleontological data is being compiled in databases. The paleontological data contained are often restricted based on taxon, time period, project, or geography and seldom contain details of research and collection activities, previous taxonomic assessments, or multimedia, such as videos, animations, and images. Paleontological database websites are typically managed by one person and lack user-friendly interfaces and features of community-driven websites. These databases may be either non-database managed systems (non-DBMS) or database-managed systems (DBMS). DBMS more efficiently handles the access, creation, and modification of data. PaleOasys is a new community driven website application for paleontological research activities with a relational DBMS back-end. It integrates collection activities, lab work, curational tasks, locality details, geologic data, specimen information, GIS operations, research analyses, and multimedia into a single one-touch platform. The application design is ideal for high-resolution tracking, reporting, and analyzing of paleontological research activities. Our research group is using PaleOasys to address questions regarding biotic changes near the Cretaceous-Paleogene boundary in northeastern Montana. The system may capture data during each phase of research into one or more of 128 related tables. The user interface uses a community driven architecture that allows many people to interact easily with each other and the system. Statistics, reports, and charts may be generated for numerous permutations or subsets of the data and may be easily and quickly modified. In sum, PaleOasys uniquely combines the ability to track research and collection activities through a variety of multimedia, run quantitative analyses on subsets of the data, and generate easily modifiable reports with the user-friendly community features. As such, it is ideal for use in broad, collections- and field-based research collaborations, such as ours based within the Hell Creek study system.

8: 2:00 PM, Booth 37
Presenter: DOMINICI, STEFANO

MEDITERRANEAN FOSSIL WHALES AND THE ADAPTATION OF MOLLUSKS TO EXTREME HABITATS

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Biota of deep-sea ephemeral habitats such as hydrothermal vents and cold seeps, and biota living by decomposing whale carcasses possess chemosymbiotic adaptations acquired to

exploit reducing compounds. This shared ability has suggested that whale falls - and marine reptile carcasses before them - have acted as evolutionary stepping stones to chemosynthetic habitats, raising the question if chemosymbiotic specialization first evolved at shelf depths. Natural shallow-water whale-falls are rare on the shelf and artificial implantations are too young to test the complete ecological succession. The Mediterranean fossil record is here analyzed for clues to the role of large carcasses as ecosystems. A recent excavation of a 10 m long Pliocene baleen whale has offered a template to evaluate other 13 museum large whales as a source of information. A quantitative family-level comparison between mollusk assemblages from extreme reducing environments at different depths (whale-falls, cold seeps, hydrothermal vents, wood-falls) and analogue assemblages from normal bottoms confirm the substantial difference between shallow- and deep-water reducing ecosystems. The shelf break is the most likely place for evolutionary innovation to take place, being the threshold between high-diversity shelf and deep bottoms where chemosynthesis is a substantial alternative to photosynthesis as a trophic route.

8: 2:00 PM, Booth 38
Presenter: KOOT, MARTHA B.

TESTING THE POTENTIAL MONOSPECIFICITY OF THE SABRE-TOOTH CAT GENUS *HOMOTHERIUM* USING COMPARATIVE DATA FROM RECENT LARGE CATS

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Numerous fossil remains of the sabre-tooth cat of the genus *Homotherium* - that lived during the Pliocene and Pleistocene - have been found on the continents of Africa, Europe, Asia, and North America. These specimens have been studied since the beginning of the 19th century and were attributed to a large number of different species. Many of these species, however, have similar stratigraphic occurrences and morphologies. This research tests the hypothesis that the genus consisted of only one or a couple of species. In that case, the differences between the specimens would be due to the very broad geographic range and also to individual variation, sexual dimorphism, or age. All available descriptions, figures, and measurements from primary and secondary literature were studied and analysed to ascertain the validity of these species. The results lead to the conclusion that likely all species must be united into one single species as the morphological differences between the specimens were deemed too trivial. In order to more firmly establish this somewhat unlikely conclusion of a single, widespread species of *Homotherium* existing unchanged for such a long period of time, additional comparative data were required. The data of the sabre-tooth cat were compared to

measurements of the dentition, mandible, and cranium of recent lions (*Panthera leo*) and tigers (*Panthera tigris*) from a variety of geographic regions. The results demonstrated convincing differences between lions and tigers, and also between the recent cats and *Homotherium*. However, the intraspecific variation found in lions and tigers is very similar to the variation in the sabre-tooth cats; supporting the previous hypothesis that the genus *Homotherium* is monospecific.

8: 2:00 PM, Booth 39
Presenter: JOHNSON, KENNETH

CORALLOSPHERE.ORG: BIODIVERSITY INFORMATICS FOR EXTINCT AND EXTANT SCLERACTINIAN CORALS.

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The field of scleractinian coral taxonomy is in the midst of a revolution as the community of taxonomists strive to incorporate new data resulting from advances in molecular systematics and the application of new technologies for extracting new kinds of morphological characters from coral skeletons. One important goal of this effort is the production of a rigorous framework providing well-circumscribed taxon concepts to allow consistent identification of corals for use by non-taxonomist colleagues. The *Treatise on Invertebrate Paleontology* is the sole authoritative reference on the morphology, taxonomy, ecology and systematics of extinct and extant scleractinian corals. Assembling the large volume of information from disparate sources that is required to produce a revised version of the *Treatise* presents a formidable challenge that is facilitated by new collaborative techniques associated with biodiversity informatics. We are using a web-based collaborative biodiversity informatics tools at corallosphere.org to address this issue. Corallosphere.org enables registered contributors to compile, review, and edit generic diagnoses from any computer connected to the internet. Main work areas covered in corallosphere.org include text descriptions for diagnoses of currently accepted genera, as well as tools for managing taxonomic synonymies, large numbers of images, a bibliography, and an illustrated glossary of morphological terms. A flexible work-flow allows users of the system to be assigned roles with differing levels of access and functionality. All users are able to post comments, and a formal peer-review mechanism is available to ensure high-quality content. The ultimate aim is to produce a system that will facilitate the rapid publication of the next version of the Treatise based on community-wide consensus, and help remove the taxonomic impediment that is currently slowing progress towards an improved understanding of the biology, ecology, and evolutionary history of the Scleractinia.

8: 2:00 PM, Booth 40
Presenter: JACOBSEN, NIKITA D.

PALAEOECOLOGICAL CHANGE THROUGH THE PERMIAN-TRIASSIC MASS EXTINCTION EVENT: COMPARISON OF METHODS

JACOBSEN, NIKITA D., Geology, University of Plymouth, School of Earth, Ocean & Environmental Sciences, Room 101, Fitzroy Building, University of Plymouth, Plymouth, Devon, PL4 8AA, United Kingdom, nikita.jacobsen@plymouth.ac.uk; TWITCHETT, RICHARD J., Geology, School of Earth, Ocean & Environmental Sciences, Room 101,Fitzroy Building, University of Plymouth, Drake Circus, Plymouth, Devon, UK PL4 8AA

Different authors use different methods to assess Permian-Triassic palaeoecological changes, yet no comparative study of different methodologies has been published. We compared two methods of assessing palaeoecological parameters such as diversity, richness and skeletal abundance from limestone thin sections: point counting and an equal-area approach. Results demonstrated that there are significant differences between methodologies. Point counting is relatively 'quick and dirty'. It is somewhat biased with respect to organism size, by overemphasizing larger taxa/bioclasts, and underemphasizing smaller taxa/bioclasts. Some point counting 'palaeoecological' data are not considered useful for measuring biotic recovery, as previously suggested by some authors, because they are affected by taphonomic processes. The presence of diagenetic veins may reduce apparent abundance; winnowing may increase it. Trends in abundance between locations and regions through time, however, tend to broadly agree between methods, although we recorded Early Triassic samples with much higher skeletal abundances (up to 75%) than in previous published studies. Data from locations in Italy, Oman, and USA were compared. The most diverse samples are Griesbachian in age from Oman, whilst the Dienerian-Smithian samples from western USA are less diverse. These data agree with previously published inferences of varying recovery rates based on analysis of tiering and trace fossils.

Session No. 9, 8:00 AM; Tuesday, 23 June 2009
Topical Session 3. Morphology, Function, Growth, and Unusual Preservation

9: 8:00 AM-8:15 AM
Presenter: BUICK, DEVIN

ADAPTIVE LANDSCAPES, BIOGEOGRAPHIC SHIFTS AND DIVERSITY DYNAMICS: EXPLORING THE EVOLUTION OF THE RELICT BIVALVE FAMILY CUCULLAEIDAE

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Quantitative studies combining changes in species richness, geographic range, morphological disparity and ecology are essential for advancing our understanding of the evolutionary dynamics of families and genera, but are often difficult to synthesize at the species level, where such changes are most pronounced. Through the construction of an occurrence-based database and using various morphometric techniques, this research documents macroevolutionary change within the bivalve family Cucullaeidae, composed almost entirely of the genus *Cucullaea*, during the past 200 million years of earth history. Intermediate in morphology between two other major arcoid families, the Arcidae and Glycymeridae, the cucullaeids diverged from the elongate morphologies of their parallelodontid ancestors in the Jurassic to establish an adaptive zone in which they would vary for the rest of the Mesozoic and Cenozoic. Morphological disparity was initially high during the Jurassic, with species occupying both ancestral and “classically cucullaeid” shell shapes across a wide area of morphospace. Subsequently, into the Late Jurassic, Cretaceous and Cenozoic, species richness increased and the family attained a global distribution, achieving a maximum in the Late Cretaceous. Throughout all this time, the position and range of the family in morphospace fluctuated little, with a few genera diverging from the family's core morphology to be preserved as dead-end evolutionary experiments. Cenozoic species richness continually declined as species became extinct throughout their worldwide geographic range. Extant cucullaeids, represented by some 1-4 species throughout the Indo-Pacific, have significantly shifted away from the long-established, core cucullaeid shell morphology, manifested in morphospace and among shell features, as living individuals show large-bodied, thinner-shelled, more triangular shell shapes. Similar in magnitude, but opposite in direction to the initial Jurassic morphological transition, this recent shift likely represents a novel evolutionary strategy for the continued persistence of this relict bivalve group.

9: 8:15 AM-8:30 AM
Presenter: HOPKINS, MELANIE J.

THE GEOGRAPHIC STRUCTURE OF MORPHOLOGICAL VARIATION IN FIDDLER CRABS (CRUSTACEA: *UCA*)

HOPKINS, MELANIE J., Dept of the Geophysical Sciences, University of Chicago, 5734 S Ellis Ave, Chicago, IL, 60637, United States, mjh@uchicago.edu; THURMAN, CARL L., Department of Biology, University of Northern Iowa, Cedar Falls, Iowa, 50614

Studies documenting geographic variation in numerous taxa suggest that species with greater geographic range should exhibit more morphological variation. We test this hypothesis quantitatively using species of fiddler crabs (Crustacea: *Uca*) from the Atlantic and Gulf coasts of North America. Samples from populations were collected across the entire geographic range for each of eight species. Range size for each species was quantified by estimating coastline length. Morphological variation of the carapace was measured using geometric morphometric shape analysis of 945 specimens. Contrary to expectations, no relationship between intraspecific variation and geographic range was found and variation did not correspond with substrate affinity, number of biotic provinces occupied, or salinity tolerance. Thus, *Uca* species do not necessarily require more carapace variation to inhabit larger geographic range sizes, nor do they necessarily accumulate more variation by virtue of range expansion. However, species with greater intraspecific variation do show more divergence among populations in morphospace. Much, but not all, of this divergence is attributed to geographically correlated allometry. These results have implications for paleobiological studies because the geographic structure of variation within species may drive patterns of divergence and speciation as well as influence taxon duration or extinction risk.

9: 8:30 AM-8:45 AM
Presenter: LAUB, RICHARD S.

THE CHELICERAL CLAWS OF *ACUTIRAMUS* (ARTHROPODA: EURYPTERIDA): FUNCTIONAL ANALYSIS BASED ON ENGINEERING PRINCIPLES AND MORPHOLOGY

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The eurypterid genus *Acutiramus*, a member of the Family Pterygotidae, is noted for its long cheliceral appendages and their unusual claws. Our study focuses on *A. cummingsi* (Late Silurian of western New York and southern Ontario). The genus is noted for a medial-proximal slant of the distal ends of the two claw rami. A barb-like feature at the medial end of this slanting terminus projects into and partly obstructs the space between the rami. Other distinctive features of the claw include several elongate, oblique, serrated denticles in the rear half of the fixed ramus, a large perpendicular denticle on the free ramus which opposes these oblique denticles, and a series of distally directed denticles at the rear-most part of the free ramus. Morphology suggests that the claw served to entrap, pierce and slice prey. Using engineering principles, we address details of how the claw may have functioned, and the sorts of objects on which it may have been used. After being channeled past the distal ends of the rami, prey would have been impaled on the longest oblique denticle, then split open as the free ramus forced it down along the serrations. This long denticle appears to have been slightly off-set from the plane of the claw, allowing it to be by-passed when the rami were

closed. The smaller serrated denticle in front of it could thus also come into play. The anteriorly directed denticles at the proximal end of the free ramus may have served to capture and to stabilize the prey as it was being sliced. We also consider how the number of appendage elements proximal to the claw (a matter of controversy) may have constrained its use.

9: 8:45 AM-9:00 AM
Presenter: SCHREIBER, HOLLY A.

THREE-DIMENSIONAL GEOMETRIC MORPHOMETRIC ANALYSIS OF RECENT RHYNCHONELLIDE BRACHIOPOD CRURA

SCHREIBER, HOLLY A. , University of California, Davis, Geology Department, One Shields Ave., Davis, CA, 95616, United States, schreiber@geology.ucdavis.edu; CARLSON, SANDRA J., Geology, University of California, Davis, One Shields Ave., Davis, CA, USA, 95616

Crura, the calcareous supporting structures of the lophophore in rhynchonellide brachiopods, are important for classification and deciphering major evolutionary lineages within rhynchonellides, but have only been evaluated qualitatively. Seventeen morphological crural types have been named and placed into four fundamental groups according to variation in overall structure and cross-sectional shape, but it is unclear how these different types are related to one another morphologically, phylogenetically, or ontogenetically. The variety of morphologies and close similarity between the different named types must be evaluated quantitatively for crural characters to be used reliably and accurately for taxonomic or phylogenetic purposes. We assess the four crural groups and investigate the morphological variability of the individual crural types using three-dimensional geometric morphometric techniques with the objective of delineating unambiguous crural guidelines for use in rhynchonellide classification and phylogenetic analyses and ultimately assessing the role of ontogeny in crural evolution. We imaged the crura of the Recent rhynchonellides *Notosaria nigricans*, *Neorhynchia profunda*, *Hemithiris psittacea* and *Frieleia halli* using x-ray computed microtomography, which allows three-dimensional images to be obtained, non-destructively, from very small objects. Three-dimensional Cartesian coordinates were collected for eleven homologous landmarks which, along with semi-landmarks, define the dimensions of the crura, the surrounding hinge area, and the curvature of the crura. We then analyzed the three-dimensional coordinate data using a generalized Procrustes analysis and principal components analysis of tangent space coordinates. We predicted that crura assigned to the predefined groups will cluster in morphospace, however preliminary multivariate statistical analyses using crural characteristics imply that there may be more than four discernable crural groups. Preliminary inspection of *Notosaria nigricans* and *Hemithiris psittacea* also suggests that the shape of named crural types varies considerably within and between species.

9: 9:00 AM-9:15 AM
Presenter: BAPST, DAVID W.

THE DEVELOPMENT OF MORPHOLOGICAL GRADIENTS WITHIN EARLY SILURIAN GRAPTOLOID COLONIES

BAPST, DAVID W., Department of Geophysical Sciences, University of Chicago, Dept of Geophysical Sciences, 5734 S Ellis, Chicago, IL, 60637, United States, dwbapst@uchicago.edu; MELCHIN, MICHAEL J., Department of Earth Sciences, St. Francis Xavier University, P.O. Box 5000, Antigonish, Nova Scotia, Canada, B2G 2W5

A theoretical model of theca development in graptoloids would have important implications for understanding the evolution of diverse graptoloid morphologies, but a single model may not accurately describe graptoloid ontogeny. Monograptid graptoloids present some of the most complex thecal morphologies and apertural elaborations in the evolutionary history of the graptoloids. These thecal shapes are not necessarily static within a colony and can change considerably with growth. If there is an integrated process driving thecal morphogenesis , those complex morphologies seen in Monograptids may be a result of simple modifications to that system. Alternatively, the restriction of these diverse modifications to within Monograptids suggest that there may have been an increase in modularity of the system, leading to an opportunity for increased morphological diversification. In order to understand these features relative to other aspects of theca formation, we focused on the Aeronian stage of the Silurian (439 to 436 MYA), an interval when many of the complex Monograptid forms first appeared. We used morphometric techniques to quantify the change during colonial development. Using a preliminary phylogeny, we compared these morphological gradients in closely related species and examined the evidence for morphological integration in Monograptid thecae. This study lays a framework for asking further questions related to morphogenesis and developing general principles of graptoloid development.

9: 9:15 AM-9:30 AM
Presenter: VALENT, MARTIN

FILLINGS OF HYOLITHID GUTS FROM THE MIDDLE ORDOVICIAN OF THE PRAGUE BASIN (CZECH REPUBLIC)

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Exceptional hyoliths are found with parts of the digestive system preserved. Only ten instances have been recorded all around the world. Among the hyolithids there is a case of a simple U-shaped gut being phosphatized, but orthothecids with a very complicated intestinal course predominate. *Nephrotheca sarkaensis* (Novak, 1891), from the Prague Basin (Barrandian area, Czech Republic), belongs to the latter group. This orthothecid species is an uncommon element of the very rich hyolith assemblage in the Sarka Formation (Darriwilian, Ordovician). Fourteen specimens have been found with their guts almost completely infilled. New available material enables a precise reconstruction of the gut. The initial intestinal tract ran near the ventral side from apertural to apical region of the conch. It was densely and sinuously folded across the whole width of conch. The infill of this gut portion is narrow. The last fold is apically oriented and the gut infill becomes slightly wider. Thereafter the gut ran axially to the apex where it turned sharply back and formed the beginning of the reverse tract. This segment having run from the apex towards the aperture lay close to the dorsal side of the folded tract. It was axially oriented and slightly bent. Its terminal part rose up sharply at the apertural region and reached up to the dorsal side of body. The infill of the reverse tract is wide for its entire length. As *Nephrotheca sarkaensis* has provided evidence of a gut filled with sediment it is clear that it was substrate feeder and its benthic mode of life is indubitable.
Acknowledgement: The research was funded by projects of the Czech Science Foundation No. 205/09/1521, the Ministry of Education, Youth and Sports of the Czech Rep. No. MSM0021620855 and the Ministry of Culture of the Czech Rep. No. DE06P04OMG009.

9: 9:30 AM-9:45 AM
Presenter: LODUCA, STEVE T.

A NEW MACROALGAL-DOMINATED KONSERVAT-LAGERSTÄTTE FROM THE SILURIAN (LUDLOVIAN) OF ARCTIC CANADA

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Intervals of thin-bedded argillaceous micrite within the Cape Phillips Formation on Cornwallis Island, Arctic Canada, contain numerous specimens of noncalcified macroalgae preserved as carbonaceous compressions. Associated fossils include dendroid and graptoloid graptolites (*Saetograptus linearis*); the latter indicate a Ludlovian (Gorstian) age for the material. This occurrence represents a further example of a distinctive and predictably recurrent type of Konservat-Lagerstätte in lower Paleozoic strata in which noncalcified macroalgae comprise the principal constituents and shelly taxa are rare or absent. Thalli of two of the algal forms consist of an erect cylindrical main axis surrounded in radial fashion by cylindrical appendages.

The appendages branch, but are otherwise simple. In this and other key aspects of external thallus morphology these forms resemble early Paleozoic taxa assigned to the extant green algal order Dasycladales, including *Archaeobatophora*, *Primicorallina* and *Inopinatella*. Also present within the assemblage are thalli with a dichotomously branched, distinctly serial-segmented form. Segments range in shape from rectangular near the base to cuneate and trapezoid in upper regions of the thallus; each comprises a central medullary region and a cortex that appears to consist of a multitude of fine filaments. The serial-segmented, corticated architecture of this form is known among members of the Bryopsidales, the sister group of Dasycladales, including the important extant sediment-producer *Halimeda*. A fourth algal form from this Konservat-Lagerstätte appears to represent a further green algal order: the Siphonocladales. Thalli of this form comprise an annulated uniaxial stalk and a capitulum formed of fine filaments, an architecture characteristic of the extant siphonocladalean *Chamaedoris*. The algal forms represented in this assemblage, in combination with those previously documented from lower Paleozoic strata, indicate that many of the thallus architectures displayed by modern green macroalgae were achieved before the end of the Silurian.

9: 9:45 AM-10:00 AM
Presenter: CACHEL, SUSAN

ARBOREAL ORIGINS OF HOMINID BIPEDALISM

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Researchers have recently argued that arboreal bipedalism found in orangutans (*Pongo*) indicates that hominid bipedalism originated in an arboreal setting (Thorpe et al., 2007). Orangutan movement on flexible branches that are small relative to the body size of the ape is identified as the locomotion pre-adapting hominid ancestors to terrestrial bipedalism. Yet, the derived hand and foot morphology of *Pongo* indicates a specialization for arboreal locomotion on small, flexible branches. The orangutan hallux and pollex are reduced, and the lateral rays are elongated. This morphology, in conjunction with the orangutan's long metacarpals and metatarsals allow the digits to double-lock when fully flexed. Climbing and feeding can consequently safely take place on small flexible arboreal supports. This specialized morphology is not found in other living hominoids, or in surviving fossils of Miocene apes, such as the African proconsulids or European *Pierolapithecus*. Furthermore, early hominid foot morphology and the 3.6 mya Laetoli trackways document the presence of a robust hallux. Hominids appear to have evolved from an ancestor that also possessed a large hallux - a trait that is characteristic of the primate order. Bipedalism may first have evolved in an arboreal setting, as illustrated by the locomotion of living small-bodied hylobatid apes. Nevertheless, a large-bodied arboreal biped using small, flexible branches would have evolved the hand and foot morphology seen in the modern orangutan. Thus, the type of arboreal

bipedalism exhibited by orangutans is unlikely to have been a precursor to hominid bipedalism.

9: 10:30 AM-10:45 AM
Presenter: GARCIA, WILLIAM

TERRESTRIAL ADAPATIONS OF THE VERTEBRAL COLUMN AMONG EARLY TETRAPODS

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The vertebral column underwent significant morphological changes during the evolution of terrestrial vertebrates. One of the most striking changes is the increased ossification of vertebral elements, typical Devonian tetrapods possess poorly ossified vertebrae and certain Mississippian tetrapods also had reduced vertebral ossifications. Poorly ossified central elements occur in Crassigryinus, and limited ossification of portions of the neural arch occurs in Pederpes and Crassigyrinus. Additional plesiomorphic characters are present in some Mississippian tetrapods including *Greererpeton*, where the neural spines of the caudal and anterior dorsal vertebrae are oriented posterodorsally as in Devonian tetrapods. While plesiomorphic vertebral characters are present in some Mississippian tetrapods, various taxa possess characters associated with increased terrestriality. Suturing and fusion of the central elements is a significant adaptation to terrestrial locomotion, providing additional stability to the vertebral column and preventing sagging of the trunk vertebrae. An early experiment with suturing of central elements occurs in *Whatcheeria*, where certain intercentra are fused to their corresponding pleurocentra in specimens from multiple localities. Interestingly, this early experiment correlates to the earliest appearance of asymmetrical phalanges in early tetrapods. Neural spine height varies regionally in *Proterogyrinus* where neural spine height increases from the pectoral girdle to the mid-trunk vertebrae and then decreases posteriorly before increasing once more toward the sacral vertebrae. Taller neural spines may increase stability of the vertebral column by increasing area for muscle attachment. In *Gephyrostegus*, the pleurocentra are expanded posterodorsally such that this element would slightly cap the following intercentrum preventing sagging of the trunk. This feature is present throughout the trunk vertebrae in *Gephyrostegus*. Mapping these morphologies on reconstructions of early tetrapod phylogeny suggests that after the initial colonization of land vertebrates engaged in an experimental phase of evolution with different stabilization strategies attempted among different clades.

9: 10:45 AM-11:00 AM
Presenter: CAMPIONE, NICOLAS ERNESTO

CRANIAL VARIATION IN EDMONTOSAURUS (HADROSAURIDAE) FROM THE LATE CRETACEOUS OF NORTH AMERICA

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Edmontosaurus is one of the most common hadrosaurid taxa, based on the plethora of complete specimens and bonebed material found in Canada and the United States. However, the species-level systematics of the five edmontosaur taxa remains uncertain. This has led to confusion regarding the alpha level diversity and biostratigraphic distributions of edmontosaurs leading up to the end-Cretaceous extinction event. Here, we use a morphometric approach to evaluate the edmontosaurs. This study incorporates a series of 33 cranial measurements and a sample of 10 complete skulls: *E. regalis* (n=5), *E. (Anatosaurus) annectens* (n=2), and the holotypes of *Anatotitan copei*, *E. saskatchewanensis*, and *E. edmontoni*. A Principal Components Analysis reveals a separation between the older Horseshoe Canyon Formation taxa (*E. regalis* and *E. edmontoni*) from the latest Cretaceous specimens along PC2 and PC3. In the bivariate analyses, most variables reveal a single trend, however, variables of the snout, specifically the distance between the anterior margin of the naris and the tip of the snout, reveal two patterns. *E. saskatchewanensis*, *E. annectens*, and *A. copei* appear to have a relatively longer snout than *E. regalis*. *E. edmontoni* is undifferentiable from *E. regalis* in this respect. Morphometric results suggest that there is a clear difference between *E. regalis* (Late Campanian Horseshoe Canyon Formation) and the Late Maastrichtian specimens. *E. edmontoni*, also from the Horseshoe Canyon Formation, clearly clusters with *E. regalis* in all analyses. Therefore, we conclude that *E. edmontoni* is probably synonymous with *E. regalis*, and not *E. annectens* as is often suggested. The data suggest that *E. saskatchewanensis* is probably synonymous with *E. annectens* but at present, more data is needed to clarify the taxonomy of the Maastrichtian taxa including the validity of *Anatotitan copei*, which remains equivocal.

9: 11:00 AM-11:15 AM
Presenter: MANNING, PHILLIP L.

450 BILLION-VOXEL FINITE ELEMENT MODEL OF THE TERMINAL UNGUAL PHALANX OF PEDAL DIGIT II OF *DEINONYCHUS ANTIRRHOPUS*

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Computerized X-ray micro-tomography (XRT) was used to reconstruct a 3D model of the microstructure of the enlarged claw of pedal digit II of *Deinonychus antirrhopus*. The model allows for exploration of the relationship between claw morphology, geometry, microstructure, materials properties and function. The scan was undertaken on a Skyscan XRT system and produced 7400 slices through the specimen. The sub-micron resolution XRT scan of the terminal ungual phalanx (~70mm in length) of digit II of *D. antirrhopus* (Yale Peabody Museum 5218) generated an XRT file of 320 gigabytes.This study generated a volume rendering from the XRT scan data of the terminal ungual phalanx. This has been translated in to a 450 billion voxel model that was rendered using a parallel visualization toolkit. The high-resolution volume of the claw allows detailed analysis of the internal microstructure and geometry of cancellous and cortical bone that can be used to enable interpretation of the mechanical function of the claw. The task of converting the voxels to a geometrically accurate finite element model was carried out using commercial software, which was specially modified for the project. The pedal digit and claw of an extant avian theropod, eagle owl (*Bubo bubo*), was analyzed to provide biomaterial input data for the *D. antirrhopus* claw Finite Element Model. The resultant model confirms that dromaeosaurid pedal claws were well-adapted for climbing as they would have been resistant to forces acting in a single (longitudinal) plane, in this case due to gravity. However, the strength of the ungual was limited with respect to forces acting tangential to the long-axis of the claw, indicating that the claw was not likely used for slashing. The modeling of the mechanical properties and potentially function of this distinctive maniraptoran theropod structure provides new insight to the behavior of this group.

9: 11:15 AM-11:30 AM
Presenter: HOLTZ, THOMAS R., JR.

HETEROCHRONY IN TYRANT DINOSAUR EVOLUTION: IMPLICATIONS FOR TYRANNOSAURID PALEOECOLOGY

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Recent advances in skeletochronology have allowed us to estimate the growth curves of a number of dinosaurian species. Across the clade the general pattern of development indicates the onset of a rapid growth phase relatively early in life (typically <5-10 years old), with full size reached by age 12 or earlier. One clade that does not demonstrate this pattern, however, is the Tyrannosauridae, a group of large-bodied Late Cretaceous western North American and Asian coelurosaurs. In this lineage, onset of rapid growth phase does not seem to take place until ages 10-12 (when other dinosaurs are reaching their full adult body size), suggesting a heterochronic shift (postdisplacement) from the ancestral dinosaurian condition. Tyrannosaurids differ from other large carnivorous dinosaurs in terms of their synecology.

Well-sampled dinosaur communities from the Jurassic through Early Cretaceous (prior to the origin of Tyrannosauridae) show greater taxonomic diversity and morphological disparity among larger (>50 kg) carnivorous taxa when compared to communities of the Late Cretaceous. Additionally, when patterns of theropod diversity are compared to their potential prey diversity, the distinctiveness of tyrannosaurid-dominated faunas remains. Small theropod taxa show comparable or greater disparity in the Late Cretaceous as in earlier faunas. In contrast, the large carnivore guild in Campano-Maastrichtian Late Cretaceous assemblages is monopolized by tyrannosaurids, with medium-sized (50-500 kg) rare or absent. The apparent "missing middle" of the Late Cretaceous theropod guilds (i.e., absence or rarity of 50-500 kg carnivores), particularly in North America, would be alleviated by subadults of tyrannosaurid species serving as the mid-sized predators. It is suggested that the apparent heterochronic shift in tyrannosaurid developmental patterns produced a life-history patterns in which the juvenile tyrants could function as the primary mid-sized carnivores of the last 15 million years of Cretaceous Asiamerica.

9: 11:30 AM-11:45 AM
Presenter: WERNING, SARAH

A QUANTITATIVE METHOD TO REDUCE THE INFLUENCE OF HISTOLOGICAL SAMPLING LOCATION ON GROWTH ESTIMATION

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Full cross-sections are preferable in histological and skeletochronological studies of extinct vertebrates, because they allow for a more thorough assessment of histology and because they reduce ambiguity about the number, circumference, and ontogenetic trajectory of lines of arrested growth (LAGs). However, full cross-sections may be impossible to produce from large, unstabilized, incomplete, or rare specimens. In these cases, the only option may be to use a partial cross-section or a core sample. Because bone grows differentially through ontogeny, samples from different locations around the circumference of the bone can include cortical drift, rest lines, or secondary remodeling, resulting in over- or underestimations of bone growth rates. Although data from partial sections and cores are biased, they do offer a partial record of growth, and thus can be useful in comparative growth studies if their biases can be assessed statistically. Here we present a quantitative method to assess the optimal location at which to sample long bones when it is not possible to take complete cross-sections. Using long bones that were digitally photographed in full cross-section, we measured along 36 transects radiating from the geometric centroid and calculated radial growth (zonal width) between successive LAGs. We compared mean radial growth estimates to those from partial data sets and digital "cores" through our full cross-sections, to determine which regions of the

bone best reflected mean radial growth across the entire section. We then compared the optimal sampling locations in different skeletal elements and through ontogenetic series. We found that whereas optimal sampling locations differ among skeletal elements, these locations are consistent through ontogeny within the same element for a given taxon. Our results also suggest that optimal sampling locations for homologous elements may be consistent among different taxa, even when the bones were subjected in life to different biomechanical loads.

9: 11:45 AM-12:00 PM
Presenter: GEARY, DANA H.

BODY SIZE, LONGEVITY, AND GROWTH RATE IN LAKE PANNON MOLLUSCS

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Ancient Lake Pannon (central Europe; Mio-Pliocene) is an unusual and noteworthy system because of its endemic molluscan diversity and because of the geologically gradual pace of morphologic change recorded in many lineages. Increases in body size and concomitant changes in shape occur over roughly three-million year intervals in various lineages of melanopsid gastropods, dreissenid bivalves, and lymnocardiid bivalves. Distinguishing among the numerous possible factors in favor of size increase is aided by an understanding of individual longevity and growth rates, which can be obtained from stable isotope profiles of serially sampled shell material. To this end, we sampled shells from multiple horizons within each of several gradually changing lineages. Results suggest that the longevity of individuals increased roughly in proportion to size increase in the lineage, i.e. that size increase was due to increased longevity rather than an increase in growth rate. Such a result argues against the hypotheses that increased size in these lineages served as a refuge from predation or as a response to improved food supply. Although the size increases within lineages are fairly monotonic, stable isotopes reveal no evidence for any gradually changing environmental variable such as salinity or temperature. Considerable geographic variability in hydrological regime is apparent, as expressed in the isotopic ranges, minima, maxima, and correlation or lack thereof between $\delta^{13}C$ and $\delta^{18}O$ among shells from different localities. Shell profiles also record significant interannual variability in growth rate within individuals.

Session No. 10, 8:00 AM (morning session) and 1:30 PM (afternoon session) ; Tuesday, 23 June 2009
Symposium S5. Fossilized Development

10: 8:00 AM-8:15 AM
Presenter: HUGHES, NIGEL

AULACOPLEURA KONINCKII AS A MODEL FOR EXPLORING TRILOBITE DEVELOPMENTAL DYNAMICS

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The Silurian trilobite *Aulacopleura koninckii* is a model organism for exploring aspects of trilobite development, and illustrates the microevolutionary variability in trunk segmentation permissible within trilobites bearing homonomous trunk segmentation. Over 500 well preserved, articulated specimens show a curious pattern of variation in the number of thoracic segments, with anywhere between 18 to 22 thoracic segments evident in maturity. *Aulacopleura koninckii* occurs in large numbers on multiple bedding planes in a 1.4 meter mudstone interval near Lodenice in the Czech Republic that is about 425 Ma old. Although *A. koninckii* co-occurs with a diverse fauna of trilobites and other shelly benthos, analysis of overall shape variation does not reveal greater variance in *A. koninckii* than in other co-occurrent trilobites, despite the fact that the other trilobites have constant numbers of trunk segments in maturity. The number of thoracic segments in the mature (holaspid/epimorphic) phase was apparently determined early in ontogeny, rather than at the point of transition between the anamorphic and epimorphic phases. Hence in *A. koninckii* the growth of individual sclerites was apparently adjusted on the basis of the final segment number, so as to achieve a particular overall target shape. This result is consistent with the fact that growth in the juvenile (meraspid/anamorphic) phase was targeted in terms of both size and shape. Dense, near monospecific assemblages on individual bedding horizons raise the possibility that *A. koninckii* populations “bloomed”, perhaps during periods of reduced oxygen availability. Particular blooms were not characterized by specific numbers of thoracic segments, as variation in mature segment number occurred with individual bedding plane assemblages. The variability in segment numbers in *A. koninckii* contrasts with the constancy of segment number in the co-occurrent *Planiscutellum planum*, which has a strongly heteronomous trunk.

10: 8:15 AM-8:30 AM
Presenter: HONG, PAUL S.

TESTING THE DEVELOPMENTAL DYNAMICS OF *AULACOPLEURA KONINCKII* USING A SELECT DATASET

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Although excellently preserved, much of the articulated material of *Aulacopleura koninckii* from Lodenice has suffered minor sclerite rotation and cracking, and rare specimens show minor shear. To test whether preservation has influenced prior results we have constructed a new dataset restricted only to specimens passing stringent quality controls. This new dataset, which is of comparable size to the previous one, shows smaller variance in the shapes of juvenile and mature morphs and in the sizes of juvenile morphs. This result suggests that the new dataset has eliminated significant preservation-related variation. We confirm the pattern of conformity to Dyar's Rule reported previously, and show that juvenile growth was targeted in both size and shape. New data also supports our prior interpretation that final thoracic segment number was determined early, rather than late, in ontogeny. Initial results suggest that growth of the mature cranidium was essentially isometric, with slight but significant differences in cranidial shape between those mature morphs with 19 and 21 thoracic segments respectively. About 10% of the mature specimens in our new dataset show incompletely released thoracic segments, but this condition is rare among juveniles. This pattern could suggest that individuals intermittently released segments during the mature growth phase, but the sample showed no significant tendency for segment number to increase during epimorphosis. Individual trunk segments were released into the thorax at relatively short lengths compared to preceding segments, and took several molts to acquire mature proportions. Our initial results confirm that the size and sclerite shape in A. koninckii was controlled precisely, but that variation in the number of mature thoracic segments was nonetheless common. Variation in segment number was perhaps an adaptive response to conditions of variable benthic oxygen availability.

10: 8:30 AM-8:45 AM
Presenter: GERBER, SYLVAIN

MODULARITY AND DISSOCIATED EVOLUTIONARY DEVELOPMENTAL CHANGES: THE GENUS *ZACANTHOPSIS* (TRILOBITA, CORYNEXOCHIDA) AS A CASE STUDY.

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Unraveling the multiple processes that structure morphospace occupation and drive large-scale morphological trends is a central task in evolutionary paleobiology. In the quest for the proper identification of these processes, a careful consideration and characterization of the ontogenies of taxa is required to obtain a better understanding of the functional and developmental constraints that shape morphological evolution in a given clade. Recent or revisited concepts in evolutionary developmental biology and their fruitful incorporation in paleobiology have opened new avenues for investigating the role of development in a paleontological context. Modularity is such a concept. Recent attention has been paid to both conceptual refinement and methodological improvement, but the idea itself already formed the core of heterochronic studies in the paleontological literature. The view of organisms as being composed of evolutionarily dissociable parts is indeed a longstanding idea and it led to the notions of global vs. local heterochrony, and mosaic (or dissociated) heterochrony. Each module has its own semi-independant ontogeny and can undergo specific ontogenetic changes from ancestor to descendant. Here, we analyze the ontogeny of two trilobite species belonging to the genus *Zacanthopsis*. Previous studies of the cranidial ontogeny emphasized the complex and polyphasic growth of these species, as well as the divergence of their ontogenetic trajectories in shape space, thus rejecting the hypothesis of global heterochrony. We investigate further the ontogenies of these related species with a detailed developmental exploration of the morphological and allometric subspaces associated with each module of the cranidium. Detecting parcellated or localized evolutionary developmental changes could be an efficient way to detect developmental modules in fossil taxa for which no a priori developmental hypothesis can be confidently advanced.

10: 8:45 AM-9:00 AM
Presenter: WEBSTER, MARK

TESTING HYPOTHESES OF DEVELOPMENTAL CONSTRAINTS ON MACROEVOLUTIONARY DIVERSIFICATION: STUDYING MODULARITY OF ANCIENT DEVELOPMENTAL SYSTEMS

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Theory and empirical studies of extant organisms have shown that phenotypic modularity (the propensity for parts of the phenotype to vary independently) is determined in part by developmental modules (internally coherent, developmentally autonomous regions). Because

trait independence influences evolvability, it has been suggested that changes in the structure of developmental modules (particularly those made coherent by direct interactions among developmental pathways) might have macroevolutionary significance. However, lack of empirical data from fossil taxa renders the validity of this claim uncertain. Developmental modules in extant species are revealed by the structure of fluctuating asymmetry (FA; random deviations from bilateral symmetry) across the phenotype, because correlated FA requires direct interactions between pathways. This involves decomposition of shape variance into between-side and among-individual components using a modified two-factor, mixed model ANOVA. This method has recently been applied for the first time to a fossil species (a Cambrian olenelloid trilobite). A significant correlation between FA structure and among-individual variation suggests that phenotypic integration was structured by direct interactions among developmental pathways in this species. Of numerous explanatory hypotheses tested, one proposing that developmental modularity was organized by Hox gene expression domains found strongest support. Demonstration that such developmental information can be extracted from fossils encourages comparative studies of developmental systems through deep time. Here we present the initial findings of a project studying the structure of modularity of agnostine trilobites. Initially high taxonomic and morphologic diversification rates were not sustained throughout agnostine history. By applying the above methods to Cambrian through Ordovician members of this clade it is possible to test whether long-term change in developmental modularity structure occurred, and whether the nature of any such change (in terms of polarity and traits affected) is consistent with hypotheses that agnostine diversification may have been directed or constrained by intrinsic properties of their developmental systems.

10: 9:00 AM-9:15 AM
Presenter: PARK, TAE-YOON

DEVELOPMENT OF TWO FURONGIAN (LATE CAMBRIAN) TRILOBITES AND POLYPHYLETIC EVOLUTION OF VENTRAL MEDIAN SUTURE

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The Order Asaphida was proposed to accommodate some Cambrian and Ordovician trilobite clades which are characterized by the possession of ventral median suture. The concept of the Asaphida has stood the test of time for the past twenty years and has been increasingly employed in trilobite classification, although there have been doubts on the monophyletic origin of the ventral median suture. Here we show polyphyletic evolution of ventral median suture based on the ontogeny of two Furongian trilobites from the Hwajeol Formation, Korea: the tsinaniid trilobite, *Tsinania canens*, and the ptychaspidid trilobite, *Asioptychaspis*

subglobosa. Tsinaniidae had been a family of the Order Corynexochida, but was recently suggested to belong to the Order Asaphida, while Ptychaspididae has been regarded as a member of the Asaphida and was inferred to possess the globular larva, termed asaphoid protaspis. The protaspid morphology of *T. canens*, however, reveals that the Tsinaniidae should be retained in the Corynexochida. Mature specimens of *T. canens* possessed a ventral median suture formed by the loss of rostral plate during development, displaying that the ventral median suture evolved within the Corynexochida. *Asioptychaspis subglobosa* has a flat and adult-like protaspis, hence not asaphoid protaspis. Free cheeks of *A. subglobosa* are fused in early developmental stage, but became split to form a ventral median suture in later development. This mode of formation of ventral median suture differs from the conventional view on the origin of ventral median suture and fused free cheeks in which a ventral median suture formed by the progressive reduction of rostral plate during evolution and the fused free cheek is a derived condition. In conclusion, this study demonstrates that the ventral median suture could have evolved polyphyletically, and therefore the current concept of the Order Asaphida should be emended.

10: 9:15 AM-9:30 AM
Presenter: MAAS, ANDREAS

ONTOGENETIC DATA FROM FOSSILS

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Individuals of a species may differ from each other significantly depending on the developmental age of the individuals. While zoologists can at best follow up the life cycle of species, paleontologists have only access to specific semaphoronts, i.e. individuals at a specific time spot of their life span, of a species. Since ontogenetic data and the entire process of ontogeny can be used for phylogeny reconstructions, it is of value to search for ontogenetic data also in the fossil record. Yet there are only few examples, in which ontogeny of fossil species could be studied more extensively, e.g. for some trilobites. Of significance is the crustacean *Rehbachiella kinnekullensis*, a branchiopod known from Cambrian 'Orsten' material preserved in 3D. Of this species no less than 25 successive stages, thus semaphoronts, could be distinguished morphologically. The latest known stage is considered to be still immature, so we have to expect even more stages until reaching adulthood. Another example from the same 'Orsten' material and also preserved in 3D is the maxillopodan crustacean *Bredocaris admirabilis*, from which we know five metanaupliar stages and, other than in the case of *R. kinnekullensis*, most likely also the adult. Particularly the specific delay in limb development

during ontogeny of *B. admirabilis* helped assigning this species to the thecostracan lineage within the Maxillopoda. An example of crustaceans preserved in a compressed state are adult specimens of the stomatopod species *Sculda pennata* from the Jurassic, to which we could affiliate a series of younger semaphoronts recently, providing partial insight of the ontogeny of this species. In many cases, however, the fossil record provides us with only very few or even only one immature or possibly larval specimen, e.g. in the case of the Cambrian chelicerate *Cambropycnogon klausmuelleri* or an early larva of the nemathelminth species *Shergoldana australiensis*.

10: 9:30 AM-9:45 AM
Presenter: HAUG, JOACHIM T.

ONTOGENY, PHYLOGENY, HETEROCHRONY AND THE FOSSIL RECORD OF ARTHROPODA

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Ontogenetic information ('4D data') contributes to phylogenetics, as it provides a significant amount of new characters. These may be larval characters absent in the adult or process characters, i.e. giving answers to when certain structures appear during ontogeny and how they change during development. Especially for taxa with aberrant adult morphologies the inclusion of ontogenetic data is simply necessary for plausible systematic placements. Additionally, ontogenetic information mapped onto a phylogram is the only suitable way to identify heterochronic events. Heterochrony is cited in many textbooks as one of the major driving forces of evolution. Thus, detection of heterochronic events can aid as a sound basis for understanding the evolutionary history of a group permitting to reconstruct plausible evolutionary scenarios. While molecular developmental biology has gained more and more attention in the recent years, the importance of including developmental information from fossil species has often remained underestimated. It seem especially to have been neglected that only information from fossils providing developmental information is capable of reconstructing developmental patterns that are not represented in Recent species. The major source of developmental information for fossil arthropods is the 'Orsten'-type-preservation. These minute but uncompressed fossils with preservation of structures in even finest detail are often represented by a number of developmental stages. This allowed the reconstruction of sometimes long successive instar sequences. The extraordinary mode of preservation of such fossils enabled us to follow up the morphogenetic changes of many features, such as eyes, limbs, or setal patterns, throughout the whole developmental sequence. Taken the early evolution of Crustacea (below the evolutionary level of Eucrustacea) as an example, these 'Orsten' fossils aided in the identification of several heterochronic events. Taking their high

age (Cambrian) into account, 'Orsten' fossils provide us with an exceptional insight deeply back into the history of arthropod development and evolution.

10: 9:45 AM-10:00 AM
Presenter: HUNT, GENE

CELLS ON SHELLS: ONTOGENY, VARIABILITY AND EVOLUTION OF OSTRACODE EPIDERMAL CELLS

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Histological research has revealed that the skeletal mesh of reticulate ostracodes can reflect the arrangement of underlying epidermal cells. Such taxa offer the rare opportunity of observing cellular morphology in fossil lineages. Previous research in *Poseidonamicus* has shown that individual cells in the postero-central region of the carapace can be readily homologized across this genus. Moreover, the number of cell-reflecting compartments increases over ontogeny, and it is possible to infer the sequence of specific cell divisions that result in the adult arrangement of epidermal cells. Here, we document this developmental system in *Poseidonamicus*, and assess variation in its modal sequence of cell divisions. Variants in the typical developmental sequence can be detected as aberrant patterns of cell arrangement; in some cases the specific developmental event causing the anomaly can be pinpointed (e.g., an extra cell division in an identified cell). In this study, we assessed the cell division arrangement in over two thousand *Poseidonamicus* specimens, and evaluated these data in the context of the ontogeny and phylogeny of this genus. Results thus far indicate that (1) evolutionary changes in the sequence of cell division are infrequent despite the commonness of individuals with aberrant cell patterns (~10%); (2) variability in cell arrangement is structured, with anatomical and ontogenetic gradients in variation; (3) the most common specific cell variant seems to be heritable and of reduced fitness relative to the modal cell arrangement. These patterns are consistent with an evolutionary dynamic in which phenotypic variation is structured by developmental processes, the imprint of which is detectable even after variants are sorted by natural selection and drift.

10: 10:30 AM-10:45 AM
Presenter: CHIPMAN, ARIEL D.

THE ORIGIN OF SEGMENTED BODY PLANS - WHAT ARE WE LOOKING FOR?

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Recent research in comparative embryology of segmented organisms, especially arthropods, has brought us closer to reconstructing the ancestral condition of the segment generation process. While it is still hotly debated whether the protostome - deuterostome ancestor (PDA) was segmented, there is no doubt that the common ancestor of each of the segmented phyla (arthropods, annelids and chordates) was segmented. My talk will initially focus on the reconstruction of the segmented arthropod ancestor, based mostly on data from centipede and crayfish development. Segments in this ancestor were generated sequentially from a posterior growth zone, with a combination of rearrangement of existing cells and the generation of new cells through cell division. The repeated pattern was generated at the molecular level through the activity of the Notch signaling pathway, and then translated into a morphologically repeated pattern. I will end by briefly discussing what we know and what we don't know about other phyla, and by suggesting what the fossil record might uncover that will help in understanding the evolution of segmentation

10: 10:45 AM-11:00 AM
Presenter: COATES, MICHAEL I.

FOSSILS, PHYLOGENY AND MODELS OF DEVELOPMENTAL EVOLUTION

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In general, hypotheses about the evolution of organismal development have been assembled from comparative (or other) studies of data from developmental biology. Research programs and conference themes have centered on, and asked questions about, the developmental basis of evolutionary change. The diversity of developmental data is arguably the most striking novelty in evolutionary biology over the past decade. However, it is worth flipping this approach around, and asking about the evolutionary basis of (inferred) developmental change. This is where fossils and phylogeny fit into the broader picture. Paleontology and phylogeny provide the necessary basis for hypotheses about large-scale changes in evolutionary developmental biology. In notable instances, fossils have been used in micro-evolutionary developmental studies too. The present talk will focus on uses of fossils as tests of developmental evolutionary scenarios. Two contrasting examples will be outlined: the evolution of vertebrate paired limbs and fins, and the link between whole genome duplications and dramatic evolutionary radiation of teleost fishes. In the first example, the set of early tetrapod fins and limbs is rich (for a fossil vertebrate dataset), and the range of anatomical patterns and character combinations extends far beyond those known from living examples. Inferred patterns of developmental bias or constraint can be examined, instances of homoplasy revealed, and sequences of character change, and by implication developmental

change, generated and tested as phylogenies are checked and re-shaped. In the second example, the advent of genomics has highlighted fundamental questions about the link between genomic evolution and phenotypic diversity. Ray-finned fish phylogeny, explored using a combination of fossil and molecular data, provides a valuable example in which the estimated position (in phylogeny) of a whole genome duplication event can be compared with evidence of correlated signal in the broad pattern of actinopterygian evolution.

10: 11:00 AM-11:15 AM
Presenter: THEWISSEN, J. G. M.

EVOLUTIONARY ASPECTS OF CETACEAN DEVELOPMENT

THEWISSEN, J. G. M., Department of Anatomy and Neurobiology, Northeastern Ohio Universities College of Medicine, Rootstown, OH, 44272, United States, thewisse@neoucom.edu; ARMFIELD, BROOKE, Anatomy and Neurobiology, Northeastern Ohio Universities College of Medicine, Rootstown, Ohio 44272, U.S.A.; COOPER, L. NOELLE, Anatomy and Neurobiology, Northeastern Ohio Universities College of Medicine, Rootstown, Ohio 44272, U.S.A.; MORAN, MEGHAN, Anatomy and Neurobiology, Northeastern Ohio Universities College of Medicine, Rootstown, Ohio 44272, U.S.A.

Ontogenetic studies of marine mammals are of great interest for evolutionary biologists because they elucidate stages of body plan formation. In cetaceans (whales, dolphins, and porpoises), some developmental constraints that normally occur in mammals have been released, and this has led to strongly derived morphologies. For example, cetaceans commonly have increased numbers of teeth, phalanges, and vertebrae and less regional heterogeneity in these organs compared to terrestrial vertebrates. In addition, cetaceans have lost such characteristic mammalian features as a hair coat and precise dental occlusion. We investigate the embryology and the developmental control of several cetacean organ systems: forelimb, hindlimb, fluke, vertebral column, and dentition. Development in these organ systems in model animals is well understood, and we compare developmental control in these model animals to that of cetaceans. Our ultimate goal is to test hypotheses regarding the effect that minor changes in expression patterns of toolkit genes have on macroevolution. The organ systems that we study are well preserved in fossils. This adds another dimension to our study, and allows us to integrate patterns of evolution and development. Evolutionary hypotheses inspired by developmental data can thus be tested against what actually happened in evolution as documented by series of intermediate fossils.

10: 11:15 AM-11:30 AM
Presenter: DONOGHUE, PHILIP C J

FOSSILIZED EMBRYOS AND EARLY METAZOAN EVOLUTION

DONOGHUE, PHILIP C. J., Department of Earth Sciences, University of Bristol, Bristol, Avon, BS8 1RJ, United Kingdom, phil.donoghue@bristol.ac.uk; BENGTSON, STEFAN, Department of Palaeozoology, Swedish Museum of Natural History, Stockholm, Sweden, SE-104 05; RAFF, RUDOLF, A., Department of Biology, Indiana University, Bloomington, IN, 47401 USA; XIAO, SHUHAI, Department of Geology, Virginia Tech, Blacksburg, Virginia, 24061 USA

The discovery of fossilised embryos contemporaneous with the emergence of metazoan diversity provides a wholly new perspective on the embryology of early animals. More than a decade has passed since the first discovery of fossilised embryos, and in the intervening years numerous localities, horizons and types of embryo have been recovered. The growing database appears so far to be dominated by the embryos of direct developing organisms. To some, this provides the final piece of evidence to reject the classical view that metazoans evolved from ancestors that underwent maximal indirect development, achieving adulthood only after undergoing a catastrophic metamorphosis from an earlier larval stage. However, the fossil record of embryos, like that of other groups, should not be read literally. The fossil record of embryos is very obviously biased in its stratigraphic extent. The implications from decay experiments are stark: under conditions that promote embryo preservation embryos can undergo aberrant patterns of cleavage, blastomeres disaggregate, inflate and reorganise into unrepresentative arrangements; blastocoels collapse. Perhaps most worrisome is the observation that even under optimal conditions the primary larvae of indirect developers decay to amorphous organic matter within a matter of hours. The message from such experiments appears to be that the record should be interpreted with great caution. At best, the fossil record of embryology provides us with a direct insight into certain stages of development of certain organisms and biases inherent in the record may be so limiting that it may never be possible to test directly such overarching hypotheses as the relationship between life history evolution and the divergence of metazoan phyla. The recognition of such biases is sobering but it does nothing to diminish the significance of the palaeoembryological record which remains our only direct insight into developmental evolution during the emergence of metazoan phyla.

10: 11:30 AM-11:45 AM
Presenter: BENGTSON, STEFAN

VIRTUAL DISSECTION OF AN EARLY CNIDARIAN EMBRYO

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The Lower Cambrian Manykay Formation at the Bol'shaya Kuonamka River in northern Sakha (Yakutia) contains phosphatized embryos together with the first assemblage of skeletal fossils (anabaritids). An embryo previously reported by us (Kouchinsky et al. 1999: Geology 27) is about half a millimeter in diameter and shows a surface feature reminiscent of the double tentacle circles of actinula larvae of some modern hydrozoan cnidarians, including the free-living Actinulida. Synchrotron-radiation X-ray tomographic microscopy (srXTM) of this specimen reveals its internal structure down to micrometer resolution. The tentacles turn out to be long and well-developed, and partly folded within the enveloping egg membrane. Whereas the basal parts of the tentacles have a smooth epithelium, the epithelium of the middle and distal parts are studded with rounded bodies of low X-ray attenuation, some 4-5 µm in diameter. Because of their distribution, size, shape and distinct preservation, these bodies may be interpreted as cnidocysts. Although the further developmental history of this animal is not known, the formation within the egg membrane of what resembles a fully developed actinulid suggests that the Kuonamka embryo represents another case of direct development among early fossil animals.

10: 11:45 AM-12:00 PM
Presenter: RAFF, RUDOLF A.

FOSSILIZATION OF EMBRYOS AS A BIOLOGICAL PROCESS

RAFF, RUDOLF A., Biology, Indiana University, 909 S. Highland Ave., Bloomington, IN, 47401, United States, raffr@indiana.edu; RAFF, ELIZABETH C., Department of Biology, Indiana University, Myers Hall, 915 East Third Street, Bloomington, IN, USA, 47405

Recent embryos and larvae undergo rapid evolution, and such evolution may have had a role in rapid divergences in early metazoans. Fossils of organic remains of soft-bodied organisms and even embryos provide vital information into understanding the early animals, their life histories, and their modes of development. Microscopic investigation of mineralized embryos replaced by calcium phosphate dating from Late Proterozoic and Cambrian deposits show exquisite cellular and sub-cellular structure. However, the means by which embryos were fossilized has not been understood. Studies on modern embryos similar in size to fossil embryos offer a window to development in early metazoans, and to possible taphonomic biases. Experimental taphonomy requires approaches that examine processes at biochemical, cellular and microbial levels that operate in biological time scales. We have found that early steps of fossilization are the consequence first of cellular processes operating in a newly killed marine embryo and microbial processes that follow. The rapid self-destruction of embryos can be blocked by anaerobic or highly reducing conditions analogous to those that occur in the sea. Microbial processes involve the rapid colonization of autolysis-blocked embryos by environmental bacteria that produce biofilms. These form pseudomorphs, replicas of cellular structures that the biofilm has consumed and replaced. It is possible to obtain rapid microbial catalysed mineralization under a number of experimental conditions by controlling aerobic vs.

anaerobic conditions, pH and specific ion concentrations. DNA tools allow rapid identification of taphonomic microbial populations, and the mapping the locations of individual microbial species within taphonomic biofilms. In addition, we are investigating the production of microbiologically defined taphonomic biofilms that will open new investigations to genetic understanding of the relevant microbial processes under various environmental conditions.

10: 1:30 PM-1:45 PM
Presenter: BOYER, JAMES S.

MODELING THE DEVELOPMENT OF EARLY LAND PLANTS

BOYER, JAMES S., Education, The New York Botanical Garden, 2900 Kazimiroff Blvd, Bronx, NY, 10458, United States, jboyer@nybg.org; STEIN, WILLIAM E., Biological Sciences, State University of New York, Binghamton, NY 13902-6000

The Silurian-Devonian fossil record provides excellent information about the form and origin of the basic body plan in early vascular plants. However, serial plant development makes point-for-point determination of homology very difficult. A methodology that faithfully addresses the developmental processes underlying plant form is therefore crucial. Fortunately, living and fossil plants provide interpretable relationships between development and position in the plant. To study this relationship, the morphologies of two basal euphyllophytes, extant *Psilotum nudum* and the Lower Devonian *Psilophyton dapsile* from Gaspé, Quebec, were examined to obtain quantitative information about aerial shoot morphogenesis. Time-based growth studies of *Psilotum* revealed aerial shoots that elongate using a combination of serial apical accretion and subapical extension. This pattern is mostly in line with observations from other living plants but contrasts sharply with classical ideas of primitive plant form based on Zimmermann's Telome Theory. Comparable morphometric information was collected from *Psilophyton dapsile* following spatially defined developmental trajectories. Combining results, a computer model was constructed simulating primitive plant development following a simple set of rules including both apical and sub-apical processes plus aspects of an energy budget. Some morphometric information, primarily involving boundary conditions on size and developmental rate, was used to set model parameters expected for *Psilophyton*. Model output values specifying morphology were then compared with detailed morphometric information on developmental trajectories. A match between the model's output and the fossil morphology provides us with a viable hypothesis for development and its relationship to mature form in *Psilophyton dapsile*. From this, we suspect that differences between multiple Devonian fossil species of *Psilophyton* can be addressed using a very similar developmental framework. In addition, similar approaches, modifying or extending telomic theory, should allow assessment of homology between multiple groups with probable Devonian origin, including horsetails and ferns.

10: 1:45 PM-2:00 PM
Presenter: JACOBS, DAVID K.

TOWARD A NEUTRAL THEORY OF MORPHOLOGY (DIVERSITY/DISPARITY) IN THE PALEOBIOLOGIC STUDY OF DEVELOPMENT AND ECOLOGY

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Van Valen stated that evolution is “the control of development by ecology.” Indeed, paleobiologists have claimed that ranks in the Linnaean hierarchy function as proxies for species diversity and disparity, revealing how development or ecology shape evolution. While arguments about ecological and developmental influences on evolution continue, how characters are considered has changed as rank-free phylogenetic and character-state studies have increased at the expense of Linnaean taxa. To understand the implications of these changes, one must assess how character classes linked to development and ecology map onto changing taxonomic practices and through canonical geological events, such as the Cambrian, Ordovician and Post-Permian radiations. That taxon-based studies and character-state studies have often come to similar conclusions leads to two obvious possibilities, either Linnaean taxa are good proxies for diversity and disparity, or both methods fail to detect biases inherent in the fossil record. To assess impacts of development or ecology on disparity, null models that express an expected linkage between diversity and disparity are needed. Analogy to neutral evolutionary models of non-recombining allelic sequences in populations may provide an appropriate set of nulls for character-based disparity analyses. In such an application, the character state is the smallest increment of disparity and taxonomic apomorphy. Thus, morphologic diversity and disparity both accumulate through a process analogous to point mutation of sequences, and are lost to extinction in a manner analogous to coalescence or drift. The expected relationship (mismatch distribution) between diversity and disparity would be inferred from an analogue of the preceding trajectory of population size - the diversity history of the group in a paleontological context. We approach these issues with brachiopod and arthropod examples. Arthropods are particularly interesting, as changing taxonomic tradition has altered interpretations of the Cambrian radiation, and one can clearly articulate developmental genetic constraints on arthropod character evolution.

10: 2:00 PM-2:15 PM
Presenter: MITCHELL, CHARLES E.

GRAPTOLITE ASTOGENY: CONTROLLING URBAN SPRAWL IN THE PLANKTON

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The graptolite colonial edifice (rhabdosome) was a modular built structure constructed by the coordinated activity of a clone of discrete zooids. Phylogenetic analysis suggests that graptolite zooids, like pterobranchs, constructed the thecae externally to their body via the mortaring application of their cephalic disc. Thecae, therefore, were domiciles not skeletons, and record zooid behavior, perhaps more so even than they reflect zooid anatomy. Pelagic graptoloid graptolites are entirely extinct but we can make some reasonable inferences about their anatomy and ecology from the development of their colonies. Graptoloids constructed rhabdosomes with great precision. Rhabdosomes exhibit levels of variance in thecal shape and size, as well as gradients in these features, that are comparable to the adaptively constrained skeletal features of bones, teeth, and shells. Growth abnormalities, particularly patterns of repair following damage to thecae, demonstrate that construction of this complex of domiciles and feeding modules was controlled by the interaction of zooids in response to genetically coded information that specified the architecture of thecae and local positional cues mediated by the presence of neighbors and the expected adjacent structures. Abnormalities exhibit a mix of stereotypic response and pragmatic lability in behavior. Graptolite development looks remarkably like organismal anatomy rather than an assemblage of individual behaviors. Graptolite evolution also displays the effects of developmental constraints. Primitively, graptoloid colonies were multibranched forms that produced branch dichotomies at their growing tips by a sequence of specialized features of three successive thecae. Several lineages independently lost this dichotomizing (“isograptid”) structure and their descendent species were unable to produce primary multibranched rhabdosomes. Instead, multiple lineages subsequently converged on mulitbranched forms by forming secondary branches (cladia) that arose from individual thecal apertures in much the same way that replacement thecae form to heal damaged branches.

10: 2:15 PM-2:30 PM
Presenter: SHAPERO, JEREMY L.

MORPHOMETRIC ANALYSIS OF GRAPTOLITE ASTOGENY FOR DEVELOPMENTAL AND EVOLUTIONARY TRENDS

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Graptolites were a diverse clade of organisms whose colonies varied in size, shape, morphology, and more. Graptolites constructed colonies composed of a series of iterated modules (thecae) that housed the constituent zooids. Based on a series of landmarks placed around the sicula (domicile of the founding individual) and across a succession of pairs of thecae, we used geometric morphometrics to assess changes in thecal shape during the astogeny of the Upper Ordovician diplograptids *Geniculograptus pygmaeus*, *Geniculograptus typicalis*, *Amplexograptus latus*, and the more distantly related *Normalograptus kukersianus*, all of which have broadly similar "climacograptid" thecal form. This approach allows us to describe colonies in terms of the unique features of their proximal development, their basic thecal form, and an astogenetic gradient in thecal form. We are then able to compare the astogenies of these species quantitatively in terms of the differences in these components of form. We suggest that this dynamic description can provide an effective and efficient means to assess colony form and glean information about the contribution of astogenetic heterochrony to transformation of colony form during graptolite evolution. Differences in astogenetic shape vectors may provide an additional means by which to recognize convergence in colony shape and so to independently test alternative cladistic reconstructions of graptolite phylogeny.

10: 2:30 PM-2:45 PM
Presenter: HAGEMAN, STEVEN J.

FOSSIL MODULAR ORGANISMS (COLONIAL INVERTEBRATES) AS MODELS TO STUDY EVOLUTIONARY RATES IN DEVELOPMENTAL REGULATORY GENES

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Although relatively little is known about the composition and variation of homeobox regulatory genes within groups of modular organisms (e.g. bryozoans, cnidarians ascidians), examples of these genes have been identified and used convincingly in establishing phylogenetic relationships among major, problematic clades. Homeobox genes presumably function to control the ontogenetic development of individuals (modules) in an integrated colony in a manner similar to homeotic gene regulated developmental mechanisms in a solitary organisms. Many colonial organisms have polymorphic expression of individual modules within a colony, resulting in morphologically discrete, functionally specialized individuals. Homologous structures can be found among polymorphic modules, but morphologic gradients among types of polymorphs are not common. The genetic composition

of all modules in a colony is identical. Evidence exists for external, environmental control on polymorph development in some cases, but in many other cases polymorph generation and distribution is controlled by colony age or generational position within the colony. Controlling factors are on polymorph distribution are unclear in many cases.This idea that developmental controls among modules are under colony wide control is not novel, however the potential to systematically test variation in homeotically controlled traits with a rich fossil record has not been explored. In each major skeletalized bryozoan clade (cheilostomes and stenolaemates) primitive, stratigraphically lower taxa have no polymorphs and their occurrence and complexity increase with time. By simultaneously documenting the evolution of polymorphic modules in a clade and detailed characterization of differences in the development of genetically identical modules (colony), the potential exists to lay out major evolutionary questions that can be addressed as the identity of the controlling regulatory genes are identified in extant forms.

10: 2:45 PM-3:00 PM
Presenter: LATHAM, MICHAEL L.

PATTERNS OF DEVELOPMENT IN THE ISOROPHIDA: IMPLICATIONS FOR HOMOLOGY OF THE PERISTOMIAL COVER PLATE SYSTEM IN EDRIOASTEROID ECHINODERMS

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For over 70 years, the peristomial cover plate pattern of edrioasteroids (Echinodermata) has been used as a tool of taxonomic classification. Bell (1976) organized this pattern into a scheme of primary oral cover plates (POO), lateral bifurcation plates (LBPP), shared cover plates (SCPP) and secondary oral cover plates (OO'). Plate types in this system were assumed to be homologous between taxa, particularly in isorophid edrioasteroids, but exact homology between individual plates remained unknown. To better understand the elemental homology, the timing and fate of each oral cover plate was examined within a developmental framework. This is possible because in situ populations of specimens killed in obrution events preserve individuals at nearly every developmental phase. This recent work on the ontogeny of several isorophid taxa has supported the homology of the POO and LBPP, but has revealed a more complex picture for the development and evolution of other elements in the cover plate series. The POO and LBPP are the first plates to develop. Next, one anterior pair and two posterior pairs of SCPP are inserted between the POO and LBPP proximally to distally. No new SCPP are added in this way after onset of expression of the distal ambulacra. New SCPP are added as OO' between the proximal SCP and POO until the adult number of SCPP is reached. This pattern suggests that expression of the first three pairs of SCPP is strongly conserved in

edrioasteroid evolution. Indeed, examination of the peristomial cover plate patterns of basal isorophids and even edrioasterids such as *Edriophus* lends support to this observation. It is tentatively proposed that this represents the plesiomorphic condition for edrioasterid and isorophid edrioasteroids.

10: 3:00 PM-3:15 PM
Presenter: PARSLEY, RONALD L.

ONTOGENY AND FUNCTIONAL MORPHOLOGY IN LOWER AND MIDDLE CAMBRIAN GOGIID EOCRINOIDS (ECHINODERMATA) FROM GUIZHOU PROVINCE, CHINA

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Numerous gogiid eocrinoid specimens representing three genera from the outer shelf/upper slope of the Jiangnan Slope Belt on the eastern margin of the South China (Yangtze) Platform, Guizhou Province, China are preserved as external molds that mirror surficial detail with excellent fidelity and clearly document complete ontogenetic sequences. Specimens are from the Lower Cambrian Balang Formation (*Guizhoueocrinus*, ca. 1000+ specimens) and from the basal Middle Cambrian Kaili Formation [Kaili Biota] (*Sinoeocrinus*, 1500+ specimens and *Globoeocrinus*, 3500+ specimens). Ontogenetic development is measured in reference to thecal height (TH =) but the metric is only roughly equivalent in developmental stages between genera. Earliest juveniles are without sutural pores and begin growth with a 1-0-1 or 2-0-2 ambulacral system; later juveniles develop a 2-1-2 or five brachiole system. In early mature stages all three genera double the number of brachioles to a ten brachiole system but maintain the 2-1-2 pattern. Late mature specimens of *Sinoeocrinus* add another set of brachioles (Σ=15) but maintain the same 2-1-2 pattern. Lower to Middle Cambrian genera develop reduced numbers of thecal plates in ontogeny (paedomorphic development) but emplacement of sutural pores and their development is accelerated (peramorphic development). Pore emplacement starts under the ambulacral plates in juveniles followed by a narrow band just above the thecal-stalk junction in older juveniles. Overall emplacement of pores occurs in late juvenile to early mature specimens. Pores originate as circular openings between two plates and with plate growth become increasingly oval with wall-like rims. In the Middle Cambrian genera sutural pores enlarge and through resorption and redeposition (older mature specimens), become triangular and are formed by three not two plates. Stalks in Middle Cambrian genera retain juvenile (paedomorphic) characters and circlets of small platelets would seem to provide the pathway to holomeric stalks common in younger species.

10: 3:15 PM-3:30 PM
Presenter: WATERS, JOHNNY A.

FOSSILIZED LARVAL DEVELOPMENT IN BLASTOIDS

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Although the study of developmental paleobiology is an emerging field in paleontology, the recognition of larval blastoids has a long history. Smith (1906) is an early study of juvenile blastoids. Smith's smallest specimen of *Pentremites conoideus* measures 0.82 mm in length and is a conical calyx composed of 3 basals and 5 radials. Smith's comment that the specimen "had ...just emerged from the free-swimming larval stage, grown a shell, and assumed a sedentary mode of life" is similar to interpretations 100 years later. Cronies and Geis (1940) presented an intriguing study of very small blastoids illustrating what they interpreted as larval stages of development from a small spherical embryo-like structure through a stage that resembles cystidean larvae of modern crinoids. Sevastopulo (2005) reinterpreted the microcrinoid genus *Passalocrinus* as a juvenile blastoid. Perhaps the most important specimen in the early ontogeny of blastoids was recently recovered from an Upper Carboniferous black shale exposed near Xinxu, China. The specimen is a conical theca composed of basals and radials. The oral surface lacks ambulacra but has three food grooves leading to brachiolar attachment pits in each ray. Available material suggests a two stage larval history of blastoids (cystidean and pentacrinoid) similar to modern crinoids. No information is available on the presence of doliolariae larval or auricularia larval stages in the material currently at hand. Passalocrinus represents a cystidean stage of development for blastoids and the Chinese specimen represents a pentacrinoid stage of development. The onset of growth line accretion is associated with the transition from a non-feeding cystidean stage to a feeding pentacrinoid stage. In blastoids,the transition from pentacrinoid to adult stage would be marked by the development of true ambulacra and the insertion of deltoid plates in the theca.

10: 3:30 PM-3:45 PM
Presenter: SUMRALL, COLIN D.

USING FOSSILIZED DEVELOPMENT TO UNRAVEL THE PERISTOME OF STEMMED ECHINODERMS

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One of the greatest challenges in reconstructing the phylogeny of echinoderms is to generate an accurate and robust homology scheme for elements of the theca. Although the EAT theory is a major step forward, it is general enough in nature to be uninformative for unraveling homology on a scale necessary for phylogenetic analysis of major inclusive echinoderm clades. However, plates bordering and covering the peristome hold great promise for building suites of characters that may be useful in phylogeny reconstruction. These plates form early in

ontogeny, and show changes in the timing of formation, expression, and interplate relationships. Furthermore they are critical in patterning the bodyplan. Oral plates (interradial elements that form the peristomial border and proximal ambulacra) plesiomorphically are added in two stages, proximal elements forming the three primary ambulacra (A, shared BC, and shared DE), and lateral elements forming the bifurcation of the shared ambulacra. Some clades modify this pattern by forming all oral plates in synchronously forming pseudo-five fold symmetry, or loose the lateral orals by paedomorphic ambulacral reduction. Primary peristomial cover plates topologically lie atop the oral plates but rather than form the peristomial border, the form a protective cover. These plates show several different developmental fates. Plesiomorphically, they are somewhat differentiated from other elements in the cover plate series, but in some clades they become undifferentiated. In others, they become exceedingly large by neoteny precluding cover plate formation of the shared ambulacra. Changes in development seen in these two plate series act independently. Coronoids and the hemicosmitid *Caryocrinites* both have enlarged neotenic primary peristomial cover plates, but the former shows pseudo five fold symmetry of the oral plates whereas the latter paedomorphically looses the lateral oral plates.

Session No. 11, 8:00 AM (morning session) and 1:30 PM (afternoon session) ; Tuesday, 23 June 2009

Symposium S6. Through the End of the Cretaceous in the type locality of the Hell Creek Formation and Adjacent Areas

11: 8:15 AM-8:30 AM
Presenter: CLEMENS, WILLIAM A.

FROM *T. REX* TO ASTEROID IMPACT: EARLY STUDIES (1901-1980) OF THE HELL CREEK FORMATION IN ITS TYPE AREA.

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From discovery of dinosaurs in the valley of Hell Creek in 1901 to 1980, when the hypothesis of their demise as a consequence of an asteroid's impact was proposed, studies of the Hell Creek Formation contributed significantly to shaping paleontological and geological research. Initially, Barnum Brown led expeditions from the American Museum of Natural History focused on collection of dinosaurian skeletons for its exhibit halls, a reoccurring theme in subsequent field research. Often overlooked is his and his associates' interest in collecting and studying the paleoflora, invertebrate fauna, and vertebrates other than dinosaurs of the Hell

Creek Formation. During the 1930s, surveys of coal resources in eastern Montana and fossils collected by workers building the Fort Peck dam would significantly influence research after World War II. In the 1960s, Bruce Erickson of the Science Museum of Minnesota and Harley Garbani of the Natural History Museum of Los Angeles County came to the valley of Hell Creek in search of dinosaurs for exhibit halls. Both projects grew in unforeseen ways. Robert Sloan from the University of Minnesota, who worked with Erickson, and Leigh Van Valen from the American Museum collected small vertebrates, especially mammals, from deposits in the valley of Bug Creek and adjacent areas. They developed a hypothesis of gradual extinction of dinosaurs leading up to the Cretaceous-Paleogene (K/Pg or K/T boundary). In the early 1970s, discovery of microvertebrates in the valley of Hell Creek led to an invitation to the University of California Museum of Paleontology to join Garbani's project. Quickly research projects, including detailed mapping and sedimentological studies of the K/Pg boundary section as well as analyses of its palynological record and molluscan and vertebrate faunas, were under way. Thus, in 1980, the stage was set for the paradigm shift struck by the asteroid extinction hypothesis.

11: 8:30 AM-8:45 AM
Presenter: JOHNSON, KIRK R.

THE AGE AND DURATION OF THE HELL CREEK FORMATION AND ITS RELEVANCE AS A RECORDER OF REGIONAL AND GLOBAL EVENTS: THE EVOLVING RECORD FROM THE CEDAR CREEK ANTICLINE IN MONTANA AND THE DAKOTAS

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The Hell Creek Formation has long been known for its dinosaur-rich badlands and as the source of the best documented terminal Cretaceous biota. Interest in the K-T boundary has resulted in focus on the upper portion of the 85-110m thick formation. The Cedar Creek Anticline (CCA) is a NNW-SSE trending, 160-km, asymmetrical Laramide structure cored by Pierre Shale. Areas of good Hell Creek exposure and scientific interest around the CCA include Glendive, Iron Bluffs, the area north of Baker, and Ekalaka, Montana; Harding County, South Dakota, and the Marmarth, North Dakota area. With few extensive marker beds and badlands with elevations less than formation thickness, regional correlation has proved challenging. Despite this, a coherent age model for the formation in this area has begun to emerge. The formation is bracketed by the 65.51 ± 0.1 Ma K-T boundary and the 70.00 ± 0.45 Ma *Baculites grandis* Zone of the uppermost Pierre Shale. Age extrapolations based on the percentage of the formation composed of C29R yield an estimated duration of 1.36 Ma for the formation,

suggesting a significant basal unconformity. Ongoing paleomagnetic and U-Pb geochronologic studies can improve this resolution. Outstanding questions that remain to be resolved include: 1) the age of the base of the formation; 2) distribution of time within the formation; 3) variability of the level of theC29R-C29N contact within the formation; and 4) the presence and duration of the Hell Creek-Fox Hills unconformity. Resolution of these questions will bear on the understanding and timing of 1) the retreat of the Pierre-Fox Hills sea way; 2) the age and duration of the Lancian vertebrate fauna; 3) the age of the C29R/C29N global warming event; 4) the K-T boundary and presaging events; and 5) potential calibrations of magnetostratigraphic and astronomical cycles.

11: 8:45 AM-9:00 AM
Presenter: BUTLER, RAYMOND D.

THE NAMING AND FORMAL DESIGNATION OF THE CRETACEOUS HELL CREEK FORMATION, MONTANA

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Very few formations have received as much attention as the Hell Creek Formation. However, Brown's 1907 inaugural study of the formation did not assign a stratotype; Brown noted the beds were typically expressed in the valley of Hell Creek and nearby tributaries of the Missouri River. Current studies suggest outcrops near and on Flag Butte serve this important referential purpose. This large butte lies between Reid and East Reid Coulees (sec. 29, T. 21 N., R. 38 E.) in the middle of Brown's “type” area. Brown correctly distinguished freshwater strata of the Hell Creek as unconformable (erosional) with the underlying marine and brackish Fox Hills Formation, and conformable with overlying nondinosaur-bearing “Fort Union?” lignitic beds (Tullock Member, Fort Union Formation). Brown reported a thickness (barometric) along Hell Creek of 94.5 m, with an average of 100 m along Crooked and Gilbert Creeks (range 84.1-128.0 m). A Hell Creek thickness of 88.4 m is measured on the west face of Flag Butte. Brown's subdivided the Hell Creek into a lower continuous basal sandstone and an upper unit of alternating claystone and sandstone, which remain generally valid. However, the lower contact of the basal sandstone unit is problematic in places, and lateral changes in upper unit beds require caution in over valuing a type section as typical. For example, Brown described two relatively continuous upper unit sandstone beds at ~4.6-m thick. At Flag Butte, these steep rampart-forming beds are 8.4-m (11.9 m where stacked) and 1.6-m thick, respectively. A classic regressive-sea sequence is recognized for the marine shale (Bearpaw), overlying marine fringe and distributary channel sands (Fox Hills), and delta plain fluvial channel sands and floodbasin shales (Hell Creek). Ongoing studies suggest regional subdivision of Hell Creek units may be possible, and discriminating time within the formation a potential outcome.

11: 9:00 AM-9:15 AM
Presenter: FOWLER, DENVER W.

A SEQUENCE STRATIGRAPHIC SUBDIVISION OF THE HELL CREEK FORMATION: BEGINNINGS OF A HIGH-RESOLUTION REGIONAL CHRONOSTRATIGRAPHIC FRAMEWORK FOR THE TERMINAL CRETACEOUS

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The late Maastrichtian fluvial Hell Creek (Montana, North Dakota, South Dakota) and Lance Fms (Wyoming) are notable for their vertebrate fossils and for the KT mass extinction at or near their upper boundaries. Despite the units' similar age, past efforts at accurate correlation have met with very limited success, mainly due to problems with lithostratigraphic methodology, discontinuous outcrop, lateral discontinuity of facies, poorly constrained biostratigraphy, lack of radiometric dates, and magnetostratigraphic data of limited use. This has hindered our ability to study this important interval in earth's history. By use of terrestrial sequence stratigraphic methods, this study has subdivided the Montanan Hell Creek Fm into three, possibly four sequences. These reflect 4th order base-level cycles superimposed on the 3rd order base-level rise under which the formation was deposited. These previously unrecognized sequence boundaries are defined by three, possibly four, laterally continuous disconformities within the Hell Creek Fm of Fort Peck, Montana. The disconformities are overlain by amalgamated channel complexes, or less commonly, correlative interfluve paleosols. Disconformities were formed by pauses in the creation of accommodation space, associated with base-level stabilization or fall during 4th order cyclicity. Amalgamated channel deposits at the base of the new sequences occur in the same stratigraphic positions within the Montanan Hell Creek Fm as brackish units observed in the North Dakotan Hell Creek Fm, which are similarly indicative of 4th order base-level cyclicity. Magnetostratigraphy and new biostratigraphic data support correlation of the upper Montanan sequence with the North Dakotan Cantapeta tongue (and overlying fines) and Canadian Scollard and Frenchman Fms. Recognition of 4th order cycles in subsurface data is being used to map a regional high-resolution chronostratigraphic framework for the terminal Cretaceous. This is already being used to study evolutionary trends in vertebrates, leading up to the Cretaceous-Tertiary mass extinction.

11: 9:15 AM-9:30 AM
Presenter: LECAIN, REBECCA M.

MAGNETOSTRATIGRAPHY OF THE HELL CREEK AND LOWER FORT UNION FORMATIONS IN NORTHEAST MONTANA

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The Hell Creek and Fort Union Formations of Montana preserve an excellent fossil record of a late Cretaceous to early Paleocene continental ecosystem. The Cretaceous-Paleogene (K/Pg) boundary in this area is well preserved and includes indicators of impact and extinction. Because of this, the boundary has been extensively studied with different dating techniques to constrain its timing; however, time constraints farther away from the boundary are more limited in both formations. Where the rocks have been dated, they frequently have not been correlated to fossil finds directly, so it is difficult to determine a precise age for many of the fossils from this region. To expand upon and better understand the timing of the Hell Creek and Fort Union Formations and the biological processes recorded within them, a thorough magnetostratigraphic evaluation of a well-exposed stratigraphic section in northeast Montana has been undertaken. Preliminary results indicate that most samples exhibit stable demagnetization behavior, with coercivities of approximately 50-60 mT. Characteristic remnant magnetizations show clear magnetostratigraphic patterning, which should correlate well to the geomagnetic polarity time scale (GPTS). Localities in Montana that have been sampled for fossil studies have been mapped and correlated to the same stratigraphic section as the magnetostratigraphy, and so can be correlated directly to the GPTS. This new magnetostratigraphy will also be used to correlate to the well documented late Cretaceous to early Paleocene deposits of the San Juan Basin in New Mexico, making it possible to directly compare the composition of coeval Puercan faunas from significantly different latitudes. Understanding the age of the Hell Creek and Fort Union Formations and their sedimentation rates will also add to the growing geochronological database for this time period and help to better date fossils in correlative formations.

11: 9:30 AM-9:45 AM
Presenter: ARENS, NAN CRYSTAL

CARBON ISOTOPE STRATIGRAPHY AND SEDIMENTOLOGY OF THE HELL CREEK FORMATION IN EASTERN MONTANA: CORRELATION, CLIMATE AND EVENTS

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A nearly complete (96%) stratigraphic section was measured through the full 92 m of the Hell Creek Formation near Seven Blackfoot Coulee, approximately 40 km west of the Hell Creek type area. Sediments were described in detail and sampled at approximately 20 cm intervals for bulk organic stable carbon isotopes. Secular variation in carbon isotope values ranged from approximately -23.5‰ to -25.5‰. Three cycles of decreasing and increasing average values were recognized. Similar, but lower magnitude, variation is evident in marine sections of corresponding age, suggesting that this secular variation reflects global changes in carbon cycling, perhaps due to climate variation, input of volcanic CO2 or both. Five negative carbon isotope excursions and six positive carbon isotope excursions were recognized throughout the section. These, coupled with secular variation, can be used to correlate plant macrofossil localities worked by our team between 1997-2000.Parallel studies of the sedimentology of the section included a detailed stratigraphic log with descriptions of bedforms and sedimentary structures, analyses of sedimentary percent organic carbon content and grain size. The lowermost approximately 10 m of the formation are fluvio-deltaic facies representing an estuarine environment. The overlying 5 m are characterized by poorly sorted sediment with residual mm-scale bedding and sparse root traces. This represents the inception of floodplain development. Sediment becomes finer grained and soil development more pronounced up section to approximately 25 m above the Fox Hills-Hell Creek contact. The remainder of the formation is characterized by channel and proximal floodplain sediments alternating with distal floodplain deposits. These may represent migration of the channel across the ancient landscape or periodic avulsive intervals. The abundance of well-developed well-drained soils may explain the paucity of plant fossils from the upper portion of the Hell Creek Formation in this region.

11: 9:45 AM-10:00 AM
Presenter: HUNTER, JOHN P.

UP FROM THE ASHES: REFINING THE CRETACEOUS DISAPPEARANCE AND CONSEQUENT RAPID RECOVERY OF FAUNAS AND FLORAS IN THE EARLY PALEOCENE OF SOUTHWESTERN NORTH DAKOTA

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A consensus has emerged that an extraterrestrial impact near the Cretaceous-Paleogene (K/Pg) boundary devastated terrestrial ecosystems and caused a global mass extinction among terrestrial plants and animals. Debate continues, however, over the course and rate of recovery during the early Paleocene. Was there a protracted recovery interval, or was

recovery underway immediately post-impact? New collections of floras and vertebrate faunas from the uppermost 10 m of the Hell Creek Formation and lowermost 10 m Fort Union Formation of North Dakota provide evidence for a rapid early Paleocene recovery. Aquatic vertebrates occur continuously throughout this stratigraphic sequence, whereas dinosaurs and Paleocene mammals are only separated by a few meters thickness that includes the K/Pg, identified on new palynological criteria, within a mudstone sequence. Dinosaurs disappeared at the onset of this mudstone and the paleoenvironment that it represents, whereas Paleocene mammals and floras occur in the local environment where it ended. Seemingly, only selected Cretaceous floral and faunal assemblages were able to pass through the paleoenvironment represented by mudstones bracketing the K/Pg. Mammals occur at several localities within 10 meters above the K/Pg, starting with the Wilkening Locality at 1.33 meters above the base of the Ludlow (1.10 meters above K/Pg). The Wilkening mammals are a low diversity assemblage of known boundary-crossers with a few earliest Paleocene first appearances. Low diversity and ecological simplicity (small-bodied omnivores and insectivores) at Wilkening suggests a depauperate post-disaster fauna. The sample of mammals from the Merle's Mecca Locality, at just 9.05 meters above the K/Pg, is strikingly different, including larger and more derived species than at Wilkening. The origin of new species and the appearance of new ecological niches (as evidenced by increased body size) within the limited time between the Wilkening and Merle's Mecca mammalian faunas suggest a rapid intervening recovery.

11: 10:30 AM-10:45 AM
Presenter: DETTMAN, DAVID L.

ISOTOPE HYDROLOGY OF THE WESTERN WILLISTON BASIN, LATEST MAASTRICHTIAN

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Freshwater mollusk shells are abundant at a number of stratigraphic horizons near the Cretaceous-Tertiary (K-T) boundary in the Williston Basin of eastern Montana. Shells are dominated by Unionidae. XRD, SEM, and cathodoluminescence microscopy demonstrate that, although the prismatic layer is often altered or missing, the shells are aragonite and preserve original nacreous shell structure. Specimens were collected northwest of Jordan, Montana, (107.0W, 47.55N). Samples straddle the K-T boundary and are mostly from overbank splay deposits.The oxygen isotope ratio of unionid shell reflects the isotopic ratio of the river water. Although temperature affects shell $^{18}O/^{16}O$, its effect can be minimized with either a conservative seasonal temperature model or by taking advantage of growth biases for unionids. This allows the back-calculation of river water $^{18}O/^{16}O$. Although temporal resolution is coarse, eight rivers / time intervals over 1.7 Ma, we see little evidence for a dramatic change in the hydrology of rivers in this western portion of the Williston Basin across the K-T

boundary.The average annual oxygen isotope ratio of river water in this area ranges from 9.7 to 20.2‰ SMOW. In the latest Cretaceous, rivers carried either local low elevation rain runoff, or distant high elevation precipitation. The near co-occurrence of rivers averaging -11 and -20‰ SMOW suggests that there is a major elevation difference in these catchments. This in turn suggests that some of the Rocky Mountain region was at high elevation during the late Maastrichtian. The similarity of these rivers to modern rivers of eastern Montana suggests that elevation contrasts were similar to today at the beginning of the Laramide orogeny. In the earliest Paleocene, the one river system studied here has intermediate and highly variable oxygen isotope ratios, suggesting little change in regional hydrology or the elevation profile of the river catchments.

11: 10:45 AM-11:00 AM
Presenter: HARTMAN, JOSEPH H.

THE END OF DAYS - RETHINKING PRE-CRETACEOUS-PALEOGENE BOUNDARY CONTINENTAL MUSSEL NOMENCLATURE

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A common paleontological practice has been to assign fossil continental mussels and snails to extant genera and subfamilies. This approach began with the scientific exploration of the West (e.g., Hall with Frémont, 1845; Harris with Morton and others, 1845; Meek with Hayden, 1856). A nomenclatural legacy and subsequent mentality have persisted largely unabated to the present day. One exception was Loris Russell (e.g., 1964), who introduced notable examples of fossil genera for fossil mussels. His nomenclatural additions were reasoned on the basis of comparisons to modern species assignments to genera with similar morphologies. Russell's efforts were preceded by Henderson's 1935 compilation of “non-marine” North American mollusks, where virtually every mussel and most snails were assigned to modern genera. “*Unio*” and “*Anodonta*” represented 98 percent of all mussel assignments. By the end of Russell's contribution (though not as comprehensive), his mussel assignments (except the traditional *Anodonta*) were removed from “*Unio*” and assigned to extinct or to modern non-”*Unio*” genera. Russell's assignment or his basic nomenclatural intent has largely been followed by others. The consequence of the generic nomenclatural history is the presumption that mussels had very long-lived genera (with significant hiatus between fossil and modern) or relatively short-lived genera (brief fossil record only). Modeling mussel evolution on the basis of this dichotomy, at best, will lead to confusing results. K/Pg boundary studies have produced a number of geochemical, geophysical, and paleobiological models. Similarly, our studies have now indicated more than just loss of continental species at or near the K/Pg boundary. We recognize that the morphological similarity of fossil and modern species (á la Whitfield in

1907), now placed in a global understanding of modern adaptive convergence, makes assignment to modern genus-group names tenuous at best. Initially, we suggest a rethinking of the use of all extant pre-K/Pg continental molluscan names.

11: 11:00 AM-11:15 AM
Presenter: BRINKMAN, DON B.

FISH OF THE HELL CREEK FORMATION

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Fish assemblages of the Hell Creek Formation have traditionally been regarded as being dominated by basal taxa with teleosts being of low diversity. However, this is likely a bias resulting from the ease with which isolated elements of primitive fish can be identified. A parataxonomic approach to study of isolated teleost elements demonstrates that a high level of diversity of teleosts is also present. With a more comprehensive understanding of the diversity of fish in this assemblage, differences in the fish assemblages of the Hell Creek Formation and mid-Campanian Judith River Group and changes fish assemblages through the Hell Creek can be recognized. The fish assemblages of the Hell Creek Formation differ from those of the Judith River Group in that the chondrichthian *Lonchidion* and the vidalamiinine *Melvius* are present in the Hell Creek but not the Judith River Group, amiinines are of much greater abundance in the Hell Creek Formation than they are in the Judith River Group, and the probable semionotiform “Holostean A” is more abundant in the Judith River Group than in the Hell Creek Formation. Based on centra, acanthomorph teleosts are more abundant in the Hell Creek Formation than in the Judith River Group and the diversity of non-acanthomorph teleosts is reduced. The fish assemblages of the upper and lower Hell Creek Formation differ in that the lower Hell Creek assemblages have a greater abundance of “Holostean A” while Lonchidion is present only in the upper Hell Creek and the abundance and diversity of and acanthomorphs is greater in that interval. These differences are interpreted as a result of a combination of shifts of latitudinal patterns of distribution in response to climate changes and an increasing importance of acanthomorph teleosts in aquatic paleocommunities through the late Cretaceous.

11: 11:15 AM-11:30 AM
Presenter: MAGUIRE, KAITLIN CLARE

PALEOECOLOGY OF A MAASTRICHTIAN MICROVERTEBRATE SITE FROM PETROLEUM COUNTY, MONTANA

MAGUIRE, KAITLIN CLARE, Integrative Biology, UC Berkeley, VLSB 3060 Bldg No. 3140, UC Berkeley, Berkeley, CA, 94720, United States, kcmaguire@berkeley.edu; CARRANO, MATTHEW, T, Department of Paleobiology, Smithsonian Institution, Washington, DC, USA, 20013-7012; KAYE, THOMAS, G, 404 Hillcrest, Prospect Heights, IL, USA, 60070

The Koenig Site, a new microvertebrate-bearing locality from the Lower Hell Creek Formation in Petroleum County, Montana, is described and compared to well-known Lancian sites in eastern Montana, Wyoming and Canada. This new site is of particular significance because the fossil-bearing horizon occupies a relatively low stratigraphic position, close to the boundary with the underlying Fox Hills Formation, which represents a slightly earlier time interval than most known Hell Creek microvertebrate sites. Also, it is among the most western of these sites, geographically extending the existing sample of Lancian microvertebrate communities. Specimens were collected from the surface of a fossiliferous layer, identified to the most precise taxonomic level possible (often family level or higher due to excessive water-wear) and then assigned to one of several diet and habitat categories. At the Koenig site, taxonomic richness is highest among dinosaurs, followed by osteichthyans, then turtles. Specimen abundance (MNI) is highest for osteichthyans, then dinosaurs and turtles. The fauna is dominated by terrestrial and amphibious taxa, consisting mostly of small carnivores. Although the site is both earlier and farther west than most Lancian sites, it shows broad similarities with them in taxonomic content and abundances. In general, the Koenig site yielded proportionally more dinosaur specimens and significantly fewer amphibian and mammal specimens than other Lancian sites, but these differences are more likely taphonomic than ecological. The Koenig fauna supports the interpretation that much of the Hell Creek depositional environment shared a similar vertebrate fauna throughout most of Lancian time, and suggests that little turnover occurred prior to the end of the Cretaceous.

11: 11:30 AM-11:45 AM
Presenter: SANKEY, JULIA

HIGH ABUNDANCE OF SHARKS IN UPPERMOST HELL CREEK FORMATION, NORTH DAKOTA: SEA LEVEL RISE DUE TO THE LATE MAASTRICHTIAN GREENHOUSE EVENT?

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Vertebrate diversity leading up to the K/T boundary was estimated in a previous study from a high resolution stratigraphic section of the Hell Creek Formation of southwestern North Dakota. This work was based on numerous specimens and sites from surface collection and excavation, but not from screening. Were small specimens missed? If so, does this change

paleoenvironmental interpretations of the Hell Creek Formation, of latest Cretaceous terrestrial ecosystems, and of vertebrate diversity leading up to the K/T? To address these questions microvertebrate sites were wet-screened from this section using fine-mesh screens, and the resulting matrix was sorted with a microscope. Two microvertebrate fossil sites are reported here: 1) PTRM 86002, a channel deposit 29.9 m below the K/T and ~65.9 Ma and 2) PTRM 89003, a crevasse splay 8.4 m below the K/T and ~ 65.6 Ma. In both sites, fish were the most numerous specimens. From the remaining 1432 identifiable specimens there are small specimens from sharks and rays (79%), amphibians (5%), lizards (2%), snakes (0.2%), crocodilians/champsosaurs (7%), hadrosaurs/ceratopsians (2%), theropods/birds (2%), and mammals (3%). Surface and screening collection methods do produce vastly different assemblages. For example, surface collection yielded more teeth of dinosaurs and other larger specimens, yet sharks and rays are rare or absent. Discovery of numerous sharks and rays changes the paleoenvironmental picture for the uppermost Hell Creek, and indicates the presence of a seaway in this area just prior to the K/T. Additionally, because both sites were deposited during or close to the late Maastrichtian greenhouse event (~66.1-65.7 Ma), when there was a sharp increase in CO_2 and temperatures (~2-4° C), this event may have caused a rise in sea level. Severe fluctuations in climate and sea levels would have stressed and altered terrestrial ecosystems, contributing to the background extinctions leading up to the K/T.

11: 11:45 AM-12:00 PM
Presenter: HOLROYD, PATRICIA A.

TURTLE DIVERSITY THROUGH THE LATEST CRETACEOUS OF THE HELL CREEK FORMATION, MONTANA

HOLROYD, PATRICIA A., UCMP, Museum of Paleontology, University of California, Berkeley, CA, 94720, United States, pholroyd@berkeley.edu; WILSON, GREGORY P., Department of Biology, University of Washington, 24 Kincaid Hall, Seattle, WA, USA 98195; HUTCHISON, J. HOWARD, Museum of Paleontology, University of California, Berkeley, CA, USA 94720

Latest Cretaceous turtle assemblages of western North America show significant biogeographic variation among formations and basins. Some regional differences have been attributed to climatic controls on the ranges of some taxa, whereas local habitat heterogeneity has been suggested as a mechanism influencing diversity. However, without adequate stratigraphic range data for most taxa, we have not previously been able to assess the influence of temporal trends or climate change on these patterns.This study focuses on successive turtle assemblages from localities that densely sample the ~93 meter section of the Hell Creek Formation in Garfield County, Montana and span the final ~1.8 Ma of the Cretaceous. These localities have yielded a minimum of 8 families and 20 genera, making it the most diverse turtle fauna known. We are now able to document temporal ranges of these turtle taxa within a local chronostratigraphic framework and stratigraphically constrain occurrence data. Based on paleomagnetic data and recognition of the K-P boundary, this

section has been correlated to areas in North Dakota where fossil assemblages provide data on megafloras and continental climate change. Taxonomic composition is consistent through the formation, with all but the rarest taxa ranging through the section. By contrast, relative abundances (measured by site occupancy) vary greatly. The lower part of the Hell Creek Formation is dominated by chelydrids and plastomenine trionychids, whereas assemblages in the upper part of the formation are more even and no particular taxa dominate. Highest taxonomic richness occurs only in the upper part of the formation, coincident with a presumed warming 400-500 ky prior to the K-P boundary. Nonetheless, hypotheses that some taxa may have climatically mediated ranges are not supported by our data.

11: 1:30 PM-1:45 PM
Presenter: HORNER, JOHN R.

HELL CREEK FORMATION DINOSAUR CENSUS REVEALS ABUNDANT *TYRANNOSAURUS*

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From 1999 to 2008 the Upper Cretaceous (Maastrichtian) Hell Creek Formation, exposed around Fort Peck Reservoir in eastern Montana, has been the focus of a comprehensive biotic and geologic study (Hell Creek Project) to evaluate a terminal Cretaceous ecosystem. One of the primary missions of this evaluation was to acquire census data on the dinosaur assemblages throughout the formation in order to determine diversity and population variation leading up to the terminal event. Dinosaur census data was retrieved from the lower third and the upper third of the Hell Creek Formation, each third representing approximately 30 meters of strata (Hell Creek Formation is approximately 100 meters thick). Two census methods were devised: (1) counting skeletons, as defined by the occurrence of at least three associated skeletal elements; (2) counting identifiable (family level), isolated skeletal elements from a regional lag deposit in the basal third, and a large localized lag deposit in the upper third. Method 1 from the lower third (L1) included 41 specimens represented by the following percentages: 36% *Triceratops*, 24% *Tyrannosaurus*, 15% *Edmontosaurus*, 10% *Thescelosaurus*, 10% *Ornithomimus*, and 5% *Ankylosaurus*. Method 2 from the lower third (L2), consisting of 60 specimens produced the following percentages: 36% *Triceratops*, 23% *Tyrannosaurus*, 17% *Edmontosaurus*, 12% *Thescelosaurus*, 7% *Ornithomimus*, 3% *Pachycephalosaurus*, and 2% dromaeosaurid. Collection of specimens from the upper third of the formation has occurred over a shorter time period, and is therefore represented by much smaller sample sizes, but provides tantalizing percentages suggesting that Triceratops populations grew through time (U1): 70% *Triceratops*, 18% *Tyrannosaurus*, and 12% *Edmontosaurus*. U2: 54% *Triceratops*, 23% *Tyrannosaurus*, 15% *Edmontosaurus*, and 8% *Ornithomimus*. The abundance of *Tyrannosaurus* precludes a role as an apex predator.

11: 1:45 PM-2:00 PM
Presenter: GOODWIN, MARK B.

THE FOSSIL RECORD OF *TRICERATOPS* FROM THE HELL CREEK FORMATION, MONTANA

GOODWIN, MARK B., Museum of Paleontology, University of California, Berkeley, CA, 94720, United States, mark@berkeley.edu; HORNER, JOHN R., Museum of the Rockies, Montana State University, Bozeman, MT 59717-0040 USA

For decades following the description of *Triceratops* by O. C. Marsh in 1889, the typical collector attitude was, “Bigger is better.” Subadult *Triceratops* fossils were seldom collected or reported in the literature. The Hell Creek Project, a multi-institutional, multi-year field program centered at the Museum of the Rockies (MOR) since 2000, built upon earlier collections in the Hell Creek Formation by the University of California Museum of Paleontology (UCMP). This collaboration produced a significant record of baby (post-neonate), juvenile and subadult Triceratops skulls and cranial elements in the MOR and UCMP reported here. Complete, undistorted adult *Triceratops* skulls are found primarily in sandstones and siltstones, which contribute generously to the sedimentary composition of the Hell Creek Formation, Montana, and equivalent strata in the Western Interior. Disarticulated and occasionally highly concreted adult *Triceratops* skulls may occur in Hell Creek Formation mudstones, but we observed that nonadult *Triceratops* are seldom found in sandstones and siltstones, except as isolated cranial elements within channel lag deposits or as surface “float” bone. Comprehensive exploration of the Hell Creek Formation demonstrated that ontogenetically younger skulls and cranial elements are preserved nearly exclusively in mudstones. Vertebrate fossils eroding out of mudstones often appear fragmentary and incomplete due to expansion and shrinkage of these sediments during wet/dry periods and seasonal weather conditions. Consequently, these nonadult *Triceratops* skulls and cranial elements were either not recognized or evaluated sufficiently and left uncollected in the field. We propose this resultant historical collecting bias contributed to: (1) the current scarcity of nonadult *Triceratops* in museum collections; (2) a mistaken view that nonadult *Triceratops* are rarely preserved in the fossil record and (3) a limited understanding of the systematics and paleobiology of *Triceratops*.

11: 2:00 PM-2:15 PM
Presenter: KEENAN, SARAH W.

TAPHONOMY OF A *TRICERATOPS* BONEBED FROM THE UPPER HELL CREEK FORMATION, GARFIELD COUNTY, MONTANA

KEENAN, SARAH W., Earth Sciences, University of Bristol, Deans Court Flat 37, 3 St Georges Road, Bristol, Avon, BS1 5UL, United Kingdom, swkeenan@gmail.com

Ceratopsid dinosaurs are notable for their common occurrence in bonebeds, however until recently this has not been encountered for the chasmosaurine *Triceratops*. The aim of this investigation was to examine 'Quittin' Time' (Museum of the Rockies locality HC-430), a *Triceratops* bonebed in the Hell Creek Formation, Garfield County, Montana, and to establish facies interpretations and the taphonomy. The locality was associated with abundant organic material, including woody debris, large seeds and other fragments in isolated silty lenses, all incorporated within a mudstone matrix, indicating preservation within a floodplain environment. From the repetition of cranial elements, the minimum number of individuals (MNI) was determined to be three, with the possibility of a fourth juvenile. Based on the level of articulation and association of many of the elements, lack of abrasion or any preferred orientation, the individuals accumulated as a result of transport and deposition via “bloat-and-float” through a fluvial system. Such a process also explains the loss of distal elements. Whether or not these individuals - one adult, one sub-adult and a likely juvenile - died synchronously could not be determined. Due to preservation within the same horizon, similar condition of the bones and close proximity, the remains likely accumulated during the same or closely spaced flooding event(s). The relatively small scale of the bonebed, both in terms of total area and number of individuals, implies that future work on Triceratops sites requires careful scrutiny of cranial elements examined with an understanding of ontogeny, as these are key to establishing MNI.

11: 2:15 PM-2:30 PM
Presenter: SCANNELLA, JOHN B.

ANAGENESIS IN *TRICERATOPS*: EVIDENCE FROM A NEWLY RESOLVED STRATIGRAPHIC FRAMEWORK FOR THE HELL CREEK FORMATION

SCANNELLA, JOHN B , Paleontology, Museum of the Rockies, Montana State University, 600 W. Kagy Blvd., Bozeman, MT, 59717, United States, jscannella@gmail.com; FOWLER, DENVER, W., Paleontology, Museum of the Rockies, Montana State University, 600 W. Kagy Blvd. , Bozeman, MT, USA, 59717

The dinosaur fauna of the Hell Creek Formation presents the clearest view of dinosaur diversity and evolutionary trends just prior to the terminal Cretaceous extinction event. However, our understanding has been hindered by poor internal stratigraphic resolution of this unit. We have used a newly resolved stratigraphic framework for the Hell Creek Formation to study *Triceratops* cranial variation, placing variant morphologies into temporal context at the end of the Cretaceous Period. *Triceratops* is the most commonly recovered dinosaur in the formation and though it has long been the subject of cranial studies, the lack of reliable stratigraphic data has obscured evolutionary trends within the genus. A temporal

context for specimens reveals an increase in the length of the nasal horn core over time as well as trends in the shape of the post orbital horn cores, elongation of the rostrum, and closure of the frontal fontanelle. These features have all previously been considered diagnostic of the two currently recognized *Triceratops* species - *Triceratops horridus* and *Triceratops prorsus*. There is no stratigraphic overlap of these species; rather the new temporal framework suggests that the morphologies which define them fall within an anagenetic lineage of Triceratops.

11: 2:30 PM-2:45 PM
Presenter: WILSON, GREGORY P.

HIGH-RESOLUTION MAMMALIAN FAUNAL DYNAMICS LEADING UP TO AND ACROSS THE CRETACEOUS-TERTIARY BOUNDARY IN NORTHEASTERN MONTANA

WILSON, GREGORY P, Biology, University of Washington, 24 Kincaid Hall, Box 351800, Seattle, WA, 98195, United States, gpwilson@u.washington.edu

The Cretaceous-Tertiary (K-T) extinction event dramatically restructured biotic communities and redirected the course of evolution. On land, it caused the collapse of dinosaur-dominated terrestrial ecosystems and led to an early Paleocene biotic recovery that transitioned into an unrivaled adaptive radiation of mammals and their rise to ecological dominance. The study system represented by exposures of the Hell Creek and Tullock Formations in the Williston Basin, NE Montana provides one of the few opportunities to document and analyze this critical episode in detail. It preserves a ~190 m thick, non-marine sedimentary sequence spanning ~3 million years across the K-T boundary and features an impressive amount of paleontological and geological data with which to investigate ecologically-relevant vertebrate faunal patterns of the K-T extinction and recovery. I compiled a fossil database of nearly 3500 mammalian specimens identifiable to species-level. Specimens derive from 100+ fossil localities that densely sample the Hell Creek and lower part of the Tullock Formations in Garfield County and are tied into a high-resolution temporal framework via stratigraphic positional data. Using this database, I documented changes in mammalian species richness, taxonomic composition, relative abundances, dental morphospace occupation, and body size structure leading up to and across the K-T boundary. During the ~1.7 million years leading up to K-T boundary, relatively minor changes in mammalian taxonomic composition and relative abundances strongly correlated with changes in megafloral and paleoclimate proxy data from the published literature. Within ~100 thousand years of the K-T boundary, nearly 75% of all mammalian species in local faunas went extinct. A recovery of pre K-T species richness and morphological disparity rapidly occurred within the first ~200 thousand years of the Paleocene fueled by immigration and in situ evolution.

11: 2:45 PM-3:00 PM
Presenter: ALLEN, SARAH E.

A FLORULE FROM THE BASE OF THE HELL CREEK FORMATION IN THE TYPE AREA OF EASTERN MONTANA: IMPLICATIONS FOR DIVERSITY, CLIMATE AND ENVIRONMENT

ALLEN, SARAH E., Geoscience, Hobart and William Smith Colleges, 2945 Scandling Center, Geneva, NY, 14456, United States, sa4393@hws.edu; ARENS, NAN CRYSTAL, Geoscience, Hobart & William Smith Colleges, 300 Pultney St., Geneva, NY, USA 14456

The Late Cretaceous Hell Creek Formation in Garfield County, northeastern Montana has yielded numerous well-preserved leaf macrofossil localities that provide insight into the climate, ecology and vegetation structure of the latest Cretaceous landscape. The most basal such locality so far reported in the Hell Creek type area (UCMP PB99057 equals MOR HC-278 associated with a partial posterior skeleton of a large Edmontosaurus MOR-1142) occurs in large channel sandstones approximately 10 m above the contact with the underlying Fox Hills sandstone. The locality represents a fluvial/estuarian environment. Leaf macrofossils occur as impressions in clay drapes within channels of fine to very fine-grained sandstone, probably produced when the incoming tidal bore balanced stream discharge in this reach, permitting deposition of fines. In this collection, angiosperms are dominant (approximately 44 morphotypes). Gymnosperms including *Metasequoia* and *Ginkgo* are present but rare; ferns are absent. Leaf Margin Analysis produced a mean annual temperature estimate between 6-7°C. This is considerably below the approximately 13°C MAT reconstructed from floras at the base of the Hell Creek Formation in North Dakota. However, it is commensurate with a single MAT reconstruction of 7°C from approximately 66.3 Ma in North Dakota. Leaf size analysis suggested a mean annual precipitation (MAP) of 47.8 cm. In this collection, partial specimens are more common among larger morphotypes, potentially biasing the result toward low MAP. These estimates will be compared to results from Climate Leaf Analysis Multivariate Program (CLAMP), which is more robust to partial specimens. While some morphotypes in this collection are familiar from the well-documented Hell Creek I zone from southwestern North Dakota, many others are not, suggesting greater spatial and/or temporal heterogeneity in the Hell Creek flora than has been previously appreciated.

11: 3:00 PM-3:15 PM
Presenter: THOMPSON, ANNA

VEGETATION INDICATORS OF ENVIRONMENTAL STRESS PRECEDE THE CRETACEOUS/TERTIARY BOUNDARY

THOMPSON, ANNA, Biology, Feather River College, 570 Golden Eagle Ave, Quincy, CA, 95971, United States, athompson@frc.edu; ARENS, NAN CRYSTAL, Geoscience, Hobart & William

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In North America, extinction of 15% to 30% of pollen and spore species marked floral change across the Cretaceous/Tertiary (K/T) boundary. K/T boundary extinctions have been attributed solely to global environmental catastrophe caused by a bolide impact. However, recent work suggests that the extinction power of such catastrophes is enhanced in ecosystems already stressed or undergoing significant environmental or ecological change. While the K/T extinction is a prime candidate for such a press-pulse mechanism, environmental conditions during the millennia preceding the impact, and the role these changes may have played in the differential character of terrestrial extinctions, have not been explored. Using fine-scale stratigraphic sampling in northeastern Montana, we show that the number of dicot angiosperm pollen taxa declined from 44 to 11 in the uppermost 3.5 m of Cretaceous sediments. This loss of diversity was not associated with changes in depositional style or pollen preservation. Similar declines in local species richness have been reported in this stratigraphic interval at other localities throughout the Western Interior of North America. However, species lost at one locality commonly persist at others, demonstrating that the diversity declines represent local extirpation, not gradual extinction. Therefore, latest Cretaceous plant communities were becoming more heterogeneous, which may have altered habitat for some vertebrate lineages and rendered them vulnerable to extinction in the face of bolide-induced environmental disturbance. This combined mechanism may better explain differential vertebrate response to the K/T boundary event.

11: Poster
Presenter: WILSON, GREGORY P.

AMPHIBIAN PALEOCOMMUNITY DYNAMICS OF THE HELL CREEK FORMATION IN NORTHEASTERN MONTANA AND THE CRETACEOUS-TERTIARY EXTINCTION EVENT. For full abstract, see *25: 2:00 PM, Booth 14*

11: Poster
Presenter: POLTENOVAGE, MICHAEL A.

PALEOASYS: AN APPLICATION FOR HIGH-RESOLUTION TRACKING, REPORTING, AND ANALYZING PALEONTOLOGICAL RESEARCH ACTIVITIES WITHIN THE HELL CREEK STUDY SYSTEM. For full abstract, see *8: 2:00 PM, Booth 36*

11: Poster

Presenter: SHOUP, BEN

SEDIMENTOLOGY AND TAPHONOMY OF A SHELL BED ASSEMBLAGE FORM THE UPPER CRETACEOUS HELL CREEK FORMATION OF EASTERN MONTANA. For full abstract, see *25: 2:00 PM, Booth 24*

Session No. 12, 8:30 AM; Tuesday, 23 June 2009
Symposium S7. Taphonomic Fidelity and Infidelity in Modern and Ancient Communities

12: 8:30 AM-8:45 AM
Presenter: KLUG, CHRISTOPHER A.

EPISODIC TIME AVERAGING IN DIFFERENT DEPOSITIONAL ENVIRONMENTS IN COPANO BAY, TEXAS

KLUG, CHRISTOPHER A., Dept of Geology and Geophysics, Texas A&M University, Mail Stop 3115, College Station, TX, 77843, United States, kluger22@neo.tamu.edu; OLSZEWSKI, THOMAS,D. , Geology and Geophysics, Texas A&M University, Mail Stop 3115 , College Station, TX 77843-3115

Establishing the duration of death assemblage accumulation is critical in determining the time available for taphonomic alteration and the length of memory of past ecological conditions in death assemblages. Postmortem age distributions obtained from six sites in Copano Bay, Texas were determined via amino acid racemization using the abundant bivalve Mulinia lateralis. The six sites represent two samples from each of three major substrate types in the bay: mud (A, B), sand(C, D) and shell (E, F). Attempts at calibrating amino acid dates using ^{14}C data have revealed that all specimens analyzed are younger than peak atomic atmospheric testing (~ 50 years ago), thus establishing that these death assemblages have had a relatively short residence time. Nevertheless, postmortem age distributions demonstrate three distinct time periods during which shells entered the death assemblages. Muddy site A contains the two youngest time periods, whereas muddy site B only contains the middle time period. In contrast, sandy substrate assemblage C contains shells from the two youngest time periods, while sandy substrate assemblage D contains shells from all three time periods. Shelly substrate E only includes the youngest time period, whereas shelly site F contains both of the two youngest time periods. Sites A, C, and E have death assemblages matching the present-day living communities at the sites, whereas sites B, D, and F have death assemblages that are anomalous when compared to living communities. These results indicate that within a substrate category, death assemblages without recent contributions can record assemblages

different than those living at the same site in the present day. Therefore, interpretation of fossil communities must take into account both inter-substrate difference, local episodicity of time averaging, and the effects of anomalous death assemblages in the geological record.

12: 8:45 AM-9:00 AM
Presenter: KOSNIK, MATTHEW A.

TAPHONOMIC BIAS AND TIME-AVERAGING IN TROPICAL MOLLUSCAN DEATH ASSEMBLAGES: DIFFERENTIAL SHELL HALF-LIVES IN GREAT BARRIER REEF SEDIMENT

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Radiocarbon-calibrated amino acid racemization ages of 428 individually dated shells representing four molluscan taxa are used to quantify time-averaging and shell half-lives with increasing burial depth in the shallow-water carbonate lagoon of Rib Reef, central Great Barrier Reef, Australia. The top 20 cm of sediment contain a distinct, essentially modern assemblage. Shells recovered at depths from 25 to 125 cm are age-homogeneous and significantly older than the surface layer. Taxon age distributions within sedimentary layers indicate that the top 125 cm of lagoonal sediment is thoroughly mixed on a sub-century scale. The age distributions and shell half-lives of four taxa (*Ethalia*, *Natica*, *Tellina* and *Turbo*) are found to be largely distinct. Shell half-lives do not coincide with any single morphological characteristic thought to infer greater durability, but they are strongly related to a combined durability score based on shell density, thickness, and shape. These results illustrate the importance of bioturbation in tropical sedimentary environments, indicate that age estimates in this depositional setting are sensitive to taxon choice, and quantify a taxon-dependent bias in shell longevity and death assemblage formation.

12: 9:00 AM-9:15 AM
Presenter: PYENSON, NICHOLAS D.

CARCASSES ON THE COASTLINE: MEASURING THE ECOLOGICAL FIDELITY OF THE CETACEAN STRANDING RECORD IN THE EASTERN NORTH PACIFIC OCEAN

PYENSON, NICHOLAS D., Department of Zoology, University of British Columbia, No. 2370-6270 University Blvd., Vancouver, BC, V6T 1Z4, Canada, pyenson@zoology.ubc.ca

Traditional fidelity studies have relied on nearshore, marine invertebrate assemblages for many reasons, including their logistical ease, high abundance and comparable census data from living communities. For marine mammals, like cetaceans, measuring their diversity in living ocean ecosystems is difficult and expensive, although increasingly critical for understanding the structure of marine communities. Beached marine mammals provide a natural death assemblage for comparison with living communities, although previous fidelity studies have considered such data at very narrow spatiotemporal scales that do not precisely match the scales of their habitat and life history.In the eastern North Pacific Ocean, two sets of data are ideal for cetacean fidelity studies: detailed line-transect surveys from ship-based platforms; and a record of strandings along coastlines directly adjacent to the live surveys, conducted over the same time period. Using fidelity metrics and sample-based rarefaction analyses, I determined that the stranding record samples the living cetacean community with high fidelity, across fine and coarse taxonomic ranks and at large geographic scales (>1000 km of coastline). Also, very little time (<10 years) is required to generate a saturated death assemblage. The high fidelity of the stranding record, measured by taxonomic composition, richness and abundance, indicates that ecological structure from living cetacean communities is recorded in the death assemblage, a finding that parallels marine invertebrate assemblages, though at far different spatial and temporal scales.Many important potential biases may still affect the stranding data (including human-related impacts, climate change and observer bias), and such issues will be examined with more detail with smaller data sets. Nonetheless, the results of study suggest two major implications: the stranding record may prove more useful for studying modern ecology than previously suspected; and well-sampled fossil cetacean assemblages from geochronologically constrained stratigraphic sections may faithfully sample ancient diversity.

12: 9:15 AM-9:30 AM
Presenter: TOMAŠOVÝCH, ADAM

DISCRIMINATING EFFECTS OF NATURAL AND SAMPLING VARIATION FROM EFFECTS OF POSTMORTEM VARIATION ON COMPOSITIONAL FIDELITY OF DEATH ASSEMBLAGES

TOMAŠOVÝCH, ADAM, University of Chicago, Department of Geophysical Sciences, 5734 S Ellis Ave, Chicago, IL, 60637, United States, tomasovych@uchicago.edu; KIDWELL, SUSAN M., Department of Geophysical Sciences, University of Chicago, Chicago, Illinois 60637

In modern molluscan communities, species abundances are positively rank correlated between living and death assemblages, but it remains unexplored how much of the total live-dead variation in composition can be accounted for by premortem variation alone. We quantify the proportion of total live-dead variation explained by premortem variation in 31 marine molluscan datasets generated by sampling living and death assemblages from multiple spatial stations in one habitat. We partition the total live-dead variation (sum of squares of

dissimilarities between death assemblages and the centroid of living assemblages) into a premortem component related to sampling and natural biological variation (sum of squares of dissimilarities between living assemblages and their centroid) and a residual component related to between-species differences in population turnover and preservation rates and/or time averaging (residual sum of squares) because (1) death assemblages are frequently dominated by recently dead cohorts, (2) living and death assemblages sampled at the same time in the same region can be temporally autocorrelated, and (3) centroid location integrates compositional variation across multiple replicate samples. Under variable degrees of dispersal limitation that affect the degree of temporal autocorrelation, neutral-model simulations show that centroids of living and unmodified death assemblages have similar locations in multivariate space and predict that premortem variation is equal to the total live-dead variation in composition. In molluscan datasets, premortem variation explains about 70% of total live-dead variation, but death assemblages are still significantly over-dispersed relative to the centroid of living assemblages (death assemblages occupy a portion of multivariate space that is not shared by living assemblages) in 25-60% of datasets, depending on the metric used. Partitioning of variation with our approach can identify how much of total live-dead variation is accounted for by premortem variation alone and takes into account effects of temporal aucorrelation that can increase live-dead fidelity.

12: 9:30 AM-9:45 AM
Presenter: JACKSON, STEPHEN T.

REPRESENTATION OF FLORA AND VEGETATION IN QUATERNARY DEPOSITS: THE KNOWN, THE UNKNOWN, AND THE NOT-YET-KNOWN-TO-BE-UNKNOWN

JACKSON, STEPHEN T., Dept. of Botany, University of Wyoming, Laramie, WY, 82072, United States, jackson@uwyo.edu

Pollen and plant macrofossils are the primary source of information on terrestrial flora and vegetation of the Quaternary. They are found in a variety of depositional settings, most notably lakes, peatlands, and packrat middens. Despite their broad utility and importance, interest in the taphonomy and representation of pollen and plant macrofossils in Quaternary sediments has waxed and waned over the past five decades. Enough is known to impart confidence that pollen and macrofossil assemblages are rich sources of information. At the same time, much more needs to be known in order to extract the information more effectively and accurately. Greater demands are being placed on pollen and macrofossils not only as sources of information on species abundance and distribution and community composition, but also as sources of material for studies of ancient DNA and stable isotopes. Provenance of tissues and molecules needs to be better understood in order to draw accurate and informed inferences from molecular and isotopic analyses. Conceptual, observational, and experimental studies of modern systems can be integrated to advance understanding of patterns and processes, and what can and what cannot be inferred from fossil pollen and

macrofossil assemblages. Relevant processes include atmospheric physics, sediment biogeochemistry, plant biology, and animal behavior, requiring interdisciplinary perspectives and collaborations.

12: 9:45 AM-10:00 AM
Presenter: TERRY, REBECCA C.

ON RAPTORS AND RODENTS: ASSESSING THE ORIGINS AND IMPACTS OF TAPHONOMIC BIAS IN RAPTOR DERIVED SMALL MAMMAL DEATH ASSEMBLAGES

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Natural accumulations of skeletal remains represent a valuable source of ecological data for paleontologists and neontologists alike. Confident use of these records requires assessment of the degree to which biasing factors impact how accurately ecological information from the living community is recorded in the sedimentary record. This has been a main focus of taphonomy, yet terrestrial systems - particularly communities of small-bodied taxa - have remained relatively unstudied, limiting our ability to assess the potential origins and impacts of post-mortem bias in modern and fossil assemblages. Predation is a common mechanism by which small-mammal skeletal remains are concentrated; raptors regurgitate their prey's remains in pellets rich in skeletal material which accumulate below long-term roosts, especially in areas such as caves and rock shelters. Here I compare data from modern trapping surveys and small-mammal death-assemblages concentrated via owl predation at Two Ledges Chamber, a long-term owl roost in Nevada, to evaluate (1) their ecological fidelity to the modern community, (2) the effects of temporal variation and time-averaging (over months to centuries) on live-dead agreement, and (3) how spatial averaging affects the landscape-scale picture of the small-mammal community as reconstructed from dead remains. Despite potential obstacles to the recovery of ecological information from deposits generated via predation, I find high live-dead agreement across all ecological metrics and all temporal comparisons. I also find that the effects of time-averaging (specifically increased richness of the death-assemblage) only become significant at the century-scale. Finally, I combined a mixing model approach with a Principal Coordinates Analysis to show that the owls at Two Ledges Chamber sample from all habitats present in the immediate vicinity of the cave, producing a high-fidelity snapshot of the community that is spatially integrated at the local landscape scale.

12: 10:30 AM-10:45 AM
Presenter: STROMBERG, CAROLINE A. E.

ABUNDANCE MEASURES AND EVENNESS IN FOSSIL FLORAS: A CASE STUDY IN THE LATE CRETACEOUS BIG CEDAR RIDGE FLORA, WYOMING

STROMBERG, CAROLINE A. E., Biology & Burke Museum, University of Washington, Box 351800, 24 Kincaid Hall, Seattle, WA, 98105, United States, caestrom@u.washington.edu; WING, SCOTT L., Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, 10th Street and Constitution Ave, Washington, DC, 20560 USA

The relative abundance distribution of plants is vital for understanding floral diversity and vegetation structure in modern and fossil ecosystems. Typical fossil leaf litter deposits reflect small areas and little time, but may be too mixed for detecting changed in relative abundance across microhabitats. In addition, such floras tend to be biased against, in particular, herbaceous plants. In contrast, event beds (volcanic or other) can preserve snapshots of past plant communities that record all plant habits (herbs and trees) as well as small-scale vegetational heterogeneity, allowing for analysis of relative abundance and diversity. The methods by which paleobotanists have collected fossil plant census data for abundance analysis vary widely between studies - a situation not unlike that in modern ecology. The question is, how do different censusing approaches affect abundance analysis and resulting diversity indices? To investigate this question we contrasted two published approaches to measuring relative abundance in fossil floras using census data from the Big Cedar Ridge ashfall flora (BCR) of the Late Cretaceous Meeteetse Formation, Wyoming. The BCR flora was censused at 100 sites along a 4 km long outcrop using a line-intercept method that provided a measure of abundance in the form of 2-D cover data. We compared this approach to the quadrat method of Pfefferkorn et al., widely used in Paleozoic work, which quantifies relative abundance of a taxon as the proportion of studied rock slabs ('quadrats') that preserve it. The two techniques provide similar results in terms of rank abundance order, with slight variation possibly relating to differences in average plant fragment size among taxa. The quadrat method depresses the relative frequency of abundant taxa, resulting in higher evenness/diversity measures for individual sites. Differential popularity of these methods in the Paleozoic and post-Paleozoic may have impaired comparison of plant evenness over geologic time.

12: 10:45 AM-11:00 AM
Presenter: EDELMAN-FURSTENBERG, YAEL

ECOLOGY AND TAPHONOMY OF MOLLUSCAN SHELLS ACROSS THE BENGUELA UPWELLING SYSTEM, SW AFRICA

EDELMAN-FURSTENBERG, YAEL, Geological Survey of Israel, 30 Malchei Yisrael St., Jerusalem, 95501, Israel, yael@gsi.gov.il

This study is a first attempt to investigate the taphonomic and paleoecological significance of macrobenthic invertebrate death assemblages accumulated under upwelling conditions. Specifically, it explores macrobenthic evidence for bottom-water conditions across the Benguela upwelling tract off the Namibian coast, SW Africa, and the role of bottom oxygen levels and/or organic matter concentrations in shaping the benthic system. Contrary to stereotypes, benthic community structure is highly variable across the upwelling tract and discrete taphofacies could be recognized. A gradient in macrobenthic death assemblage structure from low species richness and high abundance of deep-burrowing deposit-feeding or chemosymbiotic bivalves, to significantly higher richness and decreased levels of deep burrowing, deposit feeding and chemosymbiotic bivalves is observed. This is in accordance with the upwelling facies-gradient from diatomaceous ooze in areas of maximum upwelling intensity outward to the aerated but food-abundant carbonate oozes and spatially coexisting phosphorite concentrations. Additionally, the following taphofacies are recognized across the upwelling region: Taphofacies 1 (opal-organic rich) has a very low damage profile with high frequency of shell articulation and rare edge modification. Taphofacies 2 (carbonate-rich) is characterized by an intermediate taphonomic profile, while taphofacies 3 (phosphate-rich) has the highest damage profile, having relatively elevated numbers of rounded, fragmented and bored shells and very little associated sedimentary matrix. Thus, with increasing distance from the upwelling cells there is an increase in both predators and micro-boring animal abundance, which fosters post-mortem shell destruction and is presumably related to a decrease in organic load and increase in bottom oxygen concentrations but possibly also resulting in time-averaging. This study describes and categorizes the preservable, and thus predominantly molluscan, component of the macrofauna death assemblages of sub-environments within the northern Benguela upwelling system. This is especially important for assembling actualistic data that can later serve for identifying similar settings in the geological record.

12: 11:00 AM-11:15 AM
Presenter: BADGLEY, CATHERINE

FIDELITIES AND INFIDELITIES OF THE MAMMALIAN RECORD

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Both the modern and fossil records of species and ecosystems have major strengths and shortcomings for evaluating ecological and evolutionary properties and processes. The challenge is to query both records for insights that neither record alone could reveal. The fidelity of the continental mammalian fossil record varies across biogeographic scales. At the macro-scale, tectonics and climate control sedimentation and erosion, resulting in long-term records from predominantly low-elevation depositional environments. Modern montane gradients in North and South America have greater alpha and beta diversity of mammals and higher speciation and extinction rates than in adjacent lowlands. Thus, low-elevation records

present a skewed sample of species richness and evolutionary dynamics. At the meso-scale within long-term records, different taphonomic contexts preserve different forms of fidelity to the original communities, based on the Paleogene record of the Bighorn Basin (Wyoming, USA) and the Neogene Siwalik record of Pakistan. For example, fossil assemblages that accumulated by fluvial transport result from mixing over tens to thousands of years and tens to hundreds of km2; the resulting faunal composition is equivalent to modern surveys of mammals (>1 kg) over the floodbasin for decades or longer. In contrast, autochthonous fossil assemblages document habitats and individual predator behaviors at the micro-scale, comparable to bone assemblages in carnivore dens or owl-pellet accumulations over several years in modern ecosystems. Stable-isotopes indicative of diet and drinking water from fossil mammals can reveal micro-scale habitat fidelity, comparable to the kilometer-scale spatial associations documented in modern ecosystems. Long fossil records can test models of biotic turnover in relation to different forcing mechanisms, well beyond the scope of any modern records.

12: 11:15 AM-11:30 AM
Presenter: BEHRENSMEYER, ANNA K.

HIGH FIDELITY BONE TAPHONOMY IN THE AMBOSELI ECOSYSTEM OF SOUTHERN KENYA

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Parallel documentation of living vertebrate populations and associated bone assemblages in Amboseli National Park, Kenya, over 4 decades provides comparative data for ~169,000 live (Western) and ~1500 dead (Behrensmeyer) individuals representing 15 ungulate species and 4 vegetation habitats (swamp edge, plains, woodland, bush). Sorting of these data using bone weathering stages calibrated to years since death results in discrete live and dead samples for 1964-69, 1970-76, 1993-98, and 1999-2004. Live vs. dead speciesabundances for all time intervals combined are significantly correlated (Spearman's rho, p<.0001), showing that the time-averaged abundance structure of a living large vertebrate community can be accurately recorded in its bone assemblage. Live-dead comparisons for each of the four time bins also show high fidelity (all p<.01), indicating that bone survey data are sensitive enough to accurately track population structure over sub-decadal time intervals. Non-metric MDS analysis shows that live vs. dead species abundances are paired within different habitats (plains, swamp edge, woodland, bush) and accurately track major changes in these habitats over time. High live-dead fidelity occurs in spite of a marked increase in bone destruction that accompanied a shift from lion- to hyena-dominated skeleton processing. Fidelity also holds for a sub-sample of bones (230 individuals) that were partially buried. Modeling of longer-term time-averaging (1000 yrs) demonstrates the relationships of species abundances, accumulation time, and sample size. Applications to the fossil record depend on how fidelity

survives additional post-mortem taphonomic processes, which may include spatial and temporal mixing that selectively preserve species as a function of body size and/or bone durability. Reconstructing credible relative abundance data in fossil assemblages will require analysis of depositional circumstances and taphonomic biases, but the Amboseli results indicate that ecological fidelity can survive the first critical steps in the transition between a living community and the vertebrate fossil record.

12: 11:30 AM-11:45 AM
Presenter: MILLER, JOSHUA H.

TESTING HABITAT-CONTROLS ON ECOLOGICAL FIDELITY OF TERRESTRIAL VERTEBRATE DEATH ASSEMBLAGES

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Paleoecological comparisons of vertebrate assemblages from different depositional environments require detailed understanding of the taphonomic pathways that generate such accumulations. However, while modern ecosystems are an excellent source of this information, data addressing how depositional environments sample living vertebrate communities are uncommon. The distribution and survival of vertebrate skeletal remains across a landscape are influenced by biological factors including species distributions, habitat preferences, and prey consumption, as well as abiotic factors affecting bone decomposition and burial. Quantifying taphonomic patterns and the ecological fidelity of skeletal remains in modern settings provide more detailed understanding of how faithfully different depositional systems capture ecological data and how those data may most appropriately be sampled and compared. Using the modern surficial ungulate-dominated bone accumulations of Yellowstone National Park, WY, I test the habitat-controls on ecological fidelity. Death assemblage data were collected using transects in four habitats (grasslands, lake-margins, river-margins, and forests). The Minimum Number of Individuals represented by bone accumulations in each transect (then pooled by habitat) were compared to surveys of the living community to quantify habitat variability in ecological fidelity (e.g., richness, evenness, relative abundance). Death assemblages of the four habitats differentially sample richness and community structure. Lake-margins show exceptionally high fidelity in richness and community structure to the living ungulate community, and also capture the broadest vertebrate diversity. River-margins and grasslands also show strong ungulate live-dead agreement. Forested areas (environments with the lowest fossilization potential) provide community data that are the least representative, but still provide a rich assemblage of small-bodied fauna (due to raptor pellets). Rarefying the richness and community data from individual habitats illustrate sampling strategies for comparing ecological metrics among environments applicable in both paleobiological and modern conservation contexts.

12: 11:45 AM-12:00 PM
Presenter: JACKSON, JEREMY B. C.

BACK TO THE PRESENT

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Human exploitation and pollution have shifted the baselines of contemporary marine ecosystems almost beyond recognition from their formerly pristine state. Megafauna were virtually eliminated, size distributions of species severely reduced, and food webs altered from dominance by large apex predators to smaller fish and invertebrates. Thus, historical, archeological, and paleontological data provide the only means to reconstruct the composition, structure, and function of most Recent ecosystems that were severely degraded by human impacts before modern scientific investigations began. Historical and archeological data have the advantage of first hand human observation, but the disadvantage inherent in human choice. Paleontological data are comparatively immune to such human bias but suffer potentially equivalent distortion through the vagaries of preservation. Most importantly, the fossil record offers the only direct test of the extent to which environmental change has altered community composition in comparison with human impacts. I will explore these questions as they pertain to our understanding of how coral reef ecosystems have been severely altered by human activities over the past few millennia and how the resulting deeper time perspective bears on goals for conservation and restoration.

Session No. 13, 8:15 AM (morning session) and 1:30 PM (afternoon session) ; Tuesday, 23 June 2009
Symposium S8. IGCP 503: Ordovician-Silurian Oceanic/Climatic Events and Biotic Response

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13: 8:30 AM-8:45 AM
Presenter: SERVAIS, THOMAS

CAMBRIAN EXPLOSION AND ORDOVICIAN BIODIVERSIFICATION OR CAMBRIAN BIODIVERSIFICATION AND ORDOVICIAN EXPLOSION?

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MUNNECKE, AXEL, GeoZentrum Nordbayern, Universität Erlangen-Nürnberg, Loewenichstraße 28, 91054 Erlangen, Germany

Besides the terms Cambrian Explosion and Cambrian Substrate Revolution, the term Great Ordovician Biodiversification Event has recently been introduced to designate the most important increase of biodiversity of marine life during Earth's history. While a high number of scientists focused research on the so-called Cambrian Explosion, only few workers concentrated research on the Ordovician radiation of marine invertebrates. The Cambrian Explosion (some 545 to 530 Ma ago) resulted in a series of spectacular findings of "new" animals that mostly come from famous Fossil-Lagerstätten such as the Burgess Shale or Chengjiang. These Konservat-Lagerstätten might be considered taphonomic windows that allow a view to the 'new' Cambrian animals. For the first time, most animal phyla became "visible", although molecular-clock data suggest that these lineages split some 800 Ma or more before their appearance in the fossil record. As such, the Cambrian Explosion involved the origins of skeletalisation and a range of new body plans, and is considered a major event in Earth's history. Some 40 to 80 Ma after the Cambrian Explosion, the diversity of the new phyla quantitatively 'exploded' during the Lower and Middle Ordovician (485 to 460 Ma ago). This Ordovician Biodiversification generated few new higher taxa, but witnessed a staggering increase in biodiversity at the family, genus and species levels, documented in all diversity counts. The Great Ordovician Biodiversification Event should therefore be considered to be an "explosion of diversity" and a term such as "Ordovician Explosion"' of diversity would be justified. The Ordovician Biodiversification had probably (Pre-) Cambrian roots, and was probably a follow up of the Cambrian Explosion. Both events seem indeed to be linked and are possibly belonging to a single large-scale evolution, because the two most significant geological triggers, the changing paleogeography and the changing paleoclimate, are long ranging factors.

13: 8:45 AM-9:00 AM
Presenter: YOUNG, GRAHAM A.

MARGINAL IMPORTANCE: THE POTENTIAL CONTRIBUTION OF SHORELINE ENVIRONMENTS TO OUR UNDERSTANDING OF ORDOVICIAN BIODIVERSITY

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The record of Early Paleozoic faunas is strongly biased toward organisms having mineralized skeletons, preserved in subtidal marine deposits. We know little about organisms without hard parts or from other settings. A case in point is the remarkably incomplete record for Ordovician marginal marine paleoenvironments (estuaries, deltas, lagoons, and tidal flats). Biomineralizing taxa are relatively rare in these facies, so marginal biotas of even modest

diversity are likely to occur only in Konservat Lagerstatten. The Ordovician marginal marine record is sparse compared with that for the Silurian, where a number of such sites have been documented and classified. The reasons for this disparity are unclear, but it may be related to sampling.Ordovician marginal marine assemblages are variable and typically contain unique endemic fossils. This study presents current knowledge of two important Upper Ordovician sites in Manitoba: at William Lake (Williston Basin) and Airport Cove (Hudson Bay Basin). Although some fossils present are common Ordovician forms, others belong to groups that are rare or unknown elsewhere. These include cnidarian medusae, eurypterids, large problematic tubes, xiphosurids, pycnogonids, and possible palaeoscolicid annelids. Marginal marine sites like these thus provide key gamma biodiversity data. Since very few Early Paleozoic examples are known, and since each possesses unique elements, we cannot yet determine temporal diversity patterns. It does appear that diversity increased during the Ordovician, through the addition of groups such as eurypterids and xiphosurids. There is no clear evidence at present about how the Late Ordovician mass extinction affected marginal marine communities. Nearly all upper-level groups in Late Ordovician assemblages of Manitoba are known elsewhere from the Silurian or later. Although the study of marginal marine associations is still in its infancy, these settings have the potential to significantly augment our understanding of Early Paleozoic biodiversity.

13: 9:00 AM-9:15 AM
Presenter: FATKA, OLDRICH

SUPPOSED CRYPTIC BEHAVIOR OF MIDDLE ORDOVICIAN HARPETID TRILOBITES IN THE PRAGUE BASIN (CZECH REPUBLIC)

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The Middle Ordovician trilobite associations of the Prague Basin are highly diversified. All feeding habits sensu Fortey & Owens (1999) are represented (Budil et al. 2007). Nevertheless, the supposed filter feeders are quite rare despite the generally high and, during the Darriwilian, even increasing species diversity. This feeding type is represented by locally common *Trinucleoides reussi* accompanied by rare *Dionide prima* and *Eoharpes primus* in the Sarka Formation (lower Darriwilian) and by rare *Trinucleoides hastapulp*, *Dionide jubata*, *Dionidella incisa*, *Raphiophorus vinipas*, *Bergamia agricola*, *Marrolithus nefernofruaton*, *Pragolithus praecedens* and *Eoharpes benignensis* in the overlying Dobrotiva Formation (upper Darriwilian). The specimens of *Eoharpes* are quite often found articulated. This taphonomic feature, together with their exoskeleton morphology, indicates their burrowing activity within the upper layer of sediment. Complete specimens were also observed inside living chambers

of cephalopods or within remains of larger trilobites (e.g. cluster of four specimens of *E. benignensis* below pygidium of *Nobiliasaphus cf. pulverigenus*). Such accumulations and occurrences are considered primary rather than explained by random transport effects by water movement. Those animals apparently haunted the larger organic remains as shelters to be protected against predators. It is interesting that no malformed remains of harpetids have been so far found in Ordovician sequences of the Prague Basin. It seems that mode of life combined with occasional cryptic behavior was effective in the case of *Eoharpes*. A. Sá and J. C. Gutiérrez-Marco (pers. comm.) observed similar Eoharpes clusters inside large asaphid pygidia at the early Middle Ordovician material from Arouca, Portugal.Budil, P., Kraft, P., Kraft, J. & Fatka, O. (2007): Faunal associations of the Sarka Formation (Middle Ordovician, Darriwilian, Prague Basin, Czech Republic). Acta Palaeontologica Sinica, 46, Suppl., 64-70.Fortey, R. & Owens, R. (1999): Feeding habits in trilobites. Palaeontology, 42, 429-465.This contribution was supported by the Czech Grant Agency project 205/09/1521.

13: 9:15 AM-9:30 AM
Presenter: GOLDMAN, DANIEL

MIDDLE AND LATE ORDOVICIAN BIODIVERSITY DYNAMICS IN MARINE MICROFOSSILS FROM BALTOSCANDIA

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During the early Late Ordovician there was a significant decline in marine biodiversity that has been variously attributed to sea level, facies, and climatic changes. In the East Baltic area several workers have described such a marked diversity decline and faunal turnover in microfossils at the Keila -Oandu Stage boundary, an event called the Oandu Crisis. To get a better understanding of microfossil diversity dynamics in the Baltoscandian Middle and Upper Ordovician succession we used constrained optimization (CONOP9) to construct a composite range chart from the stratigraphic data of 455 chitinozoan, conodont, ostracod, and graptolite species from 14 boreholes and five outcrops. We employed the CONOP composite as a timescale in which to calculate biodiversity, extinction, and origination rates through the Middle and Late Ordovician. Traditional biodiversity metrics, and more recent probabilistic methods based on capture-mark-recapture analysis, were used to estimate biodiversity and fossil recovery patterns. We divided the CONOP composite into 860 Kyr intervals spanning the Lasnamägi through Porkuni stages. Our data show that overall biodiversity increased steadily from the beginning of the Keila to the middle Rakvere stages, mainly due to an increase in ostracod diversity. Chitinozoan diversity reached a zenith in the late Keila, dropped through the Oandu Stage, and then gradually declined during the rest of the Ordovician. Chitinozoans

exhibited constant origination but variable extinction rates and underwent a dramatic diversity decline associated with the $\delta^{13}C$ isotope excursion known as the GICE event. Conodonts had diversity peaks in the early Uhaku and early Kukruse stages, and then declined gradually through the Late Ordovician. Conodonts exhibited constant extinction and origination rates and their diversity decline is attributable to higher extinction than origination rates. Interestingly, the fossil preservation and recovery rate was highly variable and appears to exert a strong influence on the observed biodiversity pattern.

13: 9:30 AM-9:45 AM
Presenter: AMATI, LISA

BIOTIC CHANGE IN THE SANDBIAN-KATIAN (UPPER ORDOVICIAN) BOUNDARY INTERVAL IN OKLAHOMA: INTEGRATING TRILOBITE BIOSTRATIGRAPHY, BIOFACIES AND CARBON ISOTOPE GEOCHEMISTRY

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The global stratotype section of the Katian Stage at Black Knob Ridge, Oklahoma is a succession of deep water shale, carbonate and bedded chert. Graptolite, conodont and chitinozoan faunas have been documented from this section but shelly faunas are absent. A supplemental section designated about 60 km to the northwest, near Fittstown, Oklahoma, records carbonate deposition (Viola Springs Formation) in shallower, storm influenced settings. In addition to other typical shallow-water organisms, trilobites and rhynchonelliform brachiopods are abundant and diverse. Here, we report on the relationship between trilobite faunas and lithofacies. Carbon isotope data allow the succession of faunas to be placed in the context of the GICE positive isotope excursion. Three distinct, environmentally-related trilobite biofacies are present in the Viola Springs Formation. The base of the section (base of the formation) is marked by a relative sea level rise. The appearance of outer ramp facies and associated Cryptolithine Biofacies corresponds to a shift towards negative isotopic values. The shift to positive values (GICE) is characterized by diverse trilobite assemblages of the *Bumastoides* Biofacies in inner ramp, skeletal shoal environments and the *Thaleops* Biofacies in mid-ramp, storm-influenced settings. Maximum positive values are associated with the mid-ramp *Thaleops* Biofacies and the immigration of such genera as *Mesotaphraspis*, *Anataphrus*, and *Achatella*. The post-excursion interval is marked by a return to outer ramp facies and graptolite-rich assemblages. Thus, lithofacies and trilobite biofacies changes, including immigration of a number of key taxa, appear to be associated with oceanographic

changes at the GICE event. Published data indicate that the first appearance in this section of the graptolite *Diplacanthograptus caudatus*, the index for the base of the Katian stage, corresponds closely to the appearance of mid-ramp facies and the *Thaleops* Biofacies. Like the trilobites, the entry of this graptolite into the succession may be environmentally related.

13: 9:45 AM-10:00 AM
Presenter: EMERSON, NORLENE R.

DIVERSE AND ABUNDANT BRACHIOPOD ASSEMBLAGES PERSIST WITH LITTLE SIGN OF EXTINCTION OR MIGRATION ACROSS THE ONSET OF THE UPPER ORDOVICIAN GICE IN THE UPPER MISSISSIPPI VALLEY

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Brachiopod species were collected from the (Upper Ordovician) Mohawkian Decorah Formation in the Upper Mississippi Valley region in order to explore patterns of benthic faunal communities in response to sedimentologic and paleoceanographic changes. The Decorah Formation, a mixed shale-carbonate unit, was deposited within shallow epeiric seas that covered most of eastern and central North America. The Decorah records several regionally traceable environmental events such as deposition of volcanic ash beds (K-bentonites), the Guttenberg carbon isotope excursion (GICE), and the M4-M5 sequence boundary. Brachiopod specimens were collected from the Decorah at nine sites in SW Wisconsin, NE Iowa, and SE Minnesota. The 6,000 specimens collected were assigned to 38 species belonging to 23 genera. Species-level and genus-level range diagrams were constructed to a high-degree of stratigraphic resolution followed by a variety of faunal analyses including SHE diversity analysis and multivariate statistical cluster analysis. Results of the faunal analyses revealed that most species had their first appearance datum (FAD) and last appearance datum (LAD) confined between the upper and lower contacts of the Decorah Formation with very few ranges crossing formation boundaries into the overlying or underlying carbonate-dominated formations. SHE diversity measures showed that a rather stable brachiopod diversity structure existed throughout deposition of the Decorah. Multivariate Q-mode cluster analyses produced two major brachiopod clusters reflecting the change from the lower shale-rich to upper carbonate-rich lithologies within the formation corresponding to the M4 and M5 sequences respectively. Of the 23 genera collected, 67% had ranges that spanned across the M4-M5 sequence boundary and the onset of the GICE. Broad ecological tolerances allowed most species to persist in the face of fluctuating oceanographic conditions resulting from a perturbation of the global carbon cycle. But, slight variability in ecological tolerances ensured that all species did not respond in lockstep to these shifting environmental conditions.

13: 10:30 AM-10:45 AM
Presenter: DATTILO, BENJAMIN F.

SHALES AND SHELL BEDS, STORMS AND STARVATION, SUBSTRATE AND FOSSILS: EXPLORING THE ECOLOGICAL AND EVOLUTIONARY IMPACT OF MUD SEDIMENTATION IN THE CINCINNATI ORDOVICIAN

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Recently the storm winnowing model of sedimentation, whereby a steady accumulation of mixed shelly mud is occasionally winnowed into shell beds and mud beds by storms, has been questioned for the Cincinnatian. Perhaps conditions alternated between periods of high terrigenous influx during which thick layers of mud accumulated, and periods of near sediment starvation during which skeletal gravels accumulated. This is known as the episodic starvation model.Episodic starvation is supported by taphonomic evidence, and has implications for the ecological stability of the depositional basin. The evidence supporting episodic starvation includes numerous obrution deposits with well-preserved multi-element fossils like trilobites and crinoids, as well as horizons of complete bryozoan colonies. Widespread pavements of the brachiopod *Rafinesquina* with attached edrioasteroid echinoderms provide particularly interesting insights. Associated *Rafinesquina* escape traces suggest that pavements were buried by single thick mud deposits. Some horizons can be correlated over large distances. This suggests that these mud deposits were widespread, smothering large areas of the seafloor.The ecological and evolutionary implications of episodic starvation have not been explored. If diversity is a function of frequency of disturbance, then these two models would predict different patterns of diversity; storm-winnowing would only link shell beds to storms, while episodic starvation recognizes ubiquitous storm winnowing in addition to blanketing mud deposits.Another difference is that the storm-winnowing model views mud-shell bed alternations as Waltherian facies phenomena directly related to depth; if a species favors a particular substrate, it need only track that facies as depth fluctuates. In contrast, episodic starvation implies basin-wide changes in sedimentary style; a species that favored a particular substrate would at times find widespread habitat and at other times be restricted to tiny refugia. Thus these sedimentary models could lead to testable hypotheses about origination, extinction, and migration within the Cincinnatian Ordovician.

13: 10:45 AM-11:00 AM
Presenter: WITZKE, BRIAN J.

LIVING ON THE EDGE: PHOSPHATIC DIMINUTIVE FAUNAS, UPPER ORDOVICIAN OF IOWA

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The basal Maquoketa phosphorite in Iowa has been termed the “fossil Lilliput” or “depauperate” zone after its fauna of tiny (most <3 mm) phosphatized fossils. However, these faunas are not “depauperate,” and include some of the most diverse benthic fossil assemblages in the formation. The faunas are overwhelmingly molluscan, dominated by archaeogastropods and bivalves (especially nuculaceans). Amphineurans, scaphopods, hyoliths, conularids, hindiid sponges, and inarticulate brachiopods are commonly noted. Similar diminutive faunas are identified from at least seven stratigraphic positions within the Maquoketa succession. Virtually all taxa are absent in “normal-sized” benthic communities of the Maquoketa, being restricted to particular phosphatic units. The fossils apparently represent mature individuals, not embryonic or immature shells. These faunas were previously interpreted to be composed of paedomorphic taxa adapted to environments of recurring stress. Vertical and lateral facies relationships between phosphatic and organic-rich strata are displayed in Maquoketa strata, suggesting that phosphatic deposition occurred near the interface between dysoxic and anoxic waters in a stratified seaway. The diminutive faunas are interpreted to have been adapted to life in benthic environments exposed to recurrent oxygen stress associated with frequent, perhaps seasonal, vertical fluctuations of the pycnocline. Living on the edges of fluctuating oxygenation would produce strong selective pressures for paedomorphosis, that is, the ability to reach sexual maturity before the next episode of oxygen depletion would annihilate the benthos. The basal phosphorite represents a complex condensed interval associated with the TST of the lower Maquoketa (Elgin) sequence. Phosphatic diminutive faunas are also associated with condensed downlapping TSTs of the succeeding two Maquoketa sequences. Similar phosphatized to pyritized diminutive faunas have been recognized in particular oxygen-stressed depositional facies through much of the Paleozoic, suggesting that these faunas may characterize a long-lived and evolutionarily conservative benthic ecosystem along the edges of oxygenation within the marine realm.

13: 11:00 AM-11:15 AM
Presenter: ELIAS, ROBERT J.

SURVIVAL STRATEGIES AND DIVERSIFICATION OF LIBEROSESSILE SOLITARY CORALS IN THE NORTH AMERICAN LATE ORDOVICIAN EPICONTINENTAL SEA

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The Late Ordovician (Cincinnatian) Red River-Stony Mountain Province included a vast area of predominantly carbonate deposition in the North American epicontinental sea. Four of

the characteristic solitary rugosan genera were represented exclusively by liberosessile species. These corals lived unattached on soft substrates above storm wave-base, depending on sediment to support the corallum in a suitable life orientation. They were susceptible to overturning during high-energy conditions, which was fatal because these corals were unable to redirect growth from depositional orientations. Therefore, strategies that promoted survival by improving corallum stability in life position had a selective advantage, leading to speciation and to divergence of genera. One survival strategy involved corallum shapes that provided better stability on the substrate and reduced drag due to currents. Compared with corals having a circular cross-section, triangulate and trilobate forms, especially if laterally compressed, offered greater resistance to overturning. The lateral lobes of trilobate coralla, particularly in depressed forms, resisted subsidence into the sediment. Compressed triangulate shapes were especially streamlined, and trilobate forms may also have had a drag-reducing effect. Another survival strategy involved thickening of skeletal parts, which increased weight, lowered the center of gravity, and improved balance. Septal dilation generally decreased from the apical end toward the calical end of the corallum; in a few species dilation continued throughout ontogeny, thereby maximizing weight. In some species, dilation tended to be greater on the cardinal side of the corallum than on the counter side. Strategies that improved coral stability would have been especially beneficial in relatively high-energy environments, but the greatest significance may have been in reducing fatalities due to dislodgment during storms. The survival strategies available to these solitary rugosans were at least to some extent genetically determined. Ranges of variation involving corallum shape and septal dilation differed among the genera and among species.

13: 11:15 AM-11:30 AM
Presenter: BAE, BOO-YOUNG

SURVIVAL STRATEGIES AND DIVERSIFICATION OF CHAIN CORALS IN THE NORTH AMERICAN LATE ORDOVICIAN EPICONTINENTAL SEA

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The development of cateniform colony growth, resulting in chain corals, contributed significantly to the diversification of Tabulata during the Ordovician radiation. Two cateniform genera, *Catenipora* and *Manipora*, were widespread and common in the Late Ordovician Red River-Stony Mountain Province of North America. This biogeographic province included a vast area of predominantly carbonate deposition in the epicontinental sea, where storms occurred frequently. The mode of colony growth in these corals promoted survival in such environments, thereby contributing to the success of these genera and permitting the

diversification of species. The cateniform corallum provided stability on soft substrates, and colony growth compensated for subsidence and sedimentation. The arrangement of corallites in meandering ranks allowed the polyps to reject sediment everywhere on the colony surface. The lacunae enclosed by these ranks would have been effective reservoirs for sediment shed by the polyps and for sediment encroaching on the colony. Regenerative abilities of the colony permitted rapid recovery from partial mortality caused by influxes of sediment. Although there was convergence in the general skeletal morphology and environmentally related survival strategies of these two genera, there were differences in growth characteristics such as offsetting pattern, frequency of corallite increase and associated features, and annual vertical growth rate. This divergence seems to have been mainly the result of genetic factors.

13: 11:30 AM-11:45 AM
Presenter: BUDIL, PETR

TRILOBITE ASSOCIATIONS OF THE KRALUV DVUR FORMATION (CZECH REPUBLIC, PRAGUE BASIN, UPPER ORDOVICIAN, UPPER KATIAN)

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Five trilobite associations sensu Mergl et al. (2008) are distinguished in the Kraluv Dvur Formation of the late Katian age in the Prague Basin. Stratigraphic successions of these associations are especially influenced by the global climatic changes; their spatial distribution reflects lithofacies changes and paleogeographic setting. In contrast to north peri-Gondwanan character of trilobite associations in underlying formations those of the Kraluv Dvur Formation contain various elements with affinities to Baltica, Avalonia as well as Laurentia (Shaw 2000). The deeper-water *Nankinolithus granulatus* Association is locally replaced by the brachiopod-dominated *Dedzetina* Association with rare trilobites. Within the same levels and predominantly in overlying layers, the trilobite-dominated *Tretaspis anderssoni* Association occurs. The layer of impure bioclastic limestone below the top of the formation containing a rich shallow- and temperate-water fauna of the *Marekolithus kosoviensis* Association is interpreted as the remains of destroyed carbonate platform, transported into the deeper part of the basin. The forming of a carbonate ramp is considered as a manifestation of the “Boda Event” sensu Fortey & Cocks (2005). After its decline, the widely distributed *Mucronaspis* Association persisted till and partially during the onset of the glaciation at the earliest Hirnantian. The Grant Agency of the Academy of Science of the Czech Republic supported the contribution through the Project No IAA301110908. Fortey, R. & Cocks, R.L.M. 2005. Late Ordovician global warming - The Boda event. Geology, 33, 405-408.Mergl, M., Fatka, O. &

Budil, P. 2008. Lower and Middle Ordovician trilobite associations of Perunica: From shoreface endemicity to offshore uniformity (Prague Basin, Czech Republic).). In Rabano, I., Gozalo, R. & Garcia-Bellindo, D. (eds.): Advances in trilobite research. Cuadernos del Museo Geominero 9, Instituto Geologico y Minero de Espana, Madrid, 275-282. Shaw, F.C. 2000. Trilobites of the Kraluv Dvur Formation (Ordovician) of the Prague Basin, Czech Republic. Vestnik Ceskeho geologickeho ustavu, 75, 371-404.

13: 11:45 AM-12:00 PM
Presenter: JIN, JISUO

ORIGIN AND DIVERSIFICATION OF THE LATE ORDOVICIAN BRACHIOPOD FAUNA IN EPICONTINENTAL SEAS OF NORTH AMERICA

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The Late Ordovician brachiopod fauna in the epicontinental seas of Laurentia originated and diversified during a major episode of sea level rise and pronounced faunal endemism on a global scale. As a result, the brachiopod taxa that thrived in the epicontinental seas can be traced to their respective ancestral stocks that lived in continental-margin settings within Laurentia. Among several discrete evolutionary lineages, several common trends of morphological modification to the shell are recognizable when the ancestral forms are compared to their descendants in epicontinetal seas. 1) Increase in shell size is prevalent in some lineages of orthides (*Platystrophia)*, strophomenides (e.g. *Strophomena*, *Nasutimena*, *Tetraphelerella*, and *Rafinesquina*), and rhynchonellides (*Rhynchotrema-Hiscobeccus*, and *Lepidocyclus*), commonly associated with secondary thickening of the shell walls and heightened globosity due to a strongly convex dorsal valve (even in some strophomenides). 2) Increased rugosity is prominently developed separately in stocks that do not have a close phylogenetic relationship (*Nasutimena*, *Hiscobeccus*). 3) In some orthide lineages, there was a tendency of evolutionary convergence for epicontinental taxa to evolve a larger, trilobed cardinal process from its ancestral counterpart that lived in continental-margin seas and possessed a small, bilobed cardinal process (e.g. *Dalmanella* compared to *Paucicrura* and *Diceromyonia* in the superfamily Dalmanelloidea, or various species of *Plaesiomys* in the superfamily Orthoidea). Such evolutionary trends may have been related to the warmer water mass (increased supersaturation of Ca2+ and CO32-) and severe endemism (lack of competition) that were characteristic of the Late Ordovician epicontinental seas of Laurentia. The relationship between watermass and faunal characters is reflected also by detailed shell structures. The predominant dalmanelloid shells in epicontinental seas have prominent aditicules and unusually large punctae, marked by a dorsal medial costa (e.g. *Paucicrura*, *Diceromyonia*); whereas these characters are absent in continental-margin dalmanelloids of cool-water origin (*Dalmanella*, *Onniella*).

13: 1:30 PM-1:45 PM
Presenter: STIGALL, ALYCIA L.

THE BIOGEOGRAPHIC IMPACT OF SPECIES INVASIONS ON NATIVE BRACHIOPODS DURING THE RICHMONDIAN INVASION (LATE ORDOVICIAN, CINCINNATI REGION)

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The Late Ordovician strata in the Cincinnati, Ohio region record a dramatic immigration of taxa into the region from the paleoequator at the Maysvillian/Richmondian Stage boundary. This influx of extra-basinal taxa has been is termed the Richmondian Invasion and is likely related to changes in oceanic circulation that occurred at this time. The effects of the species invasion on genus-level paleoecology and biodiversity are well characterized; however, no prior analyses have examined biogeographic patterns in terms of areal extent of geographic ranges at the level of individual species at fine spatial or temporal scales. Geographic ranges for articulate brachiopod species were reconstructed using GIS generated bounding polygons to encompass points of known occurrence for each of the six depositional sequences that have been delineated within Cincinnatian strata. This provides a framework to assess biogeographic patterns before, during, and after the Richmondian Invasion. Species were divided between four groups for analyses: native species that become extinct by the end of the Maysvillian, native species that persist into the Richmondian, new species evolving in the Richmondian from native ancestors, and interbasinal invaders. Several statistical patterns emerge: native species with larger ranges preferentially survive compared to those with smaller ranges; carryover taxa exhibit neither significant increase or decrease in range size following invasion; carryover and invader species exhibit large geographic ranges and presumably broad ecological niches, while new species have small ranges and are ecological specialists. Furthermore, carryover taxa are more broadly distributed than the invading species for the first two million years of the invasion; only in the final sequence do invaders and new species establish ranges as large as the native generalist taxa. This suggests invasive species most profoundly impacted narrowly adapted, specialist species during the early stages of invasion but did not impact native generalists until much later.

13: 1:45 PM-2:00 PM
Presenter: COPPER, PAUL

WHAT HAPPENED TO THE SPIRALLY LOPHOPHORATE BRACHIOPODS DURING THE MULTIPLE LATE ORDOVICIAN MASS EXTINCTIONS?

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Brachiopods whose lophophore was supported by calcite ribbons originated during the Late Ordovician. The oldest forms, early Katian (or? Darriwilian) from Laurentia were small-shelled atrypides, possessing very simple spiral coils rotated in the plane of symmetry, directed medially. These atrypides (zygospirids) dominated the early shelly spirally lophophorate community in Baltica and Laurentia, probably evolving from rhynchonellides that lacked a calcitic lophophore base. Athyridides and spiriferides (with laterally directed spiralia) originated later in the east, either the South or North China or Kazakh plate, where they are known from the middle Katian for the smooth athyridides, and late Katian for the ribbed spiriferides, being absent in the occidental antipodes at that time. All three orders of spire-bearers appear to have started in tropical latitudes. During the Hirnantian ice ages, the athyridides invaded the west (such as *Hindella*), sailing the tropical ocean easterlies and tropical carbonate platform and reef settings. The oldest spiriferides followed suit from China-Kazakhia during the Llandovery. During the late Katian-Hirnantian, new atrypides (spirigerinids with dorsomedial spiralia), evolved alongside other spire-bearers. The spirigerinids (e.g., *Eospirigerina*, *Atrypina*) rapidly took over from the zygospirids during the Hirnantian 'pulse-pause migration' to Laurentia and Baltica, the latter becoming 'living fossils' in the Llandovery. Thus 'invaders from the east' came to dominate the global shelly benthos in the Silurian through Devonian. Only the athyridides and spiriferides were cold climate adapted to the Mid-Paleozoic malvinokaffric realm, surviving the second set of ice ages commencing in the Late Devonian. The atrypides perished during the F/F MEEs: none ever inhabited cold climates through their 100 myr long evolutionary dominance of the tropical benthos. Climate change accentuated the history of spire-bearers.

13: 2:00 PM-2:15 PM
Presenter: DESROCHERS, ANDRE

CHANGES IN THE STYLE OF CARBONATE PRODUCTION IN THE TROPICS DURING THE END-ORDOVICIAN GLACIATION

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During the End-Ordovician (Hirnantian) glacial maxima, carbonate platforms in the tropics were exposed extensively and their own diverse endemic faunas, displaced to the continental margins, suffered massive extinction. One of the best exposed and most complete stratigraphic records from a paleotropical area spanning the Ordovician/Silurian boundary is on Anticosti Island in eastern Canada. The Anticosti sequence developed within a successor

basin along the eastern margin of Laurentia under the influence of post-Taconic load. Our biostratigraphically well-controlled d13Ccarb curves and depth sensitive facies analysis allow us to recognize a distinctive shallow marine limestone unit (known as the Laframboise Member) between two prominent stratigraphic gaps in the upper part of the Ellis Bay Formation on Anticosti Island. A comparison with Hirnantian glacial successions in Morocco suggests that the two stratigraphic gaps correspond to eustatic lowstands and the deposition of diamictite units and the Laframboise limestones correspond to a eustatic highstand and the deposition of marine deposits during a brief interglacial episode. At the same time as a major faunal turnover (conodont, chitinozoan, acritarch, shelly faunas), the Laframboise limestones are characterized by the sudden appearance of abundant oncolites, reefs dominated by calcimicrobes, and other microbial features. A comparison between the Laframboise succession and other coeval shallow-water tropical successions in Laurentia, Avalonia, Baltica, Siberia and South China shows that the style of carbonate production changed from one derived largely from various carbonate secreting organisms to one dominated by widespread microbial and/or oolitic production. In contrast to the normal marine shelly faunas of pre- and post-extinction Hirnantian strata, shallow water tropical carbonates appear to be dominated by the widespread occurrence of microbial and/or abiotic deposits at a time of abrupt changes in oceanography and the global carbon cycle during the Hirnantian interval.

13: 2:15 PM-2:30 PM
Presenter: MITCHELL, CHARLES E.

SPECIES SELECTION AT THE TIPPING POINT: CLIMATE CHANGE DROVE WANTON MASS EXTINCTION DURING THE LATEST ORDOVICIAN

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In contrast to its effect on most organisms, the latest Ordovician Hirnantian mass extinction lead to dramatic changes in graptolite species richness, clade diversity, morphological disparity, and the structure of the pelagic community of which they were a part. We have compiled data on specimen abundance and species occurrence from sections in China, North America, Scotland, and the Czech Republic based on standardized collection techniques and a uniform taxonomy. Replicate sampling, rarefaction, and CMR analyses reveal that species richness peaked in the *P. pacificus* Zone. Paleotropical faunas consisted entirely of diplograptids (no normalograptids) at all localities studied. Richness declined steadily through the latest Katian as extinction rate rose and origination rates fell. Diplograptid specimen abundance crashed abruptly exactly at the base of the Hirnantian as this fauna was replaced

by a low diversity community in which 95% of specimens are *Normalograptus*, primarily *N. extraordinarius* and *N. ojsuensis*. A few relatively shallow-water epipelagic diplograptids persisted into the *N. persculptus* Zone as rare individuals. Normalograptids diversified in the paleotropics during this same interval. The abrupt crash in diplograptid specimen abundance and simultaneous immigration of *Normalograptus* coincide with the steepest part of the positive C-org isotopic excursion that characterizes the basal Hirnantian and as well as with an abrupt shift to more oxic and more on-shore facies. These observations and the patterns of taxonomic turnover are robust to sampling artifacts. This history contradicts predictions of the gamma ray burst hypothesis and suggest instead that climate deterioration reached a tipping point that resulted in rapid advance of glaciers, sea level fall, and altered oceanographic conditions that favored the temperate endemic normalograptids. Decreased population size and density resulted in wanton extinction of diplograptid species. Normalograptids subsequently radiated into the vacated paleotropical ecosystem and founded the distinct Siluro-Devonian monograptid graptolite faunas.

13: 2:30 PM-2:45 PM
Presenter: SHEEHAN, PETER

COMPARISON OF ECOLOGIC RECOVERY FROM THE END-ORDOVICIAN EXTINCTION WITH OTHER MASS EXTINCTIONS

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Loss of taxa during the end-Ordovician extinction may have been exceeded only by the end-Permian extinction. However, ecologic structures of the dominant Ordovician animal groups were little changed compared to the other mass extinctions. Features that differentiate these extinctions most likely are related to the primary cause of the extinctions. The greatest Ordovician losses to the benthic fauna were in the epeiric seas, which were drained during glacio-eustatic sea level decline. In the epeiric seas low diversity for the first ~ 3 MY of the Silurian contrasts with higher diversity in areas marginal to open oceans, where extinction was less severe. Ichnofabric indexes also show that animal abundance was reduced in epiric seas during the recovery. Locally stromatolites increased in abundance and expanded out of restricted habitats, probably taking advantage of reduced animal activity. Stromatolite increases were found also after the Devonian extinction, but neither approached the massive proliferation of stromatolites following the great Permian extinction. Stromatolites have been little studied following the late Triassic extinction. No stromatolite surge followed the K/T extinction, which likely is associated with effects of the impact event and lack of broad epiric seas. The Ordovician recovery was relatively rapid in shallow open ocean environments and delayed in the more severely disrupted epiric seas. Conversely, recovery of benthic faunas from the great Permian extinction was delayed by unfavorable environmental conditions in

the shallow open oceans. Delayed recoveries in open marine benthos following the Devonian, Triassic and Cretaceous extinctions have been compared to the Permian extinction although the delays were less severe. The Ordovician extinction is thus unique in the rapid recovery of the open marine benthos, which eventually repopulated the epeiric seas.

13: 2:45 PM-3:00 PM
Presenter: HISTON, KATHLEEN

LATE ORDOVICIAN-EARLY SILURIAN FAUNAL RESPONSE TO SEA-LEVEL CHANGE: A CASE STUDY FROM A PERI-GONDWANAN SECTOR

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Recent findings, based on benthonic (brachiopods, bivalves and trilobites) and pelagic organisms (conodonts, cephalopods and graptolites), have allowed a more precise biologic picture to be defined and, for the first time, in relation to areas of the northern Gondwana margin (Cocks & Torsvik, 2002). A variety of detailed field studies on the almost complete biostratigraphically well constrained Silurian successions in the Carnic Alps (Austria) over the past decade have provided a significant database regarding the relationship between sea-level change and faunal events for the Late Ordovician-early Silurian interval for this middle paleolatitude Peri-Gondwanan sector (Ferretti & Schönlaub, 2001; Brett et al, in press; Ferretti & Histon, in press). Recognition of environmental - water depth changes using available data from shelly benthic fossil assemblages (mostly trilobites and bivalves) and pelagic faunas (such as nautiloids, graptolites and conodonts) places a tight control on small scale bioevents within precise biozones defined with conodonts, graptolites and chitinozoans, allowing their correlation within the depositional basin and with adjacent paleogeographic areas. Detailed taphonomic and microfacies studies of this interval across the local depositional basin from sections ranging from condensed dark grey-reddish micritic cephalopod limestones to deep water graptolitic shales has allowed identification of minor cycles within these beds which show significant changes in the energy levels of the depositional environment. Furthermore, analysis of “ooid pockets” and “stromatolite-like” structures within the *Pt. celloni - Pt. a. amorphognathoides* conodont Zones is also discussed with regard to their paleoenvironmental implications. Similar studies in other sectors (Oggiano & Mameli, 2006 from the Ordovician/Silurian of northern Sardinia), for this stratigraphical interval highlight that knowledge to date regarding these peculiar carbonate facies is still quite limited. In-depth studies in key areas to recognise these markers may shed light on the relative positions of microterranes along the North Gondwana margin.

13: 3:00 PM-3:15 PM
Presenter: KERSHAW, STEPHEN

UPPER CHICOTTE CORAL-STROMATOPOROID BUILD-UPS IN THE LATE LLANDOVERY OF ANTICOSTI, CANADA; ARE THEY REEFS OR NOT?

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Late Llandovery carbonate platforms on the south coast of Anticosti display spectacular stromatoporoid-coral build-ups that have been described as possessing wave resistance, and fit with the concept of robust reef structures. However, fieldwork shows that the reefs are small and poorly constructed. The presence of a rigid framework is questionable, and much of the reef material occurs as scattered debris, buried within rich encrinite deposits. Furthermore, deformed beds that have been described as Philip Structures (sagged beds beneath reefs where weight of a reef deforms the underlying beds) are reinterpreted here as either minor folds or as drapes over topography, because the apparent Philip Structures are actually anticlinal, rather than the basin structures they should be. This point reinforces the poorly-developed nature of the reefs, that have little concentrated mass. Reefs occur in repeated sequences of encrinites separated by polished erosion surfaces, that have N-S-orientated runnels indicating directional erosion. Thus the reefs seem to have developed on an open-marine wind-swept shelf in relatively shallow water. In some cases individual reefs are truncated by relative sea-level fall. Finally, one viewpoint is that the reefs show ecological succession; however, close inspection reveals that the components of such a succession occur as isolated deposits in the Chicotte, and that it has not been possible to demonstrate succession in any one reef. Thus, overall, the reef development is interpreted as poorly-developed, in short-lived phases of open marine water between sea-level falls. It seems likely that the fluctuating sea level prevented the reef system from developing into the larger reefs found elsewhere in the Silurian record.

13: 3:15 PM-3:30 PM
Presenter: MIKULIC, DONALD G.

TRILOBITES AND REEFS: BIOTIC RESPONSE TO CHANGES IN LARGE-SCALE CYCLIC DEPOSITIONAL SEQUENCES IN THE SILURIAN ROCKS OF THE CENTRAL UNITED STATES

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Silurian strata in the central United States display a cyclic succession of widespread, large-scale depositional sequences. The primary controls on sedimentary character and temporal extent of these sequences appear to be a series of glacial-eustatic events that have been recognized elsewhere in Silurian strata. Each depositional sequence exhibits a similar cyclic pattern of changing lithologies bounded by conspicuous breaks in deposition. Each sequence, however, may have its own specific biotic composition. Therefore, the extinction and origination of many taxa found in these rocks appear to be related to conditions at or following the event boundaries, and do not occur within individual sequences. Trilobites provide the best-known example of the nature of changes within a single taxonomic group. Within individual sequences, trilobites can be grouped into static environmentally specific associations, with some key taxa occurring in more than one environment. Each successive depositional sequence exhibits some corresponding trilobite associations, which are composed of morphologically similar but different taxa. Unfortunately, few other taxonomic groups have received modern systematic study in this region, making it difficult to determine if they follow similar patterns to those of the trilobites. The preliminary study of some conspicuous groups, such as pentameriid brachiopods, seems to reveal the same pattern. A different type of biotic change is demonstrated by the reorganization of reef composition and structure that takes place at the boundary between sequences. Previous studies suggested that temporal changes in the biotic composition of these reefs primarily reflected successive developmental stages controlled by environment. Recent work, however, shows that these changes are abrupt, occurring at sequence boundaries, and that they do not involve any regeneration of reef “communities.”

13: 4:00 PM-4:15 PM
Presenter: MCLAUGHLIN, PATRICK I.

SEDIMENTARY SIGNATURES OF SHIFTING CLIMATIC-OCEANOGRAPHIC REGIMES DURING THE LATE ORDOVICIAN TO MID-SILURIAN IN SOUTHERN LAURENTIA - A COLORFUL PARADOX

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The sedimentary record for southern Laurentia during Late Ordovician to mid-Silurian preserves the subtle signatures of tectonic, climatic, and oceanographic instability. During this period siliciclastics generated by the Taconic-Salinic orogenic highlands and carbonates produced by the Midcontinent platform interacted over a broad area. These interactions were dynamic as rise/fall in base level alternately favored one system over the other, resulting in a high-resolution record of sea-level fluctuation manifest as mixed carbonate-siliciclastic

cyclothems. Based on available dates and nesting of multiple scales of cyclicity, it appears that this sea-level record is dominated by the 400 k.y. eccentricity cycle. Increases in the magnitude of sea-level fluctuation occurred during major carbon isotope excursions. The magnitude of these sea-level fluctuations (~40-120 m) over the course of only a few hundred thousand years suggests a strong glacioeustatic control. Thus, we infer that a relationship existed between major carbon isotope excursions and a shift to expanded glacial systems. The strata associated with the GICE, HICE, and Sheinwoodian (Ireviken) Excursion also display a dominance of authigenic mineralization in the form of pyrite and phosphate that cuts across lithofacies (occurring in carbonaceous shales and clean limestones) that is interpreted as a shallow marine signature of oceanic anoxic events. Intervening successions show a decreased prevalence of these minerals and, at times, an increased dominance of glauconite and hematite. In particular, four marine red bed successions are widespread across Laurentia, during the late Richmondian, late Rhuddanian, early Telychian, and late Telychian. The paradox in these patterns is that they provide a picture of oceanic anoxic events occurring during periods of enhanced glaciation (when thermal-haline circulation should result in increased oxidation of the bottom) and oceanic oxidation events associated with periods of diminished glacial activity (when a decreased temperature gradient should promote stagnation and anoxia).

13: 4:15 PM-4:30 PM
Presenter: BANCROFT, ALYSSA M.

SILURIAN CONODONT BIOSTRATIGRAPHY AND CARBONATE CARBON ISOTOPE STRATIGRAPHY OF THE ERAMOSA SOUTHWESTERN ONTARIO, CANADA

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The Eramosa lithofacies were named in Ontario almost a century ago and are among the most economically significant Paleozoic sedimentary rocks in Ontario. However, the relative age, regional lithostratigraphic relationships, and depositional environments of the Eramosa are still poorly understood. The strata assigned to the Eramosa have been given formational rank, allocated as the upper member of the underlying Amabel Formation, and designated as the basal member of the overlying Guelph Formation. This research combines biostratigraphy and chemostratigraphy to generate a detailed chronostratigraphic framework for the Eramosa in southwestern Ontario. For the Wenlock, the Sheinwoodian (Ireviken) $\delta^{13}C_{carb}$ Excursion and the Homerian (Mulde) $\delta^{13}C_{carb}$ Excursion serve as chronostratigraphic markers. Dolostone samples from Wiarton and Guelph, Ontario were analyzed for conodont biostratigraphy and carbonate carbon ($\delta^{13}C_{carb}$) isotope stratigraphy and record the descending limb of the

Ireviken Excursion, indicating that the studied interval is restricted to the middle Sheinwoodian through perhaps earliest Homerian. This interpretation is consistent with the recovery of three biostratigraphically important conodonts: *Ozarkodina sagitta rhenana*, *Kockelella walliseri*, and *Kockelella ortus ortus*. *Aldridgeodus minimus* was also recovered from these faunas and co-occured with *K. walliseri*, below the last occurrence of *O. s. rhenana* (Lower *Kockelella walliseri* Zone), suggesting that the range of *A. minim*us should be extended lower into the Sheinwoodian.

13: 4:30 PM-4:45 PM
Presenter: KLEFFNER, MARK A.

CONODONT FAUNAS AND STABLE ISOTOPES ACROSS THE MULDE EVENT (LATE WENLOCK; SILURIAN) IN SOUTHERN LAURENTIA

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The late Wenlock Mulde Event can be definitively recognized in many areas of southern Laurentia (Oklahoma, Texas, Tennessee) and tentatively recognized in other areas (Indiana, Ohio). No location known in southern Laurentia preserves a faunal record of the Mulde Event comparable to its type area in Gotland, in which three conodont datum levels are recognized. Where it is possible to definitively recognize the extinction event in southern Laurentia, it is similar to that on Gotland, but confined to a single horizon. *Dapsilodus praecipuus*, *D. sparsus*, *Pseudooneotodus linguicornis*, and *Walliserodus sp.* disappear at the same level, or in random order in lower abundance samples; separate datum levels cannot be distinguished. Currently, the level of the Mulde Event in sections in Indiana and Ohio can only be approximated, due to the sparse, low diversity conodont faunas typical of the Wenlock above the *Kockelella walliseri* Superzone in those states. The appearance of *Ozarkodina bohemica longa* and/or *K. ortus* absidata above the impoverished conodont interval and a positive $\delta^{13}C_{carb}$ excursion within that interval make it possible to recognize the level of the excursion as the approximate level of the Mulde Event there. The late Wenlock Mulde positive $\delta^{13}C_{carb}$ excursion can be identified throughout southern Laurentia. It is best recorded in southeastern Laurentia, and is a dual-peaked excursion that includes the Waldron Shale, where present, comparable to its record on Gotland. The Mulde $\delta^{13}C_{carb}$ excursion is preserved only as incomplete positive $\delta^{13}C_{carb}$ peaks just below or just above an unconformity associated with a sequence boundary in southwestern Laurentia. The effect eustatic sea-level fall associated with the early part of the Mulde Event had on deposition apparently differed in southern Laurentia. Subsidence in

southeastern Laurentia and the eustatic sea-level rise following Datum 2 of the Mulde Event could have facilitated transgression and deposition in that region.

13: 4:45 PM-5:00 PM
Presenter: ZIGAITE, ZIVILE

$\delta^{18}O$ COMPOSITION OF THE SILURIAN BIOGENIC APATITE - IMPLICATIONS TO PALAEOCLIMATE, STRATIGRAPHY AND SEA LEVEL

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Biogenic apatite of phosphatic microfossils such as conodonts, and early vertebrate microremains (fish teeth and scales), are studied for their oxygen isotope composition. Oxygen isotope ratios ($\delta^{18}O_{apatite}$) are used to calculate palaeotemperatures, if the phosphates are well-preserved and not alterated by diagenetic processes. $\delta^{18}O_{apatite}$ analyses of early vertebrate microremains are performed for the first time, using the corresponding method for conodont elements.Conodont and early vertebrate microfossil material originates from the Upper Silurian (Pridolian) sections in Lithuania. The conodont colour alteration index of 1 reflects very minor thermal alteration of the Upper Silurian strata in this part of the Baltic Basin. Conodont $\delta^{18}O_{apatite}$ values are used for palaeotemperature reconstructions with the values of the samples ranging from 17.5 to 19.5 ‰ V-SMOW. The analysis of early vertebrate remains from the same samples as the conodonts gave values lower by 2.5 ‰ in comparison to conodont apatite $\delta^{18}O$. These low values translate into about 10°C higher paleotemperatures in comparison to the estimates calculated from conodont apatite. Interestingly, the general trend of the early vertebrate $\delta^{18}O_{apatite}$ curve resembles that of conodont $\delta^{18}O_{apatite}$.We may now present the first $\delta^{18}O_{apatite}$ curve from a Pridolian section in the eastern Baltic Basin (Geluva-99 borehole), which is located in the central facies belt of the Silurian of Lithuania. The position of a positive shift in the curve perfectly matches a facies change between the Lower Pridoli (Vievis Fm.), and the Upper Pridoli (Lapes Fm.). The positive excursion, indicating drop of palaeo-seawater temperature, also corresponds to an abrupt sea level drop in between Vievis and Lapes Formations in the middle Pridoli of the Baltic Basin. This formational boundary, biostratigraphically interpreted as a significant change in the faunal composition as well, is now supported by cooling event of the $\delta^{18}O$ record.

13: 5:00 PM-5:15 PM
Presenter: CRAMER, BRADLEY D.

PALEOBIOGEOGRAPHY, HIGH-RESOLUTION STRATIGRAPHY AND THE FUTURE OF PALEOZOIC BIOSTRATIGRAPHY

CRAMER, BRADLEY D., School of Earth Sciences, The Ohio State University, 125 S. Oval Mall, Columbus, OH, 43210, United States, cramer.70@osu.edu; KLEFFNER, MARK A., Division of Geological Sciences, School of Earth Sciences, The Ohio State University at Lima, 4240 Campus Drive, Lima, OH, USA, 45804; BRETT, CARLTON, E., Dept. Geology, Univ. Cincinnati, Cincinnati, OH 45221 USA; MCLAUGHLIN, P.I., Wisconsin Geological and Natural History Survey, Madison, Wi 53705 USA; JEPPSSON, LENNART, GeoBiosphere Science Centre, Lund University, Sölvegatan 12, Lund, Sweden, SE-223-62 ; MUNNECKE, AXEL, GeoZentrum Nordbayern, Fachgruppe Paläoumwelt, Universität Erlangen, Loewenichstrasse 28, Erlangen, Germany, D-91054

The integration of multiple chronostratigraphic tools, such as conodont and graptolite biostratigraphy, sequence stratigraphy, and carbonate carbon isotope chemostratigraphy, has made the Wenlock Series one of the chronostratigraphically best-constrained intervals of the Paleozoic. Portions of the Wenlock Series can now be correlated globally with precision better than ±100 kyr and such increased resolution allows us to evaluate the fidelity of individual chronostratigraphic tools. Through the use of conodont biostratigraphy, sequence stratigraphy, and carbonate carbon isotope chemostratigraphy, we can now demonstrate that the conodont *Kockelella walliseri*, an important guide fossil for middle and upper Sheinwoodian strata (lower part of the Wenlock Series), first appears at least one full stratigraphic sequence lower in Laurentia than in Baltica. Because the temporal difference between the two first appearances was so small (<500 kyr) typical Paleozoic biostratigraphy previously had been unable to identify paleobiogeographic variability on such short timescales. It is unlikely that *K. walliseri* is unique in its paleobiogeographic record, and the expansion of high-resolution studies in the future will require robust biostratigraphic zonations that integrate multiple chronostratigraphic tools and openly embrace the paleobiogeographic variability that will inevitably result. To this end, a better understanding of the paleobiogeographic migration histories of marine faunas will provide unique insights into the paleoceanographic and paleoclimatic history of the Paleozoic Era.

13: Poster
Presenter: BUDIL, PETR

FEEDING STRATEGIES OF TRILOBITES OCCURRING IN THE KRALUV DVUR FORMATION (UPPER ORDOVICIAN, PRAGUE BASIN, CZECH REPUBLIC). For full abstract, see: *25: 2:00 PM, Booth 3*

13: Poster
Presenter: FAN, JUNXUAN

CARBON ISOTOPES AND EVENT STRATIGRAPHY NEAR THE ORDOVICIAN-SILURIAN BOUNDARY, YICHANG, SOUTH CHINA. For full abstract, see *8: 2:00 PM, Booth 6*

13: Poster
Presenter: HISTON, KATHLEEN

SILURIAN MIGRATIONAL SEAWAYS: COMPARISON OF NAUTILOID FAUNAS FROM PERI-GONDWANA, AVALONIA AND LAURENTIA. For full abstract, see: *8: 2:00 PM, Booth 7*

Session No. 14, 1:30 PM; Tuesday, 23 June 2009
Topical Session T4. Phanerozoic Diversity Dynamics and Biostratigraphy

14: 1:30 PM-1:45 PM
Presenter: FOOTE, MICHAEL

EVOLUTION OF GEOGRAPHIC RANGE WITHIN SPECIES AND GENERA

FOOTE, MICHAEL, University of Chicago, Dept. Geophysical Sciences, Univ. Chicago, 5734 South Ellis Avenue, Chicago, IL, 60637, United States, mfoote@uchicago.edu; CRAMPTON, JAMES S., GNS Science, P.O. Box 30-368, 5040 Lower Hutt, New Zealand; BEU, ALAN G., GNS Science, P.O. Box 30-368, 5040 Lower Hutt, New Zealand; COOPER, ROGER A., GNS Science, P.O. Box 30-368, 5040 Lower Hutt, New Zealand

Geographic ranges of individual taxa are highly dynamic on both ecological and geological time scales. Rapid changes are observed in ecological time, and ranges also expand and contract, often rather symmetrically, over millions of years. Biotic interactions and tracking of the physical environment have both been suggested as possible explanations for the regular long-term pattern. Here we test a third possibility, that the regular waxing and waning is the outcome of a random walk in which species and genera experience random increases and decreases in their ranges throughout their durations. This is a plausible hypothesis to test, since a symmetric rise and fall is the expected outcome of a bounded random walk. By analyzing several groups of marine invertebrates and microfossils, we find that observed range histories of species and genera are historically constrained in the sense that the geographic range in a given time period depends on the range in the prior time period. Range histories are nonetheless inconsistent with random walks; they are far more volatile, and there is a

significant tendency for ranges to increase when they are narrow and to decrease when they are wide. This suggests that some factors are driving geographic range actively up and down. Identifying these factors is an important challenge for future work.

14: 1:45 PM-2:00 PM
Presenter: CRAMPTON, JAMES S.

THE LONG AND THE SHORT OF IT: CONTROLS ON SPECIES LONGEVITY IN MARINE MOLLUSCS

CRAMPTON, JAMES S., GNS Science, GNS Science, PO Box 30-368, Lower Hutt, 5040, New Zealand, j.crampton@gns.cri.nz; COOPER, ROGER, A., GNS Science,PO Box 30-368, Lower Hutt, New Zealand,5040; BEU, ALAN G., GNS Science,PO Box 30-368, Lower Hutt,New Zealand,5040; FOOTE, MICHAEL, Department of the Geophysical Sciences, The University of Chicago,5734 South Ellis Avenue, Chicago, IL 60637 USA

What intrinsic factors determine the duration of a species during times of background extinction? We analyse relationships among a range of ecological and biological traits in New Zealand Cenozoic molluscs in order to identify those that are associated significantly with species duration. The traits analysed are: geographic range size, body size, life mode, larval type and feeding type. Of these, geographic range is an emergent trait at the level of species, whereas the other four are properties of individuals. Two-way and multi-way associations between traits are analysed using log-linear modelling, a method that makes no assumptions concerning predictor and response variables. In addition, a randomized resampling protocol is used to identify phylogenetic effects. We find that bivalves have a relatively small number of simple two-way associations between traits. In bivalves, decreased extinction probability is associated with wide geographic range, which is itself associated directly and positively with body size. Both patterns have been well established in other groups of organisms. Large geographic range is also associated with a planktotrophic larval type and epifaunal life mode; however, both these associations appear to be strongly influenced by phylogenetic effects.In contrast to bivalves, gastropods display more complex interactions involving three-way associations; we infer that this pattern reflects their more complex ecology. In gastropods, decreased extinction probability is associated directly with wide geographic range, large body size, infaunal life mode, and carnivorous feeding type. Large geographic range is associated with decreased extinction risk and planktotrophic larval type in a three-way interaction. Similarly, large geographic range is associated with infaunal life mode and carnivorous feeding type in a three-way interaction, although in this case there seems to be a significant phylogenetic effect. Some ecological implications of these findings will be discussed further in the presentation.

14: 2:00 PM-2:15 PM

Presenter: KRUG, ANDREW Z.

TROPICAL TREES, BOREAL TWIGS: PHYLOGENETIC DIVERSITY AND THE SPATIAL DYNAMICS OF BIVALVIA

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Counts of species and higher taxa cannot fully capture the evolutionary history recorded in a geographic region. A direct measure of evolutionary history is phylogenetic diversity (PD), equal to the sum of all the branch lengths within a phylogenetic tree for the taxa recorded from a region (Faith 1992). Though PD scales with richness, it can be used to evaluate departures from random phylogenetic patterning/structure in the assembly of regional biotas. Here, using a spatially explicit species database and a family-level phylogeny of living shelf-depth marine bivalves, we quantify trends in PD along latitude and longitude. Branch lengths below the family level were estimated using the geologic ages of families and genera from an updated version of the Sepkoski Compendium. The null expectation for regional PDs was determined by randomly assigning branch lengths to the species in each region, repeated 1000 times. At the global scale, PD declines with latitude predictably with species richness, but departs from the null expectation above ~45° N and S. For tropical and warm-temperate provinces, PD conforms to the null, reflecting the wide geographic distributions of most bivalve families, except for the tropical East Pacific, where PD is lower than expected. However, PD is consistently higher than expected in regions above 45°, suggesting these faunas are over-dispersed phylogenetically. Though ~32% of families fail to range past 45°, most have sister taxa that do, resulting in the retention of ~85% of the family-level tree topology. Regional PDs therefore primarily reflect evolutionary history within families. The close correlation between PD and richness in the tropics suggests a link between speciation and lineage diversification there. The divergence at high latitudes suggests these processes are decoupled near the poles, with speciation and lineage invasion primarily within older and over-dispersed lineages deeper in the tree.

14: 2:15 PM-2:30 PM
Presenter: FRAASS, ANDREW

MACROEVOLUTION OF THE PLANKTONIC FORAMINIFERA

FRAASS, ANDREW, University of Wisconsin, 841 Burbank Place, Madison, WI, 53705, United States, ajfraass@wisc.edu; KELLY, DANIEL C., Geology & Geophysics, University of Wisconsin-Madison, 1215 W. Dayton St., Madison, WI, 53703, United States; PETERS, SHANAN E., Geology & Geophysics, University of Wisconsin-Madison, 1215 W. Dayton St., Madison, WI, 53703, United States

The Planktonic Foraminifera are an excellent microfossil group for evolutionary study, yet most macroevolutionary studies have treated the Mesozoic or Cenozoic parts of this history separately, rather than taking a more holistic approach. Recent publication of several new atlases with standardized taxonomies provide an opportunity for a new analysis of planktonic foraminiferal diversity trends for 615 species, 126 genera, and 20 families for the entire Late Jurassic to Recent history of the group. The overall shapes of the species-, genus- and family-level diversity curves are similar and do not appear to be strongly affected by temporally asymmetric preservation or sampling biases (e.g., “Pull of the Recent”). Diversity at all taxonomic levels exhibits peaks of similar magnitude in the Cretaceous, Eocene, and Recent that are separated by diversity minima that vary in their severity and underlying diversity dynamics. The largest diversity decline occurs in response to a transient pulse of extinction in the upper third of the last biozone of the Cretaceous. This extinction-driven event divides planktonic foraminifera into distinct sets of “evolutionary faunas.” Recovery from this well-known extinction pulse is rapid, with pre-extinction diversity levels attained by the Lutetian. The second largest decrease in diversity occurs at the E/O boundary. In contrast to the K/Pg, this longer-duration decline in diversity is driven by a sustained decrease in rates of origination with little corresponding increase in rates of extinction. Diversity does not fully recover from the Oligocene diversity minimum until the Late Miocene. These results highlight (1) the ability of genera to accurately proxy species-level macroevolutionary patterns, (2) the importance of identifying underlying origination and extinction components of observed changes in biodiversity, and (3) the importance of the greenhouse-icehouse transition in the evolution of the planktonic foraminifera.

14: 2:30 PM-2:45 PM
Presenter: PARK, LISA E.

CLADES ON CONTINENTS: CROSSING THE SALINITY DIVIDE AND ITS EFFECT ON EARTH'S BIODIVERSITY

PARK, LISA E., Geology and Environmental Science, The University of Akron, 135 Goodhue Drive, Akron, OH, 44325, United States, lepark@uakron.edu; MOTZ, GARY, J., Geology and Environmental Science, The University of Akron, Akron, Ohio, USA 44325-4101; HORVATH, KIMMAREE, A., Geology and Environmental Science, The University of Akron, Akron, Ohio, USA 44325-4101

Modern biological diversity in continental ecosystems has been estimated to be greater than in the marine; but that has not always been true. While life in the oceans has existed for 2.8 billion years, lakes were colonized only 600 million years ago; nonetheless, they have played a critical role in the history of life. How did that biodiversity arise? What are the patterns of continental colonization? How did lake colonization affect the diversity of life? In order to answer these questions, we compiled a database of lake faunas through time. In this database, each lake's sedimentology and paleontology is recorded and evaluated. Thus far, we have compiled >3000 references. Since lakes and other continental environments were established after the physical and chemical stabilization of the marine realm, the evolution of biota within the continental realm occurred at different rates and under different tectonic and climatic circumstances than those in the marine realm. Initially, lakes were nutrient-poor and had few organisms living in them. It is not until the establishment of land plants in the Silurian that lakes began to respond with higher diversities and more complex physical and chemical conditions. During the Devonian-Carboniferous, biodiversity was on the rise as food webs became more complex. Most Devonian and Carboniferous lakes formed along continental margins or in tectonic basins with occasional connection to the marine realm. The faunas from these types of lakes were comprised of mixed marine and freshwater elements and were far more diverse than more inland lakes. This “estuary effect” created a gateway through which faunas invaded the continental realm. Examining modern standing diversity, except for the echinoderms, those clades that crossed into continental settings have exponentially more species than clades that did not invade. This is most probably due to a clade's osmoregulation strategy.

14: 2:45 PM-3:00 PM
Presenter: MOTZ, GARY J.

GASTROPOD DIVERSITY IN THE MARINE AND CONTINENTAL REALMS: A RECIPE FOR INCREASED RESISTANCE TO EXTINCTION

MOTZ, GARY J., Dept. of Geology and Environmental Science, University of Akron, 275 Fountain St, Akron, OH, 44306, United States, gjm18@uakron.edu; PARK, LISA, E., Department of Geology and Environmental Science, University of Akron, Akron, OH 44325-4101; HORVATH, KIMMAREE, M, Department of Geology and Environmental Science, University of Akron, Akron, OH 44325-4101

A systematic study of global diversity shows that there is a large discrepancy in the diversity patterns of clades that solely inhabit the marine realm and those that have colonized freshwater and terrestrial niches. Diversification within many clades show marked differences in diversity. This study demonstrates that the class Gastropoda supports the claim that “terrestrialized” taxa have elevated rates of diversification.This study examines the evidence for the terrestrialization of the gastropods, evaluating how diversity within this clade has changed through time before and after they invaded land. Data from the Paleobiology

Database is enriched with data derived from the “Lake Faunas Through Time” database. This cross-referential, literature based dataset details paleoecological, lithostratigraphic and geographic information in primarily lacustrine and estuarine settings. Diversity indices and diversity curves were generated for genera within the Gastropoda, and compared with other gastropods of differing ecological niches.Diversification patterns of marine and continental gastropod groups indicate that they had differing rates, and that the ability to invade land contributed to a greater overall diversity for those clades than clades that did not. Thus, those groups of organisms not able to cross the salinity divide between marine and fresh water habitats may have suffered in their overall diversity as a result.

14: 3:00 PM-3:15 PM
Presenter: PETERS, SHANAN E.

THE GEOLOGICAL COMPLETENESS OF PALEONTOLOGICAL SAMPLING IN NORTH AMERICA

PETERS, SHANAN E., Geology & Geophysics, University of Wisconsin-Madison, 1215 W. Dayton St., Madison, WI, 53703, United States, peters@geology.wisc.edu; HEIM, NOEL A., Geology & Geophysics, University of Wisconsin-Madison1215 W. Dayton St., Madison, WI 53703 USA

A growing body of work has linked many macroevolutionary patterns, including short- and long-term changes in biodiversity, rates of taxonomic extinction and origination, and patterns of extinction selectivity, to temporal variability in the sedimentary rock record. Here we establish a framework for more rigorously testing alternative hypotheses for these and many other results by documenting the large-scale spatio-temporal intersection of the North American sedimentary rock and fossil records. To do this, we combined 32,127 fossil collections in the spatially explicit Paleobiology Database with a comprehensive macrostratigraphic database consisting of 22,520 lithostratigraphic rock units compiled from 803 geographic regions across the United States and Canada. Geological completeness of paleontological sampling, here defined as the proportion of the available sedimentary rock record that has been documented to have at least one fossil occurrence, is measured at four different levels of stratigraphic resolution: (1) lithostratigraphic rock units, (2) gap-bound rock packages, (3) geologic columns, and (4) sediment coverage area (km2). Mean completeness estimates for 86 Phanerozoic time intervals range from 0.16 per interval in the case of lithostratigraphic units to 0.22 per interval for gap-bound packages and columns. Geologic completeness estimates at all four levels of stratigraphic resolution exhibit similar temporal variation, including a significant long-term increase during the Phanerozoic that is accentuated by an abrupt Campanian-Maastrichtian peak. This Late Cretaceous peak is approximately four times greater than the least complete Phanerozoic time intervals (Cambrian, Early Devonian, Late Permian, Early Cretaceous). Geologic completeness in the Cenozoic is, on average, 50% greater than in the Paleozoic. Temporal patterns in geological completeness do not appear to be controlled by variation in the frequency of subsurface rock units or an increase over time in

the proportion of terrestrial rock, but instead may be general features of both the marine and terrestrial fossil records.

14: 3:15 PM-3:30 PM
Presenter: HEIM, NOEL A.

MACROSTRATIGRAPHY AND THE NORTH AMERICAN FOSSIL RECORD: THE STRATIGRAPHIC DISTRIBUTION OF FOSSILS WITHIN GAP-BOUND SEDIMENT PACKAGES

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Previous attempts to quantify aspects of global and continental diversity from the fossil record have been made without the spatio-temporal context provided by the structure of the sedimentary rock record. We present here some results from a database that has allowed us to quantify the intersection of the Phanerozoic rock and fossil records. We have combined data from stratigraphic correlation charts for the United States and Canada with the Paleobiology Database into a database that contains 4199 gap-bound sediment packages comprised of 18667 lithostratigraphic units and 28376 paleontological collections. Each of the paleontological collections is linked to a specific lithostratigraphic unit at one of 797 stratigraphic summary columns distributed over the continent. One of the great advantages of this database is that it allows us to begin testing hypotheses of how the structure of the geologic record influences patterns of fossil occurrences. Preliminary results show that the temporal distribution of fossil collections within sedimentary packages is asymmetrical. Although there is variation through time, the general tendency is for fossils to occur most frequently in the upper half of sediment packages. The mode of peak occupancy of paleontological collections in the upper half of packages is driven primarily by carbonates, as seen when carbonate and siliciclastic packages are analyzed separately. The stratigraphic distribution of paleontological collections has important implications for our interpretations of diversity curves and macroevolutionary rates measured from the fossil record. Our results examining the stratigraphic structure of the fossil record indicate a relatively strong correlation between the rates of sediment truncation and genus extinction. This trend is consistent with the concentration of fossil collections in the top half of gap-bound sedimentary packages and suggests that these types of analyses will enhance our understanding of the nature of the fossil record and the Phanerozoic history of life.

14: 4:00 PM-4:15 PM
Presenter: FREY, ROBERT C.

THE AGE OF NAUTILOIDS IN THE AMERICAN MIDWEST: THE PLATTEVILLE FAUNA IN ILLINOIS AND WISCONSIN

FREY, ROBERT C., Bureau Environmental Health, Ohio Dept. Health, 5696 Dorsey Drive, Columbus, OH, 43235-7230, United States, bob.frey@odh.ohio.gov; CATALANI, JOHN A., retired (teacher: Community High School District 99), 3405 High Trail, Woodridge, Illinois USA 60517-1401

Descriptive studies of fossil nautiloids from the Ordovician Platteville Group in north-central Illinois and adjacent portions of Wisconsin have identified 50 species, belonging to 27 genera, and ten orders. Nautiloids are most abundant in the ledgy, fossiliferous dolomites of the Mifflin Formation and the overlying Grand Detour Formation (Late Ordovician, Turinian). Both units represent deposition in tropical carbonate platform environments. The Mifflin fauna includes 32 species belonging to 22 genera and ten orders. The fauna of the Grand Detour is one of the most diverse nautiloid faunas known, consisting of 49 species, belonging to 27 genera and ten orders. The Mifflin fauna is dominated by numerous specimens of the small fusiform orthocerid Whitfieldoceras and an undescribed asocerid, with lesser numbers of small oncocerids and coiled tarphycerids. The succeeding Grand Detour fauna is dominated by a diverse group of cyrtoconic oncocerids plus common specimens of the large actinocerids Actinoceras and Gonioceras. These diverse early Late Ordovician nautiloid faunas in cratonic Laurentia were decimated by a regional extinction event in the latest Turinian-early Chatfieldian. Causes remain speculative but include a regression of the seas from the area, an ingress of clastic sediments, and deleterious effects from the Deicke volcanic event. Relic populations of a number of these Turinian nautiloid genera found refugia in carbonate platform environments in what is now the Arctic archipelago in the succeeding Chatfieldian. These relic taxa seeded a resurgence of nautiloid evolution leading to the development of the diverse, abundant, often gigantic taxa that characterize the Arctic Ordovician Fauna associated with widespread carbonate platform facies in Laurentia in the succeeding Edenian and Maysvillian.

14: 4:15 PM-4:30 PM
Presenter: DOJEN, CLAUDIA

EARLY DEVONIAN OSTRACODES FROM THE COAL CANYON SECTIONS (NORTHERN SIMPSON PARK RANGE, CENTRAL NEVADA)

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The Early Devonian sections of Central Nevada are of great interest for biostratigraphy as its conodont record together with those from the Pyrenees has permitted the subdivision of the Lochkovian. But in comparison with other groups of fossils, the ostracodes have received very little attention. The Coal Canyon series in the Northern Simpson Park Range predominately consist of shelly limestones yielding abundant conodonts, brachiopods, and graptolites, which are used for the correlation between the various sections. Thus, the ostracode faunas are tied to a well-established faunal network. So far, about 60 taxa belonging to 33 genera have been identified, from which 15 species, 1 genus and 1 subgenus are new. Like in the late Devonian, the Lochkovian ostracode faunas expose similarities not only to those from the Northern American, but also to the Russian Platform. Similarities to faunas from Europe are exposed, too. For the most parts relations on generic level are found, but further investigations are necessary. On the whole, the ostracode faunas are composed by both heavy-walled palaeocopes indicating shallow marine environments and thin-walled, frequently spinose podocopines typically for low-energy environments. Some of the latter such as *Tricornina sp*. aff. *T. jahnkei* and n.gen. aff *Acravicula* occur in Lochkovian strata of Nevada and the Spanish Pyrenees. Thus, they might be useful for prospective correlations between different facies and areas, as the near shore faunas from both Nevada and the Spanish Pyrenees can be used for the correlation to Canada and Celtiberia, respectively.Once the basic elements of this faunal sequence are described, we will seek to incorporate material known from other ranges in the region and to integrate the ostracode biostratigraphy with the already established conodont, graptolite, and brachiopod sequences. The combined work will establish a robust biostratigraphic framework for the region and for the time interval.

14: 4:30 PM-4:45 PM
Presenter: WAHLMAN, GREGORY P.

THE MIDDLE PENNSYLVANIAN -LOWER PERMIAN FUSULINID ZONATION FOR MIDCONTINENT NORTH AMERICA AND ITS CORRELATION TO CYCLOTHEM SEQUENCE STRATIGRAPHY

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Middle Pennsylvanian-Lower Permian (Desmoinesian-Wolfcampian) fusulinid foramininfera species range charts, and midcontinent cyclothem sealevel curves were plotted together to compare biostratigraphic and glacioeustatic sealevel patterns. The early Desmoinesian is characterized by *Beedeina* and *Wedekindellina*. The mid-Desmoinesian extinction of *Wedekindellina* and turnover of *Beedeina* species coincide with a transgression and change in paleoclimatic patterns. *Beedeina* goes to extinction near the Desmoinesian-Missourian sequence boundary, and is succeeded by a thin zone of *Eowaeringella* and rarely primitive *Triticites*. *Triticites* dominated the remainder of Upper Pennsylvanian faunas. Lower-Middle Missourian *Triticites* have small tests with plane septa. In the Upper Missourian, *Triticites* are medium-sized with more complex fluting, and *Kansanella* appears. In the uppermost

Missourian-lower Virgilian, *Triticites* are medium-sized and evenly biconvex with weak septal fluting. *Kansanella* disappears in the lower Virgilian. The middle Virgilian is dominated by medium to large *Triticites* with complex fluting and *Dunbarinella* spp.. The upper Virgilian has large *Triticites* and the first *Leptotriticites*. The uppermost Virgilian ("Bursumian") has large *Triticites*, diverse *Leptotriticites*, and the first primitive elongate *Schwagerina*. The first fusulinids above the new conodont-based Virgilian-Wolfcampian boundary (Howe limestone) are *Leptotriticites* similar to species below the boundary. In successive overlying Council Grove Group cyclothems, the first definitive Wolfcampian inflated schwagerinid *Paraschwagerina* appears in the Neva limestone, the first typical Wolfcampian *Schwagerina* appear in the Beattie Limestone, and after a stratigraphic gap in faunas, the first *Pseudoschwagerina* appear in the overlying Chase Group. Most significant fusulinid faunal changes correlate with major cyclothem boundaries, but not all major cyclothem boundaries have significant faunal turnovers. Fusulinid zonal boundaries approximate maximum sealevel lowstands, and most new genera and species appear in the regressive phases of the next cyclothem, probably because faunal migrations occurred during maximum flooding events and subsequent highstands system tracts have more paleoenvironmental diversity and thus more niches to fill.

14: 4:45 PM-5:00 PM
Presenter: STEPHEN, DANIEL A.

LOWER TRIASSIC AMMONOID BIOSTRATIGRAPHY OF CENTRAL AND WESTERN UTAH

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The Thaynes Group is a marine unit that thins from northwest to southeast across Utah, where it interfingers with the terrestrial Moenkopi Group. The limestones and shales of the Thaynes Group reflect deposition within the Sonoma Foreland Basin, and outcrops of these Lower Triassic rocks can be seen now in the Pahvant Range of central Utah and the Confusion Range of western Utah. Several sections were measured through portions of the Thaynes Group at localities in both ranges. Fossils were systematically collected from the limestone beds; fossils are quite rare in the intercalated shales. Ammonoids are abundant, though generally poorly preserved. The upper beds clearly belong to the informal *Anasibirites kingianus* Zone. The middle beds are assigned to the upper part of the *Meekoceras gracilitatis* Zone. Furthermore, the *A. kingianus* Zone correlates with the *A. multiformis* Zone (Upper Smithian), while the upper part of the *M. gracilitatis* Zone correlates with the Owenites Beds (Middle Smithian) of the Tethyan Paleoequatorial Zonation. The lowest beds also contain ammonoids, which continue to be investigated and may soon yield more significant discoveries. Our results complement recent reports of the occurrence of the Late Smithian

Anasibirites fauna in the Sinbad Formation (Thaynes Group) at several sites in southern Utah. Interestingly, ammonoids of the Middle Smithian *Meekoceras* fauna appear to be absent in the correlative Sinbad Formation localities to the south and east. Therefore, the occurrence of the *Meekoceras* fauna in the Pahvant Range represents the farthest southeast this fauna has been reported in Utah. The Pahvant Range assemblages described herein provide an important geographic link between localities to the southeast and localities to the northwest, including the Confusion Range.

14: 5:00 PM-5:15 PM
Presenter: MENLOVE, LARA

EARLY TRIASSIC CONODONTS IN CENTRAL AND WESTERN UTAH

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The Thaynes Group is a marine unit deposited in the Sonoma Foreland Basin during the Early Triassic. Rocks of this group are now exposed in numerous locations in Utah and adjacent states. In the Pahvant Range (central Utah) and the Confusion Range (western Utah), the Thaynes Group is represented by numerous, thin limestone beds separated by fissile shale intervals. The group rests disconformably upon Permian marine limestones, interfingers with the terrestrial Moenkopi Group, and is overlain by the Upper Triassic terrestrial Chinle Group. In an effort to more precisely constrain the age of the Thaynes Group, we conducted a detailed sampling at several measured sections in both the Pahvant Range and the Confusion Range. Macrofossils were collected as well as bulk rock samples for microfossil analysis. Ammonoids were abundant, especially in the upper limestone beds, whereas palynomorphs seem to be lacking in the shale intervals. The Early Triassic age of the Thaynes Group has been independently confirmed by analyses of the ammonoid fauna (reported in another presentation at this meeting). A meager collection of poorly preserved conodonts was recovered from the limestone beds. The sparse conodont assemblage includes *Furnishius triserratus*, *Conservatella conservativa*, and *Neospathodus waageni*, indicating a Smithian age for at least some of the Thaynes Group in the Pahvant Range and Confusion Range. This age determination is corroborated by studies of the ammonoid assemblages. The age of the basal strata of the Thaynes Group continues to be investigated. Conodont biostratigraphy of Lower Triassic strata in western North America has been hindered for decades, and it remains problematic for several reasons, perhaps most importantly because of trouble in defining and reliably identifying zonal boundaries. We hope our ongoing research in central and western Utah may ultimately help resolve some of these issues.

14: 5:15 PM-5:30 PM
Presenter: KAZEMI, ALI

SCOLECODONTS AND THEIR BIOSTRATIGRAPHY IN THE ORDOVICIAN AND SILURIAN OF NORTH IRAN.

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The lower Palaeozoic Sequence is well exposed in Kuh-e-Saluk ,2 km north of GHELLI village in northern Iran. In ascending stratigraphic order this sequence has been devided into MILA(519 M) LASHKARAK(250 M),GHELLI(1140 M) AND NIUR (160 M) Formations.The age relationship of each rock unit, has been determined based on Acritarches,Chitinozoans and Scolecodont microfossils.Therefore, 200 surface samples were selected from the Lashkarak,Ghelli and Niur Formations. A total of 31 species was encountered from the lower Palaeozoic rock units of the studied area. The encountered Scolecodont species have been arranged in 3 ascending local stratigraphic zones: Zone 1-2 occurs in the Ghelli formation, indicating a Middle and Late Ordovician age. Zone 3 consists of cryptospores. No attention was paid to occurrences in the Niur formation and suggest an Early Silurian age(Llandovery)based on acritarch biozones. Among the encountered families of scolecodonts were two families of Polychaetaspidae and Paulinitidae, which have more genera and species rather than other families. Moreover ,the scolecodont genera and species of Silurian sediments (member 1 of Niur Fm.) have more diversity than Ordovician strata in the LASHKARAK and GHELLI Formations. This is obviously related to the change from cold conditions in the Ordovician to warm in the Silurian. The encountered critical Scolecodonts species in this study are: *Kettnerites fjaelensis* , *Kettnerites versabilis*, *Kettnerites microdentatus*, *Kettnerites sp*., *Polychaetaspis latus*,, *Polychaetaspis warkae*, *Polychaetaspis varsoviensis*, *Protarabellites staufferi*, *Kalloprion triangularis*, *Mochtyella sp.*, *Xanioprion sp.*, amd *Tetraprion sp*. The above mentioned Scolecodont genera and species can be compared with those of contemporaneous strata from Sweden, Poland, Estonia, Italy and the United States. This comparison reveals broad similarity with the above-mentioned countries.Therefore the scolecodonts can be applied as a useful tool for biostratigraphy,paleoecology and paleogeography purposes.

Session No. 15, 1:30 PM; Tuesday, 23 June 2009
Topical Session T5. Paleobiogeography and Systematics

15: 1:30 PM-1:45 PM
Presenter: STROTHER, PAUL K

PALEOPALYNOLOGY OF THE KANOSH SHALE AT FOSSIL MOUNTAIN, UTAH, USA

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Palynomorphs were recovered from Hintze's 1973 K-North measured section of the Kanosh Shale at Fossil Mountain, Utah, USA. The assemblage includes a moderately diverse array of acritarchs, dominated by a variety of operculate forms (including *Sacculidium*) in addition to low diversity populations of small cryptospores. Palynology provides a general assessment of deposition setting as near shore, since these shales contain cryptospores but lack large and diverse acanthomorphic acritarchs typical of normal marine settings. This interpretation corroborates the conclusions of recent paleontological work on the section, but differs sharply from previous interpretations of the Kanosh as an anoxic basin. The acritarch assemblage includes several taxa known in Middle Ordovician (Arenig) sediments from China, Australia and Baltic localities, such as *Sacculidium*, *Rhopaliophora*, *Peteinosphaeridium*, *Petaloferidium*, *Cyclopospheridium*. North American reports of Middle Ordovician acritarchs are few; although some of the above taxa are mentioned in previous reports, no complete descriptions of this particular acritarch association have been published before. The acritarch assemblages of the Kanosh Shale at Fossil Mountain are clearly different from coeval assemblages of the so-called "northern" Gondwana region, which includes South America, North Africa and the Middle East, indicating paleobiogeographical differentiation of Middle Ordovician acritarch suites. Cryptospores from the Kanosh range from 8 to almost 20 µm in diameter. They are typically grouped into palisades of enclosed cryptospore pairs and sets of paired "spore packets", a topological scheme that matches the recently described cryptospore, *Agamachates casearius* Taylor & Strother, from the upper Cambrian of Wisconsin. This Kanosh assemblage is intermediate in age between the late Cambrian, Lone Rock assemblage and the Darriwilian (Hanadir Sandstone) from Saudi Arabia - establishing an important intermediary between dyad-dominated Cambrian cryptospore populations and the beginnings of tetrad-dominated cryptospore morphologies in the Middle Ordovician.

15: 1:45 PM-2:00 PM
Presenter: CARR, ROBERT K.

A BIG FISH STORY: NEW LINKS BETWEEN THE APPALACHIAN BASIN AND MOROCCO IN THE LATE DEVONIAN

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Late Devonian basins on the North American craton (Appalachian, Michigan, Illinois, and Iowa Basins) have been considered to represent biologically isolated regions affecting the distribution of vertebrates. However, new fieldwork and systematic analyses has revised our understanding of these interbasinal barriers. This work has extended beyond the North American craton to the eastern Anti-Atlas Mader and Tafilalt Basins of Morocco. Assumed barriers between the Appalachian and Tafilalt Basins include the intervening Appalachian mountain system and the Rheic Ocean (terrestrial and deep water barriers). Our ability to compare geographically separate faunas is limited by sampling biases. The Cleveland shale fauna (Famennian), with its 67 vertebrate taxa, is the best known for the Late Devonian. The Moroccan Famennian fauna is second to the Cleveland shale with only 32 taxa. Other North American basins are less well represented. Numerical differences accentuate the impression of endemism and the lack of sympatric species. From a comparison of the two best-known Famennian faunas (Cleveland and Morocco) it is becoming clear that these faunas are more similar than previously believed. This is best demonstrated by the distribution of *Dunkleosteus* and *Titanichthys*. *Dunkleosteus terrelli* is now recognized across North America from California to the Appalachian Basin. Work in progress, by colleagues, suggests the extension of this species into Morocco. *Titanichthys*, equally, is widely dispersed. A recent discovery suggests that the Moroccan species, T*. termieri*, is present in the Appalachian Basin. Additionally, the presence of mylostomatid arthrodires in the Appalachian Basin and Morocco, *Deirosteus* (a holonematid arthrodire) in Missouri and New York, and *Protitanichthys* (an arthrodire) in Michigan and Appalachian Basins all point to limited barriers among these basins. These questions can only be further addressed by renewed fieldwork in each of the basins and the systematic review of the taxa involved.

15: 2:00 PM-2:15 PM
Presenter: MAIN, DEREK J.

LATE JURASSIC-EARLY CRETACEOUS DINOSAUR PALEOBIOGEOGRAPHY WITHIN NORTHERN HEMISPHERE ECOSYSTEMS; BERINGIA AND BARENTSIA

MAIN, DEREK J., Earth Sciences, University of Texas, University Blvd., Arlington, TX, 75062, United States, maindinos@msn.com; NOTO, CHRISTOPHER, R., Biomedical Sciences, Grand Valley State University, 223 Tadnos, Allendale, MI, USA, 49401; SCOTESE, CHRISTOPHER, R., Earth Sciences, University of Texas at Arlington, University BLVD., Arlington, TX. USA, 76019

As Pangea split into separate regions in the Mid-Late Jurassic, tenuous land bridges maintained biogeographic dispersal routes in the northern hemisphere. To the east, the Barentsian land bridge connected eastern Eurasia to North America through much of the Late Jurassic. To the west, the Beringian land bridge connected eastern Eurasia to northwestern North America during the latest Early Cretaceous (Albian-Cenomanian). In order to investigate the effect of potential dispersal routes on paleobiogeographic patterns, a time-slice series of 18 maps from the Late Jurassic (Oxfordian, Kimmeridgian, Tithonian) and the Early - Mid Cretaceous (Berriasian, Hauterivian, Albian, Cenomanian) were produced that plot dinosaur and plant fossil distributions. Both 2-D rectilinear and 3-D polar projections were created utilizing: 1) plant fossil localities from the GEON and Paleobiology databases; and 2) dinosaur fossil localities from an updated version of the Dinosauria (Weishampel, 2004) database.The new paleobiogeographic maps illustrate the changing configuration of the continents, land bridge presence, and corresponding relationships of plant and dinosaurian taxa. The Late Jurassic and Early Cretaceous maps show variance in biogeographic zonation of both plants and dinosaurs that is commensurate with reconstructed climate patterns and geography. Late Jurassic maps illustrate a biogeographic connection between North America and Barentisa. Early Cretaceous maps also show a notable similarity between northeastern Asia and northwestern North American biotas suggesting Beringian dispersal events. These data are particularly useful for understanding the response of late Mesozoic ecosystems to geographic and climatic conditions that differed markedly from the present. Particularly interesting is the opportunity to track the response of taxonomic distribution and diversity patterns with the opening and closing of dispersal routes. Furthermore, studies of past biotas and their changes may elucidate the role of climatic and geographic factors in driving changes in species distributions, ecosystem organization, and evolutionary dynamics over time.

15: 2:15 PM-2:30 PM
Presenter: LAZAR, IULIANA

UPPER JURASSIC BRACHIOPOD ASSEMBLAGES FROM THE HAGHIMAS MOUNTAINS (EASTERN CARPATHIANS, ROMANIA) - TAXONOMY, PALEOECOLOGY AND PALEOBIOGEOGRAPHICAL SIGNIFICANCE

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Two outstanding fossil assemblages, very rich in brachiopods are described, from the Haghimas Mountains (Eastern Carpathians). The first assemblage is from the Lacul Rosu area (northern part of the western Haghimas Mountains), consisting of ammonites associated with the terebratulids *Pygope janitor* (Pictet) and *Nucleata nucleata* (Schlotheim), bivalves,

gastropods, irregular echinoids, crinoids, sponges, and plant debris. This assemblage corresponds to the Upper Kimmeridgian - Lower Tithonian rock sequence, built up of calcarenites and calcareous sandstones alternating with marls, and related to open sea deep water environments. The ammonite assemblages prove the zones *Acanthicum*, *Eudoxus* and *Beckeri*, with the parallel existence of *Pygope janitor*. The second assemblage from Obarsia Fagul Oltului (central part, western Haghimas Mountains) is represented by a very abundant oligospecific association, strongly dominated by the rhynchonellids *Lacunosella* (70%), *Septaliphoria*, and *Rhynchonella* (20%), related to quite distal red crinoidal limestone (*Saccocoma* facies). The presence of some brachiopod species was mentioned by Neumayr (1873). However, this is the first detailed taxonomic description of the brachiopods and consideration of their paleoecological and paleobiogeographical significance. The degree of preservation is remarkable, the attachment surface of the diductor muscles and the mantle canal patterns are very well preserved in almost all individuals. The ammonites *Sutneria*, *Ringsteadia*, *Gravesia*, and some species of *Ataxioceras*, *Lithacoceras*, and *Taramelliceras* that occur with *Pygope janitor*, indicate the Submediterranean ammonite Province. *Lacunosella* is a representative of the NW European Province, *Pygope janitor* and *Nucleata* representatives of the Mediterranean Province,(Sandy, 1988; Voros, 1993) and *Septaliphoria* considered by Ager (1994) to provide a link between Tethyan and Boreal Provinces; we assume that the studied Upper Jurassic sequences belong to an oceanic basin (corresponding to the Transylvanian Nappe System, according to Sandulescu, 1984) that allowed faunal connections between NW European and Mediterranean brachiopod provinces.

15: 2:30 PM-2:45 PM
Presenter: JUD, NATHAN A.

PALEOBIOGEOGRAPHY OF *ALNUS* IN NORTH AMERICA

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The genus *Alnus* (Betulaceae) is comprised of about 35 species of early successional, actinorhizal trees distributed widely across the Northern Hemisphere and into South America along the Andes. *Alnus* provides an excellent system for addressing evolutionary and paleobiogeographic questions because of its rich fossil record, attributed to the trees' affinity for environments that typically accumulate sediment, and the distinctive woody reproductive structures that preserve well with the leaves. The earliest *Alnus* foliage and reproductive structures in North America come from the Bighorn Basin, Wyoming. These previously unpublished fossils date to the Earliest Eocene (~55.3mya) and provided the impetus for the present study. Close examination of leaf architecture in living and fossil *Alnus* indicates that some features can be used to determine subgeneric affinities in the fossils and thereby improve taxonomic resolution. An exhaustive survey of North American *Alnus* fossils has been

carried out. The combination of widespread geographic and temporal information with a more precise identification of the fossils yields a more detailed picture of the expansion of *Alnus* and its constituent clades across the Americas. Arrangement of the pistillate catkins, the absence of subtending leaves, leaf shape, apex shape, base shape, and tooth features suggest that the earliest alders in the North America, as well as the distinctive *Alnus parvifolia*, common in the Eocene "Okanagan Highlands" of British Columbia, both belong to the most derived subgenus. Additionally, fossil wood from the Middle Eocene of Yellowstone is attributed to this clade. The abrupt appearance of the most derived subgenus suggests that the more basal clades evolved elsewhere, perhaps in Asia, and that each arrived in North America via high latitude land bridges open during the globally warm Paleogene.

15: 2:45 PM-3:00 PM
Presenter: SCOTESE, CHRISTOPHER R.

MESOZOIC PALEOGEOGRAPHY AND THE PALEOGEOGRAPHIC CONNECTIVITY INDEX (PCI)

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When Pangea broke apart in the Late Jurassic, widening ocean basins separated land areas in tropical and temperate latitudes. However, at the North and South Poles, land areas remained connected throughout most of the Jurassic and Cretaceous. In the northern hemisphere, terrestrial migration routes can be traced eastwards from Greenland to Europe and northern Asia through much of the Mesozoic via Barentsia. Connections between western North America and northeastern Eurasia, across Beringia, were more sporadic, but a good case can be made that Arctic Canada and Siberia were connected continuously from the Albian (~110 Ma). In the southern hemisphere, migration pathways were more complex. South America, Africa, Madagascar, India, Antarctic and Australia were interconnected from the Triassic, throughout the Jurassic and into the late Cretaceous (~100 Ma). In the late Aptian - early Albian, India and Madagascar became isolated from the other Gondwana continents. India became an island continent ~ 90 Ma. A paleogeographic connectivity index (PCI) was calculated to describe the availability of land bridge connections and the probability of terrestrial dispersal in the Mesozoic. The paleogeographic connectivity score decreases over time with increased separation of the continents. During the Late Triassic, when connectivity was high (PCI=100), isolation was low. Through the Jurassic, as Pangea broke apart, the continents became increasingly isolated and the paleogeographic connectivity index lowers significantly (PCI=82). In the Cretaceous, the PCI continues to fall as continents became increasingly separated. In the Early Cretaceous (PCI=44) South America, Africa, Antarctica and Australia become increasingly isolated. By the Late Cretaceous the PCI drops to a low 9-11 range, which correlates with increased dinosaur diversity and endemism via allopatric speciation. The eventual goal of this research project is to combine this measure of

paleogeographic connectivity with the pattern of dinosaur diversification and paleobiogeography during the Mesozoic.

15: 3:00 PM-3:15 PM
Presenter: MCGUIRE, JENNY L.

MICROTUS SPECIES DESCRIMINATION USING GEOMETRIC MORPHOMETRICS INFORMS THE PALEOECOLOGY OF PACIFIC-COAST QUATERNARY FOSSIL LOCALITIES

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Species-level identification of fossils is necessary to maximally interpret the biostratigraphy, evolution and paleoecology of Quaternary vertebrate localities. Rodents of the genus *Microtus* are particularly important in this regard because of their pervasiveness in the fossil record, making them useful biostratigraphic markers. Their recent diversification makes them excellent candidates for investigating evolutionary changes in morphology through time. Additionally, the pattern of molar shape variation is consistent with climatic gradients, which gives them utility as paleoenvironmental indicators. Nevertheless, the full potential of *Microtus* fossils in informing paleoecology and evolutionary theory has been limited by the difficulty of identifying paleontological specimens to species. *Microtus* fossils typically are preserved only as isolated teeth, whereas cranial and soft-anatomy characters traditionally have been used to diagnose extant *Microtus* species. Previous attempts to identify fossil *Microtus* teeth to species using traditional morphometrics have met with only limited success, particularly amongst Pacific-coast species. Here I demonstrate that geometric morphometric analyses can distinguish between the five species of *Microtus* living in California today (*M. californicus*, *M. longicaudus*, *M. montanus*, *M. oregoni* and *M. townsendii*) using only their lower first molar (m1). I performed a two-dimensional geometric morphometric analysis on the m1 of more than 150 specimens from throughout the geographic range of these species. Discriminant analysis on the resulting projected shapes correctly classifies the extant specimens to species 96 percent of the time, enabling microtine identification from several important Quaternary fossil localities. Using these techniques, I trace the history of extant species into deeper time providing the basis for future species-level investigations into the impacts of past climate change in California.

15: 3:15 PM-3:30 PM
Presenter: WAGNER, PETER J.

USING STRATIGRAPHIC COMPATIBILTY TO TEST HYPOTHESES OF RELATIONSHIPS BETWEEN CHARACTER EVOLUTION AND PHYLOGENY

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Workers sometimes suggest that particular characters or character combinations affect the long-term evolution of clades. Alternatively, workers sometimes hypothesize that particular characters are novel to particular subclades within larger clades. These ideas make predictions about the distribution of compatible character state pairs. Compatible character pairs break down into state trees of 00, 01 and 11, with multistate characters offering multiple trees. If the "middle" pair (01) appears first in the fossil record, then the most probable state tree is 00<-01->11 (e.g., rabbits<-mammals->bears or mammals give rise to multiple subclades independently). If an "end" pair appears first (e.g., 00 or 11), then it is much more probable that the state tree is 00->01->11 (e.g., mammals->carnivores->bears or hierachical evolution of taxa within subclades). We expect the former pattern (nonhierarchical compatibility) to be more common than the latter pattern (hierarchical compatibility). Characters with high compatibility tend to have low rates of change relative to taxon sampling. In such cases, the expectation is that numerous primitive (e.g., "mammal") state pairs will accumulate before the first derived state pair originates. If rates of diversification and/or character state evolution do not change, then it is most probable that the second derived pair will originate from the primitive pair, resulting in the "middle" pair appearing first in the record. Thus, rabbit<-mammal->bear pairs should be more common than mammal->carnivore->bear pairs. Analyses of 38 trilobite matrices reveal that 4 of the 38 show significantly more non-hierarchical stratigraphic compatibility than expected. This is consistent with ideas of novel character generation in some portions of larger clades. Conversely, 9 of the 38 show significantly more hierarchical stratigraphic compatibility than expected given phylogeny and compatible character evolution. The latter is consistent with hypotheses of elevated diversification rates for taxa with derived pairs relative to those with primitive pairs.

15: 4:00 PM-4:15 PM
Presenter: BELL, ALYSSA K.

SYSTEMATIC RELATIONSHIPS OF THE CRETACEOUS SEABIRDS HESPERORNITHIFORMES

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As highly derived, foot-propelled diving birds of the Cretaceous, the Hesperornithiformes serve as an excellent group for studies of avian specializations in the Mesozoic. Additionally, since their initial description by O.C. Marsh in the 1870's, hesperornithiforms have become one of the most diverse and abundant groups of Cretaceous birds. To date, 27 species in three

families from localities across the globe spanning the Early and Late Cretaceous have been proposed, however the validity of several of these taxa has been challenged. As a group hesperornithiforms were flightless, toothed diving birds well adapted for their marine habitat. These birds display a wide range of body sizes, from a bird the size of a modern Western Grebe to birds twice the length of an Emperor Penguin, yet all possess an advanced hind limb structure unique among Mesozoic birds. Despite this morphologically and geographically diverse fossil record, virtually no research has been undertaken to clarify the evolutionary relationships of these unusual birds. In order to address this gap in our understanding of early bird evolution, a robust cladistic database is being developed for the analysis of relationships among all hesperornithiform species. This paper presents the results of a preliminary cladistic analysis of the most well-known hesperornithiform birds. The species selected for this preliminary analysis are well-represented in the fossil record with unambiguous taxonomy. Future research will focus on resolving the taxonomy of more poorly known hesperornithiforms such that all valid taxa may be included in future systematic analyses.

15: 4:15 PM-4:30 PM
Presenter: CAMPBELL, KENNETH

A NEW GENUS FOR THE EXTINCT LATE PLEISTOCENE OWL (AVES: STRIGIFORMES) FROM RANCHO LA BREA, CALIFORNIA

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A review of the strigiform specimens from the upper Pleistocene Rancho La Brea asphalt deposits previously referred to the extinct owl *Strix brea*, and all newly identified specimens referrable to that species, has provided a clearer picture of this extinct owl. This review and redescription of *Strix brea* reveals that it is more appropriately placed in a new genus whose affinities remain unclear. A variety of morphometric data is provided along with the more detailed osteological descriptions of this extinct species. A total of 138 specimens from the Rancho La Brea collections in the George C. Page Museum, representing a minimum of 23 individuals, are referred to this extinct owl. An additional seven specimens of this extinct species were confirmed in collections from the upper Pleistocene asphalt deposits of Carpinteria, California. A review of all the fossil owls from Rancho La Brea indicates a greater diversity than previously recognized. An explanation for the large number of owls, which exceeds that for vultures, is presented.

15: 4:30 PM-4:45 PM

Presenter: REICH, MIKE

NEW INSIGHTS INTO EARLY DIVERSIFICATION OF SEA CUCUMBERS (ECHINODERMATA: HOLOTHUROIDEA)

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Compared to other modern Echinodermata, the early evolutionary history of holothurians is poorly understood. In part, this is due to their disjunct endoskeleton with ossicles and calcareous ring elements, which are released following decomposition of the surrounding tissue. Newly sampled Silurian sections on Gotland, Sweden, yield well-preserved echinozoan echinoderms, including more than 1000 isolated calcareous ring elements. The studied material is Telychian to Ludfordian (Early to Late Silurian) in age and reveals the presence of several new taxa of arthrochirotid (extinct) and apodid sea cucumbers as well as stem group representatives. The calcareous pharyngeal ring (CR) is a defining feature of sea cucumbers and is possessed by nearly all extant species. The CR supports the pharynx, the water vascular system and tentacle ampullae in part, as well as providing insertion points for the muscles etc. Therefore calcareous rings are distinct for systematics and phylogeny, and important evolutionary structures.Further material comes from Katian Öjlemyr flints (Ashgill, upper Pirgu stage) and the so-called Red Orthoceras limestones (Darriwlian in age), both material from Sweden. Especially the partly silicified limestones (Öjlemyr flints) yield well-preserved holothurian ossicles, including new or poorly known taxa of elasipodid, aspidochirote, and apodid holothurians or stem group representatives. This study shows that the Holothuroidea diversified significantly through Late Ordovician and Silurian times.

15: 4:45 PM-5:00 PM
Presenter: HANNIBAL, JOSEPH T.

INSIDE-OUT ARTHROPODA: NEW TAXA AND THE REINTERPRETATION OF THE ENIGMATIC DEVONIAN PHYLLOCARID *OHIOCARIS*

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Study of two new phyllocarid arthropods, one from the Famennian Chagrin Shale of Ohio and another from a ?Devonian cone-in-cone bed without recorded provenance, as well as specimens of the phyllocarid *Echinocaris*, has prompted a reinterpretation of the rare and enigmatic phyllocarid *Ohiocaris*. One of the new taxa is represented by a carapace that is clearly seen in ventral view; the other is represented by a dorsal view preserving a convex-upward shape. Phyllocarids such as the latter with broad carapaces that are preserved in concretions tend to be preserved with at least some of their originally convex-upward shape.

The holotype of *Ohiocaris*, preserved in a concretion, however, is supposedly preserved in a "concave up" position. In this reinterpretation of *Ohiocaris*, the carapace becomes convex-side up, the "left valve" of the carapace becomes the right, and the grooves bordering the "median dorsal plate" are interpreted as ridges. This reinterpretation explains some of the enigmatic features of *Ohiocaris*, including its supposed dorsally-concave preserved shape, its "rotated abdomen," mandibles deeply impressed "through" the carapace, and the presence of an unusually wide "median dorsal plate." In this reinterpretation, *Ohiocaris*, like the two new forms, lacks a median dorsal plate and retains subtle indications of a midline (hinge line). This reinterpretation is in agreement with the previous reinterpretation of the holotype of the spinous phyllocarid *Pephricaris* possibly (now probably) being preserved in ventral view. If these reinterpretations of the holotypes of *Ohiocaris* and *Pephricaris* are correct, the large mandibles mask key features of these taxa. Furthermore, the oblique fold on the holotypes of *Ohiocaris* and *Pephricaris*, a synapomorphy of the suborder Pephricaridina, is not present on one other spinous specimen assigned to the genus *Pephricaris*.

15: 5:00 PM-5:15 PM
Presenter: MONSON, CHARLES

SYSTEMATICS OF A NEW HYSTRICURID TRILOBITE SUBFAMILY FROM THE LOWER ORDOVICIAN OF LAURENTIA

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Members of the trilobite family Hystricuridae have been given considerable importance in some biostratigraphic and phylogenetic schema, but inadequate work on the alpha taxonomy of the group has made it difficult to fully evaluate these interpretations. For example, *Paraplethopeltis* has been treated as a biostratigraphically significant taxon for the upper Skullrockian Stage of the Lower Ordovician Ibexian Series (although some studies have assigned Stairsian material to the genus), and larval morphologies of putatively *Paraplethopeltis*-affiliated species have been put forward as evidence that those species belong to a proetid stem lineage. Even so, the actual membership of *Paraplethopeltis* and its phylogenetic position within Hystricuridae have never received comprehensive treatment. Over a dozen species have been at least tentatively affiliated with *Paraplethopeltis* by various authors, but many of these determinations were based on scant material and/or were primarily intended to emphasize probable stratal correlations. Some workers have argued that *Paraplethopeltis* should be restricted to the type species or considered a subgenus of Hystricurus. We recognize *Paraplethopeltis* as a valid genus and clarify its membership. Based on new material from shallow subtidal deposits in Idaho and the Ibex area of Utah, we

diagnose one new species of *Paraplethopeltis*, one new genus of tuberculate hystricurids, and new species of *Paenebeltella* and *Glabretina*. These genera make up a new hystricurid subfamily which is currently known from the Skullrockian and Stairsian stages of the Ibexian.

15: 5:15 PM-5:30 PM
Presenter: RAVELSON, M. LOVA TANTELY

CROCODILIFORM OSTEODERMS FROM THE MAESTRICHTIAN MAJUNGA BASIN: DESCRIPTION, COMPARISON, SYSTEMATICS, & PALEOECOLOGY

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Joint Stony Brook University and Tananarive University expeditions to the Upper Cretaceous Maevarano Fromation (Berivotra area, northwestern Madagascar) have yielded abundant crocodiliform skeletal elements from as many as seven ecologically diverse taxa. Isolated osteoderms, for which identifications are problematic, are some of the most common elements. Over three hundred crocodiliform osteoderms from twenty-three localities were examined for this study. Autochthonous crocodiliform skeletal material found with osteoderms facilitates the taxonomic determination of previously described taxa such as *Araripesuchus, Mahajangasuchus,* and *Simosuchus*. Surface texture of osteoderms from the latter two taxa can be compared with the texture of cranial bone to identify taxa from localities where associated skeletal material is not present. Analysis of isolated osteoderms suggests four or more additional morphotypes grouped according to similarity of texture, size, and shape. Several specimens possess unique features likely representing unnamed or unknown taxa. Osteoderms from different regions of the body have paleoecological implications, especially those from the caudal domain.

Session No. 16, 1:30 PM; Tuesday, 23 June 2009
Symposium S9. Experimental Taphonomy

16: 1:30 PM-1:45 PM
Presenter: PARSONS-HUBBARD, KARLA

STILL TOGETHER AFTER ALL THESE YEARS: THE PERSISTENCE OF ARTICULATION IN CRABS AND URCHINS AFTER 13 YEARS

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We assume that skeletal articulation is ephemeral. Scavenging, bacterial decay, and physical disturbance should lead to rapid disarticulation in nearly all depositional environments. However, a test of the longevity of crab and urchin remains suggests that articulation may be more durable than once thought. Fresh frozen blue crab, *Echinometra* urchin, and *Heterocentrotus* (pencil urchin) carcasses were loosely sewn into 4-mm mesh bags and placed on the sea floor in many environments at depths from 15m to 600m. Although the carcasses were enclosed, most samples remained in contact with fresh seawater as evidenced by the growth of encrusting filter-feeding bionts on the remains. After two years whole *Echinometra* and *Heterocentrotus* tests (with spines no longer attached and lantern parts disarticulated) were common (58% and 71% respectively). The prevalence of articulation did not change after six years and even 13 years (54% of *Echinometra* and 77% of *Heterocentrotus* tests were whole in year 13) and only two were entirely gone from their mesh bags (out of 101 urchins collected in year 13). Interestingly, articulation at deeper aphotic sites was rare, and carbonate sands and muds, no matter the depth, returned articulated tests 70-85% of the time, while siliciclastic mud preserved urchin articulation only 40% of the time. Of 68 crabs deployed for 13 years, 19% were retrieved with articulated claws. Another 25% retained significant amounts of carapace and claw material, and only six of 68 experiments came back with no crab remains at all. There were no trends in crab destruction related to depth/light levels, but 70% of crabs deployed in carbonate mud retained articulation. The experimental data show that with only minor protection (mesh bag), urchin tests and crab claws are quite durable on decadal scales at the sediment water interface.

16: 1:45 PM-2:00 PM
Presenter: WALKER, SALLY E.

BREAKING UP IS HARD TO DO: MOLLUSCAN CARBONATE RESISTS DISSOLUTION AFTER THIRTEEN YEARS ON THE COLD, SOFT-SEDIMENT DEEP-SEA FLOOR

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Particulate carbonate dissolution in deep, cold-water settings is influenced by a number of factors. At deep-water depths where temperatures are low and pressures are great, aragonite may go into solution. However, even in saturated conditions, dissolution can occur associated with biological activity. Experiments using foraminifera illustrate this trend, but we know little about metazoan carbonate (i.e., mollusc shells) and their dissolution potential in these habitats. To understand the preservation potential of aragonitic molluscan shells in deep-water environments, experimental arrays composed of "caged", tethered, and freely scattered gastropod shells were deployed via submersible in shelf (180 m) and deeper environments (to 571 meters) in the Gulf of Mexico. We assumed that when we deployed these shells in 1993, we would never see them again. We were wrong. After thirteen years on the sea floor, aragonitic carbonate is exceptionally well preserved. At outer continental shelf depths (180 m), waters above the sediment-water interface and porewaters within 20 mm of burial depth were supersaturated with respect to aragonite (Omega 2.11, pH 7.93). Consequently, exposed and buried shells were in pristine condition. Aragonite shells at deeper sites varied in susceptibility to dissolution: at 571 m (Omega 1.28, pH 7.75), exposed shell surfaces were starting to dissolve, but buried shells or shell surfaces that rested on the sediment were protected from dissolution. In contrast, chemosynthetic sites (clam site: 529 m, Omega 1.32, pH 7.77; tube-worm site: 532 m, Omega 1.36, pH 7.78) had extensive dissolution on exposed and buried shells that was mediated by microbial activity. Overall, the preservation potential for aragonitic shells is high in most of our cold, deep-water sites; even at chemosynthetic sites, shell fragmentation resulting from extensive dissolution had not occurred after more than a decade on the sea floor.

16: 2:00 PM-2:15 PM
Presenter: RAYMOND, ANNE

MUD, PINE CONES, WALNUTS AND WOOD: THE FATE OF LAND PLANT DEBRIS IN MARINE SILICICLASTIC ENVIRONMENTS

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Permineralized wood, cones and seeds from Cretaceous and Cenozoic marine siliciclastic strata contribute significantly to land-plant diversity and enable us to trace the evolutionary history of modern conifers, angiosperms, ferns, and cycadeoids. Yet the plant taphonomy of these deposits is largely unknown. Many Cretaceous and Cenozoic plant-bearing marine deposits occur in association with cold seeps, including the Middle and Upper Yezo Fm. of

Hokaido, Japan, the Budden Canyon Fm. of California (both Cretaceous), and the Makah Fm. of Washington State (Oligocene). Other ancient hydrocarbon seeps associated with fossil wood include: the Cretaceous Tepee Buttes (Colorado) and Christopher Fm. Mounds (Canadian Arctic); the Paleocene Panoche Hills Seeps (Moreno Fm. California); and the Eocene Lincoln Creek Fm. (Washington). Wood, cones and seeds deployed on the sea floor help explain the connection between hydrocarbon seeps and land plants preserved in marine environments. As a part of the Shelf-Slope Experimental Taphonomy Initiative (SSETI), we deployed 6 varieties of wood, 2 cone species, and walnuts on the sea floor in the Gulf of Mexico in seep and non-seep environments, and retrieved samples at intervals of 2, 5, 7, 10 and 12 years. Using a variety of measures (percentage of samples recovered, loss of sample volume, erosion of walnuts), non-seep sites experienced significantly more taphonomic loss of plant debris than seep sites. Walnuts were the most resistant and conifer cones the least resistant plant debris in the deployed samples. Whereas no cones survived exposure on the sea floor at non-seep sites, cones were recovered from hydrocarbon seep sites after 12 years on the sea floor. Possible explanations for the preferential preservation of land-plant debris near seep sites include rapid burial of plant material due to higher rates of effective sedimentation, and inhibition of marine detritivores.

16: 2:15 PM-2:30 PM
Presenter: WANG, WEI

THE FIRST STEP OF SOFTBODY FOSSIL PRESERVATION: ANIMALS IN SILICA SOLUTION

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Well preserved fossils like those from the Chengjiang fauna shales (Early Cambrian), Rhynie cherts (Early Devonian) are well documented, softbody impression fossils that present important details of early life. It is well documented and discussed for these fossils that preservation of softbody fossils was caused by rapid deposition within anoxic environments, but few have reported on experimental results. For the Chengjiang fauna the possible depositional paleoenvironment may have been close to a delta near land. Comparable modern environments are supersaturated in silica. We designed experiments for emulating softbody preservation of modern small animal (scaleless fish) in silica solution, in oxygenated and anoxic conditions. Our experiments indicate that skin and intestines can be preserved well in silica solution over even some months or longer in open environments, but muscles and other parts degraded very fast. The muscles and other parts rotted rapidly, being preserved for just a few days. SEM observation indicates that skin and intestines are easily coated by nano size opal which can preserve structures of skin details, but muscles and some other parts

are dissolved and degrade within one week. Duration of preservation of the softbody structure does not appear related to the degree of oxygenation. Skin and intestines mainly contain collagen, but muscles and other parts are different proteins, and from correlated experiments between muscles and collagen, collagen material can be preserved well and is easily coated by opal. Here, we suggest softbody fossil impression may mainly be correlated with formation of the animal body, and collagen should be a viable material for longer preservation as softbody fossil impression, especially in silica supersaturation.

16: 2:30 PM-2:45 PM
Presenter: NOTO, CHRISTOPHER R.

THE INFLUENCE OF POST-BURIAL ENVIRONMENT ON VERTEBRATE PRESERVATION: AN EXPERIMENTAL TAPHONOMIC STUDY

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Post-burial taphonomic processes acting on vertebrate remains have received considerably less attention than surface taphonomic processes. While studies of surface processes have provided a wealth of information, this represents only a part of the fossilization pathway. However, an empirical understanding of post-burial processes is also incomplete. Laboratory-based taphonomic experiments have been used successfully to study the decay and diagenesis of invertebrate and plant remains, providing critical information on fossilization mechanisms. A similar approach should prove useful for vertebrate taphonomy. To investigate short-term processes critical in the decay and diagenesis of buried bone, a 14-month controlled taphonomic experiment was performed that explored the individual and collective effects of 1) sediment hydrology [sand vs. silt/humus], 2) bone size [deer vs. rabbit vertebrae], and 3) plant association [gymnosperm vs. angiosperm] in controlled laboratory microcosms. Data included the measurement of leachate for calcium (Ca) using DCP-AES, sediment pH, bone mass change, and quantification of bone density change using CT imaging. Results show that plant type, sediment type, and bone size all significantly interact to influence bone decay, with the effect depending on the context. Sediment type had the strongest influence overall, driving differences in pH, anoxia, mass/density loss, and Ca leaching. Plants were found to release substantial amounts of Ca, but did not differ by type. This experiment suggests that the process of bone decay: 1) is reduced by the presence of abundant plant material, 2) occurs at a constant rate independent of element size, and 3) is sediment specific: high-flow sand-dominated sediments erode bone at a high rate, while low-flow silt/humus-dominated sediments affect bone more slowly. This study has important implications for taphonomic interpretation of individual fossil sites, understanding facies control of fossil preservation, and the use of vertebrate fossil data in large-scale paleobiogeographic reconstructions.

16: 2:45 PM-3:00 PM
Presenter: BEST, M. R.

SHELL TAPHONOMY EXPERIMENTS ACROSS LATITUDES: CONTRASTS IN NET PRESERVATION, PROCESSES, AND PATHWAYS

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In order to test for megabiases across latitudes and depositional systems, shell degradation experiments were deployed in 27 marine and freshwater study sites (0-150m water depth) in 8 geographic areas. These included both carbonate and siliciclastic environments across tropical, temperate, and polar latitudinal zones. Experimental arrays used fresh *Mytilus edulis* and *Mercenaria mercenaria* valves (8-16/treatment), deploying them above, at, and below the sediment/water interface for periods ranging from 8 days to over 5 years. In total, over 6000 shells were used. Data was collected on net weight change, and across scales of observation including macroscopic taphonomic analysis and SEM characterization of microstructural alteration. In one year, average net weight changes range across 2 orders of magnitude among sites and treatments, with maximum gain in tropical exposed shells (91%) and maximum loss in freshwater exposed shells (-51%). If shells absent at retrieval are included, max averages reach -97%. For buried *Mytilus edulis* shells, loss in temperate environments plateaus at an average of 7% across all environments, whereas in tropical environments this plateau is at 2.5%. Exceptions such as tropical seagrasses show constant rates of shell loss. Skeletal weight changes result from, in decreasing order, encrustation, breakage, erosion/bioerosion, maceration, dissolution, and authigenic mineral precipitation. Weight gain, due to encrustation and authigenic mineral precipitation, is more significant in the tropics, while shell weight loss, due to breakage, erosion, bioerosion, maceration, and dissolution, is more significant in temperate and polar latitudes. Net microstructural shell loss shows decreasing rank order across environments: temperate freshwater > > polar marine >? temperate marine ? tropical marine sea-grass > tropical carbonate marine > tropical siliciclastic marine. Significant differences across latitude and depositional environment indicate potential for significant bias in the preservation of skeletal carbonate. Attention to spatial and temporal scales of modification is important to predict net preservation.

16: 3:00 PM-3:15 PM
Presenter: ASHTON-ALCOX, KATHRYN

ON AGAIN-OFF AGAIN: THE RELATIONSHIP OF BIONTS AND TAPHONOMIC PROCESSES IN MOLLUSCAN TAPHOFACIES FORMATION ON THE CONTINENTAL SHELF AND SLOPE: EIGHT-YEAR TRENDS

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In 1993 and 1994, SSETI (Shelf and Slope Experimental Taphonomy Initiative) deployed shells of a suite of molluscan species in a variety of environments of deposition covering a range of depths and sediment types, with the goal of measuring taphonomic rates over an extended period of time. In 1999 and 2001, SSETI retrieved shells from 41 locations in the Bahamas and on the Gulf of Mexico continental shelf and upper slope that had been on the seafloor for eight years. Here, we compare taphonomic signature with biont accumulation after eight years to examine the interaction of biont presence with shell preservation. Taphonomic state rarely correlated with the distribution of biont guilds among environments of preservation (EOPs). The preservable and nonpreservable biont guilds were also routinely orthogonal. Several coincidences of taphonomic trait and biont guild did occur. For example, green discoloration consistently co-occurred with boring algae while bacterial films were associated with the development of chalkiness and a soft shell surface. EOPs of disparate taphonomic signature and biont guild complement occur in similar sediment types and environments with similar rates of burial. In particular, lack of biont coverage is no more a reliable indicator of rapid burial, than is a limited degree of shell degradation. The suggestion that some preservable bionts might protect shells from taphonomic processes is not well supported by the data. Shell preservational state, including taphonomic signature and biont coverage, is influenced in a complex way by environment of deposition. Clustering of EOPS reveals that visually distinctive environments of deposition may be taphonomically and biotically similar. Visually similar environments of deposition may be quite disparate in taphonomic state and biont complement.

16: 3:15 PM-3:30 PM
Presenter: KOSLOSKI, MARY

DISTINGUISHING BIOTIC VS. ABIOTIC BREAKAGE OF THE QUAHOG, MERCENARIA MERCENARIA, BY THE STONE CRAB, MENIPPE MERCENARIA: AN EXPERIMENTAL TAPHONOMIC APPROACH

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Sub-lethal predation traces are often used to study the fossil record of predation. Lethal predation traces are notably less common as predation indicators, since lethal acts of predation such as peeling and crushing often severely damage or destroy shells, leaving only fragments (with drillholes serving as a notable exception). Past work on durophagous predation in the fossil record has studied the occurrence of adaptive morphologies in predator and prey genera. A method for assessing whether or not shell fragments have resulted from lethal predation would allow a more accurate assessment of predation frequencies. This study system focuses on an unusually powerful predator for the western Atlantic, *Menippe mercenaria*. Extant since the Pliocene, this robust crab preys on a wide variety of mollusks and is capable of generating very high crushing forces. Current research aims to use living (and very recently dead) organisms to test whether or not lethal breakage of clam shells (*Mercenaria mercenaria*) caused by the stone crab (*Menippe mercenaria*) can be distinguished from breakage wrought by abiotic sources. To this purpose, clams have been fed to stone crabs over the past year, and these instances of known lethal breakage have subsequently been compared to abiotic breakage induced by tumbling and crushing. Preliminary results suggest that while lethal biotic breakage is not always obvious, in a large proportion of cases (40% to 70%), breakage can be confidently assigned to the correct biotic source. The percentage correctly identified increases with larger valve fragment size, and also increases when crabs with smaller chelae are used experimentally. The methods used to identify biotic breakage will be applied to bulk samples from the Plio-Pleistocene, which may allow estimation of predation rates in past ecosystems.

16: 3:30 PM-3:45 PM
Presenter: POWELL, ERIC N.

TAPHONOMIC CHARACTERISTICS DO NOT ALWAYS INDICATE SIMILAR ENVIRONMENTAL PROCESSES: SSETI AFTER 12 YEARS

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Sites in the Shelf and Slope Experimental Taphonomy Initiative (SSETI) for the Gulf of Mexico span a variety of environments of preservation (EOP) including terrigenous sands and muds, brine and petroleum influenced regions, and deepwater carbonate bottom. Suites of molluscan shells have been deployed at these sites since 1993. Sample retrievals were conducted at 2 years, 8 years, and 13 years after deployment. Between-habitat differences in shell degradation rate were significant for most 'physical' taphonomic attributes and generally

highly so. These included: dissolution, abrasion, edge-rounding, and discoloration. Between-species differences were minor in comparison. Thus, taphofacies, the product of the independent actions of a suite of taphonomic processes, originate from and provide information on environmental conditions. Species composition has a lesser inherent influence on the outcome. Not uncommonly, the rates of change in shell condition differed significantly between EOPs although the direction of change was coincident. This was particularly true of the summary indices such as maximum discoloration or the average degree of dissolution on the outer (for bivalves) and spire (for gastropods) shell surfaces. The taphonomic process is highly nonlinear in time and this nonlinearity is EOP-dependent, becoming a defining attribute leading to disparate taphofacies types. Some taphonomic processes cannot proceed expeditiously without prior preparation of the shell through other taphonomic means. Some taphonomic conditions such as chalkiness can be intermediate states. In most EOPs, the incidence of chalkiness declined after two years as the surface evolved into more extreme surface conditions. The presumption that similar taphonomic characteristics between EOPs are indicative of similar environmental processes operating at similar rates is falsified by SSETI sites in which similar taphonomic indices at Year 13 accrue from different time-varying degradational rates during the preceding years.

Session No. 17, 2:00 PM; Tuesday, 23 June 2009
Poster Session PS2. Biostratigraphy, Education, Palebiogeography and Paleoclimatology

17: 2:00 PM, Booth 1
Presenter: LOCH, JAMES D.

FINDING THE CAMBRIAN-ORDOVICIAN BOUNDARY IN LAURENTIAN PLATFORM CARBONATES: REFINED SPECIES CONCEPTS IN THE TRILOBITE GENUS SYMPHYSURINA

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Precise recognition of the international Cambrian - Ordovician boundary using trilobites and other macrofossils in the extensive carbonate platform deposits of Laurentian North America has been difficult since the GSSP for the base of the Ordovician System was defined in the Green Point section, Newfoundland, Canada at the FAD of the conodont *Iapetognathus fluctivagus*. At the time the GSSP was established it was believed that this horizon could be

closely approximated in Laurentian sequences by the base of the *Symphysurina bulbosa* Subzone, the medial subzone of the *Symphysurina* trilobite Zone. However, more recent work has shown that an overly broad species concept for S. bulbosa was used in defining and correlating that boundary.In this study, we document the distribution of 3 new species of *Symphysurina* from the Cambrian - Ordovician boundary interval in two of the most thoroughly studied sections in the western USA: the Bat Cave Gulch section (Bliss Formation and El Paso Group, Caballos Mountains, New Mexico) and the Lawson Cove section (House Limestone, Ibex region, Utah). In both sections, the C-O boundary has been placed precisely at the FAD of *Iapetognathus fluctivagus* in conjunction with the cosmopolitan trilobite *Juyjuyaspis* in relation to closely constrained conodont zones and subzones. *Symphysurina new species A* (characterized by an elevated pygidial spine) and *S. new species B* (characterized by an elongate pygidial axis that reaches the posterior margin), largely precede the C - O boundary. *S. new species C* (a punctate species characterized by a broad, upwardly concave pygidial border) was recovered from the basal Ordovician. The recognition of any of these short-ranging species will allow identification and differentiation of the highest Cambrian and lowest Ordovician portions of the *Symphysurina* Zone in subsequent studies.

17: 2:00 PM, Booth 2
Presenter: GOLDMAN, DANIEL

BEDDING PLANE CO-OCCURRENCE OF BIOSTRATIGRAPHICALLY USEFUL CONODONTS AND GRAPTOLITES IN ORDOVICIAN SHALE SEQUENCES

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Bedding plane co-occurrence of biostratigraphically useful conodonts and graptolites in Ordovician shale sequences enhances the overall precision of correlation between platform and deep water successions. Darriwilian shale successions in Tarim, western China, and Alabama and Idaho in North America contain the key conodont zonal indicator species *Pygodus anitae*, *P. serra*, and *P. anserinus* (as well as more long-ranging taxa) on bedding planes with *Pterograptus elegans* to *Nemagraptus gracilis* Zone graptolites. Three of the Pygodus bedding plane associations appear to be partial conodont apparatuses. The occurrence of bedding plane conodonts with graptolites across the Sandbian-Katian boundary at Black Knob Ridge (Atoka County, Oklahoma, U.S.A.) was a key factor in the selection of Black Knob Ridge as the GSSP for the base of the Katian, the middle stage of the Upper Ordovician Series. The *Amorphognathus tvaerensis* Zone - *A. superbus* Zone boundary is tentatively identified at 5.7 meters above the base of the Bigfork Chert in the lower

Diplacanthograptus caudatus graptolite Zone. New collections across the Sandbian-Katian succession at the Hartfell Score section near Moffat, Scotland also contain biostratigraphically important conodonts. *Amorphognathus tvaerensis* is present 1.6 meters below the FAD of *D. caudatus* and *A. superbus* is present 9.4 meters above it. Thus, at Hartfell Score the *A. tvaerensis* Zone - *A. superbus* Zone boundary occurs within an interval of 11 meters in the *D. caudatus* graptolite Zone. These bedding plane co-occurrences provide more precise ties between graptolite and conodont biozonations and support the potential for additional resolution with further collecting at these and other localities. Not all Sandbian-Katian successions have yielded biostratigraphically important conodonts. For example, the Læså section at Vasegård on Bornholm is dominated by long-ranging, coniform conodont taxa (e.g., Scabbardella altipes). This suggests that graptolite-bearing dark shale successions may contain at least two distinct conodont biofacies

17: 2:00 PM, Booth 3
Presenter: ABOUSSALAM, ZHOR SARAH

NEW CONODONT FAUNAS FROM AROUND THE MIDDLE/UPPER DEVONIAN BOUNDARY OF THE MONTAGNE NOIRE (S. FRANCE)

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Since the pioneer papers by Feist and Klapper (1985) and Klapper (1985), the southern Montagne Noire is famous for its important conodont faunas around the Middle/Upper Devonian boundary, which allowed to fix the basal Frasnian GSSP at Col de Puech de la Suque. So far, only the ancyrodellids have been documented in fine detail. Our study concentrated on two sections, Col de Tribes and the improved trench at La Serre A. For comparison the GSSP succession was re-sampled right around the boundary. At Col de Tribes a relative thick succession of crinoidal limestones of the *norrisi* Zone transgressed unconformably on the Pharciceras-bearing topmost Middle Givetian *semialternans* Zone. Partly very rich assemblages include first records of taxa for the region (*Polygnathus tafilensis*, *aequidivisus*, *dengleri sagitta*, *Klapperina vysotzkii*), downwards range extensions (*Playfordia primitiva*), and unusual new taxa, representing new, rare species of *Polygnathus*, "*Ozarkodina*", and *Schmidtognathus*, as well as two new genera. At the GSSP rare early morphotypes of *Ancyrodella rotundiloba pristina* precede more advanced morphotypes and *Ad. rotundiloba binodosa* (Bed 42b/43). At La Serre, an *Ad. rotundiloba pristina* fauna is first found between limestones of the *norrisi* Zone and the onset of black shales. As in the Tafilalt (Morocco), this shows that the main eustatic rise and hypoxic pulse of the global Frasnes Events post-dates the *pristina* or MN 1 Zone. The new data are important for a better understanding of the significant end-Givetian conodont faunal overturn. The extinction of all Klapperina,

Schmidtognathus and some other forms (*Po. limitaris*, "*Ozarkodina*" *plana*) towards the end of the *norrisi* Zone is confirmed. *Po. paradecorosus*, *alatus*, *Mesotaxis guanwushanensis* and *"Mesotaxis" ovalis* enter in the transgressive *norrisi* Zone. The latter are associated with nothognathellan Pb elements that support the idea that the descendant "*Mesotaxis*" *unilabius* Group represents an un-named genus homoemorphic to *Klapperina*.

17: 2:00 PM, Booth 4
Presenter: KRAFT, PETR

THE KRALUV DVUR FORMATION - UPPER KATIAN DIVERSITY MAXIMUM AND GRAPTOLITE ASSEMBLAGES IN THE PRAGUE BASIN (CZECH REPUBLIC)

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The Kraluv Dvur Formation represents an important lithostratigraphic unit in the Prague Basin. It is of the upper Katian age and beginns with a prominent change in sedimentation, traceble in the whole "Mediterannean Province". Black shale lithofacies was succeeded by fine greenish mudstones with micritic carbonate nodules. Change in lithology is associated with a prominent faunal change. The *Aegiromena-Drabovia* fauna of underlying units was replaced by low diversified associations (assigned to *Foliomena* Fauna) the diversity of which sharply increased in the uppermost part of the formation. This peak of diversity is, however, followed by a dramatic impoverishment in response to global climatic changes.Graptolite fauna is rare to absent in the majority of the Upper Ordovician successions of the north-western peri-Gondwana. Within this graptolite "desert", Katian succession of the Kraluv Dvur Formation makes a kind of moderate exception. Rare normalograptids and dicellograptids have been reported since the end of 19th century. "*Glyptograptus*" teres Perner, and some, so far undetermined biserial rhabdosomes are known from the lower part of the formation; two dicellograptid species (*Dicellograptus laticeps* Storch and *Dicellograptus* cf. *morrisi* Hopkinson), rare plegmatograptids ("*Plegmatograptus chuchlensis* Pribyl"), early normalograptids (*Normalograptus angustus* (Perner)) and so far undescribed climacograptids and pararetiograptids come from the middle and upper parts of the Formation. *Normalograptus ojsuensis* (Koren` et Mikhaylova) sensu Storch (1989) is confined in the topmost part of the formation. Observed patterns of graptolite occurrence reflect global climatic changes along with specific local conditions. The Grant Agency of the Academy of Science of the Czech Republic supported this contribution through the project No. IAA301110908.Storch, P. (1989): Late Ordovician graptolites from the upper part of Kraluv Dvur Formation of the Prague Basin (Barrandain, Bohemia). Vestnik Ustredniho ustavu geologickeho, 64(3): 173-186.

17: 2:00 PM, Booth 5
Presenter: CASIER, JEAN-GEORGES

OSTRACODS, LITHOFACIES AND MAGNETIC SUSCEPTIBILITY OF THE GIVETIAN/FRASNIAN PARASTRATOTYPE AT NISMES (DINANT SYNCLINORIUM, BELGIUM).

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The auxiliary stratotype for the G/F boundary in neritic facies exposes the 15 last meters of the Fromelennes Fm (top of the Givet Group) composed of a succession of pluri-decimetric limestone beds, and the stratotype for the Nismes Fm (base of the Frasnes Group) containing the nodular limestones of the Pont d'Avignon Mbr, and the shaly Sourd d'Ave and La Prée members. The G/F boundary corresponding in neritic facies to the entry of the conodont species *Ancyrodella rotundiloba*, is fixed in the base of the Sourd d'Ave Mbr.About 1,700 ostracods have been extracted from 69 samples collected in the Nismes section and 46 taxa belonging to the Eifelian Mega-Assemblage are recognized. The study displays that the only significant change in the ostracod fauna in the Nismes section is the progressive passage from lagoonal and semi-restricted environments to open marine environments in the upper part of the Fromelennes Fm, and consequently several meters below the G/F boundary.The sedimentological analysis confirms that the G/F boundary in the lower part of the Sourd d'Ave Mbr does not correspond to a particular event. The evolution of the lithological curve in the Nismes section allows the recognition of 5 sequences recording a general drowning of the Givetian carbonate platform. No effective barrier system worked at that time suggesting that the Givetian carbonate platform was already dismantled before its definitive drowning. The magnetic susceptibility measured on 95 samples in the Nismes section displays on the contrary a clear change of signal straddling the G/F boundary.The *Polyzygia beckmanni beckmanni* and *Favulella lecomptei* zones established on metacopid ostracods are recognized at Nismes, and the simultaneous presence of these two species in a sample collected in the upper part of the Sourd d'Ave Mbr implies the emendation of the definition of the *Polyzygia beckmanni beckmanni* Zone.

17: 2:00 PM, Booth 6
Presenter: CIURCA, SAMUEL J., JR.

THE EARLY DEVONIAN PTERYGOTID (EURYPTERIDA), *ACUTIRAMUS*, IN NEW YORK STATE

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Recent years have seen a renewed interest in eurypterid faunas and nowhere else does there seem to be an assemblage of distinctive eurypterid horizons than in the state of New York and adjacent areas (Pennsylvania, West Virginia and Ontario, Canada in particular). Except for a eurypterid described by Clarke and Ruedemann in 1912, little is known about the eurypterid horizons above the Silurian-Devonian boundary. Within the type areas of the Early Devonian Olney and Manlius Limestones of central New York, facies changes are rapid but the distribution of eurypterid remains was traced across the outcrop belt. While *Erieopterus microphthalmus* is the most common and characteristic eurypterid occurring in the limestone facies, the pterygotid (*Acutiramus*) is common and characteristic of a distinctive lithology associated intimately with stromatoporoid biostromes and brachiopods, gastropods and prolific algal remains. Newly recovered material includes excellently preserved telsons, metastoma, coxae and nearly complete chelicerae. This material, together with specimens collected earlier (Ciurca, 1978), are assigned to *Acutiramus* n.sp. based upon similarity with the well-known *Acutiramus cummingsi* from the Late Silurian Williamsville Waterlime (Bertie Group). Two (eurypterid) biofacies are now recognized within the Early Devonian Manlius Group; an *Erieopterus* Biofacies and a pterygotid or Acutiramus Biofacies each occurring within apparent lagoonal deposits representing varying distances from a paleoshoreline. *Erieopterus* is found within limestone beds replete with *Howellella*, ostracods and pelecypods and thin mirobialites representing inshore and strandline deposition. *Acutiramus* occurs within very fine dolomitic sediment formed in parts of the lagoon behind (backreef) stromatoporoid banks/biostromes (and low lying carbonate islands?). Occurrences are almost mutually exclusive: *Erieopterus* has not been found associated in the same beds with *Acutiramus*, however *Acutiramus* is extremely rarely associated in the same beds with prolific *Erieopterus* (e.g. at Split Rock Quarry near Syracuse, New York).

17: 2:00 PM, Booth 7
Presenter: HUBERT, BENOÎT L.

BIOSTRATIGRAPHIC & PALAEOBIOGEOGRAPHIC CORRELATIONS: CAN ANALYSIS OF STROMATOPOROID DISTRIBUTION BE A TOOL?

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The Palaeozoic stromatoporoids are generally observed as fossils predominantly or moreover strictly associated to their environment: the reefal carbonated environment. Thus, they are regularly considered as non-adequate biostratigraphic markers.In spite of the large progress in the taxonomy and the knowledge of the temporal and spatial distribution of Palaeozoic stromatoporoids since the last 30 or 40 years, these important reef-building organisms are rarely used in order to establish biostratigraphic correlations and at large scale palaeogeographic links. Nevertheless, using stromatoporoids taxa and/or stromatoporoid assemblages at different level (generic and/or specific) seems potentially useful for biostratigraphic datation and, additionally, for palaeogeographic correlation.The particular case of *Stachyodes australe*, a well-known and largely recognized Frasnian species, present from Australia to Western Europe and in North America, is here evocated. Moreover, some comparisons are also developed with the distribution of the modern sponge (i. e. *Merlia*).

17: 2:00 PM, Booth 8
Presenter: SNYDER, DANIEL

A FAUNAL STUDY OF THE “MECCA QUARRY” SHALE IN WESTERN ILLINOIS

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Fredrick Rubin Jelliff (1854-1936) excavated fossil fish and sharks from a Carbondale Formation (Pennsylvanian) black shale in Court Creek, T11N R2E, near Knoxville, Illinois. Jelliff sent many prize specimens to Edward Drinker Cope, while a few remain in the possession of Knox College in nearby Galesburg. To establish more accurate stratigraphic position for Jelliff's fossils, three outcrops of black shale in and near Court Creek were studied. In contrast to Jelliff's collections, two years of fieldwork in the black shale have yet to produce articulated vertebrate specimens. Collection bias is undoubtedly one factor. But the Court Creek's shale is laterally heterogeneous, and preservation bias cannot be excluded. The vertebrate macrofauna is dominated by *Listracanthus* cf. *L. hystrix*, with *Petrodus* sp. less common. Other vertebrate macroremains include actinopterygian scales and selachian teeth. Copious phosphatic nodules are present, but few possess remains that can be classified with confidence. There are abundant conodonts, with *Scottognathus* and *Illinella* unquestionably present. There is no sign of a basal shell breccia, however pyritized bivalve mollusks are preserved in the strata. The fauna of the Court Creek black shale lies within a large stratigraphic window. It is generally similar to the Mecca Quarry Shale of eastern Illinois and Indiana, but shares no unique taxa. Geochemical analysis of the sediments may prove more useful for stratigraphic correlation.

17: 2:00 PM, Booth 9

Presenter: WANG, XIANG-DONG

A CATHAYSIAN RUGOSE FAUNA FROM THE CARBONIFEROUS-PERMIAN TRANSITION OF CENTRAL IRAN

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Carboniferous and Permian coral faunas of Iran have received extensive studies in the last century. However, most studies focus on Permian materials and mainly on the Alborz areas, North Iran, with a few exceptions such as Mississippian corals described from northern Iran and eastern Iran. Nevertheless, no Late Pennsylvanian and Early Permian corals were reported from Iran because of lack of limestone at this time interval in most areas. Very recently, the Gzhelian and Asselian carbonate sequence was discovered, which provides the possibility of finding corals in this interval. Seven massive rugose species belonging to four genera *Antheria*, *Ivanovia*, *Streptophyllidium* and *Nephelophyllum*, are discovered from the Carboniferous and Permian transition in the Anarak section, eastern Esfahan, Central Iran. Three of these massive genera belong to a single family, Kepingophyllidae, a typical Cathaysian representative occurring only in China and Indo-China. Late Pennsylvanian corals are unknown from Gondwanaland, or from the Cimmerian (Peri-Gondwanan) continent because of a depositional hiatus or lack of limestone, where this absence of coral faunas was followed by Early Permian coral faunas characterized by non-dissepimented solitary types. In contrast, abundant large dissepimented solitary and compound corals occur in the Paleotethyan regions during the Late Pennsylvanian and Early Permian. Therefore, the presence or absence of Late Pennsylvanian compound and large solitary corals is a good indicator differentiating Tethyan paleobiogeographical affinity from Gondwanan (also Peri-Gondwanan). The family Kepingophyllidae, which occurs mainly in the Upper Pennsylvanian and Lower Permian and is composed of all massive corals, is known only from China and Indo-China and therefore is a typical Cathaysian representative. Thus, the occurrence of Kepingophyllidae in Central Iran implies that this region may have a close biogeographic relationship with China.

17: 2:00 PM, Booth 10
Presenter: JIANXIN, YAO

TRIASSIC SPOROPOLLEN ASSEMBLAGE FROM THE SAILIYAKEDABAN GROUP

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Tectonically located in the West Kunlun-Karakorum orogenic belt at the junction between the Indian plate and the Eurasian plate, the Sailiyakedaban, southern Yecheng County, Xinjiang Uygur Autonomous Region is one of the most important regions for the research on geological evolution of the Karakorum-Kunlun Mountains, where field geological survey and research are greatly difficult, because natural conditions of this area are very bad , and transportation is inconvenient. The determination of the stratigraphic age of the Sailiyakedaban Group in the Western Kunlun Mountains was mainly based on *Neocalamtes* sp., *Eumorphotis* sp. and *Claraia* sp., but no evidence of microfossils has been obtained in it. Sporopollen *Limatulasporites limatulus* (Playford) *Helby* et Foster, *L. parvus* Qu, *L . fossulatus* (Balme) *Annulispora cf. folliculosa* (Rogalska) , de Jersey, *Polyciglatisporites* sp., *Densos porites* sp., *Cingulizonotes* sp., *Lundbladispora* sp., *Leiotriletes* sp., *Punctatisporites* sp., *Retusotriletes arcticus* Qu, *Cyathidites* sp., *Concavisporites cf. bohemiensis* Thiergargart, *Cyclogranisporites* sp., *Acanthotriletes* sp., *Apiculatisporis* sp., *Lophotriletes* sp., *Verrucosisporites* sp., *Convolutispora* sp . *Alisporites* sp., *A. parvus* de Jersey , *Vitresporites, pallidus* (Reissinger) Nilsson*, Klausipollenites schaubergeri* (Potonie et Klaus) *Jansonius*, *Sulcatisporites* sp., *Falcisporites* sp., *Padocarpidites* sp., *Piceaepollenites* sp., *Pinuspollenites* sp., *Taeniaesporites* sp., *Copectopollis* sp., *Potonieisporites* sp., *Crucisaccites ornatus* (*samoilovich*) Dibner were found in the Sailiyakedaban Group recently, which provides important basis for the determination of the age of the Sailiyakedaban Group, stratigraphic division and correlation in the West Kunlun orogen and research on the geological evolution in the Mazar-Kangxiwar suture zone.

17: 2:00 PM, Booth 11
Presenter: ZHANG, KEXIN

EARLY TRIASSIC SEDIMENTARY SEQUENCES AND CONODONT ZONES OF THE MEISHAN SECTION IN CHANGXING, ZHEJIANG PROVINCE, SOUTH CHINA

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The Lower Triassic, consisting of the Yinkeng Fm., Helongshan Fm. and the lower part of the Nanlinghu Fm., is well developed at the Meishan Section of Changxing County, Zhejiang Province, South China. Four third-order sequences and 8 conodont zones are subdivided from the Uppermost of Changxing Fm to the lower part of Nanlinghu Fm of the Meishan Section. Sequence one (Sq1), corresponding in lithostratigraphy with the topmost Changxing Fm,Yinkeng Fm and the basal Helongshan Fm, is from the latest Changhsingian to the early Griesbachian in age, covering the conodont zones from lower to upper: upper *N. changxingensis yini-H. praeparvus zone*, *N. meishanensis meishanensis-H. eurypyge* zone, *H. parvus* zone, *I. staeschei* zone, *I. isarcica* zone and lower *N. tulongensis-N. planata* Zone.

Sequence two (Sq2) is corresponding in lithostratigraphy with the Lower Member of the Helongshan Fm and including the conodont zones from upper *N. tulongensis-N. planata* zone to lower *N. kummeli* Zone. Its age is from the late Griesbachian to earliest Dienerian. Sequence three (Sq3) composed of the lower Upper Mb of the Helongshan Fm, covering the conodont zones of the upper *N. kummeli* Zone and the lower *N. cristagalli-N dieneri* Zone from lower to upper. The age is the early Dienerian. Sequence four (Sq4) is composed of the upper part of the Upper Helongshan Fm and the lower part of the Nanlinghu Fm and the conodont zone is upper *N. cristagalli-N. dieneri* Zone of the late Dienerian.

17: 2:00 PM, Booth 12
Presenter: ZHANG, KEXIN

PALAEOENVIRONMENTAL CHANGES REVEALED BY ANALYSIS OF MIO-PLIOCENE POLLEN IN THE GYIRONG BASIN, TIBET, CHINA

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609.91m thick Neogene deposits were shed into the Gyirong Basin (E85°17'56", N28°45'01") of the High Himalayas. The late Cenozoic sequence is mainly Oma Formation, consisting of lacustrine and fluvial deposits. However, Danzengzhukang Formation, a conglomerate segment, is newly found at the base of the section, attributed to alluvial sequence. Through abundant palynological analysis, 88 samples were collected, of these, 52 samples were productive. In total, 43 palynological genera had been identified. Then, the environmental changes could be showed on it temporally and spatially. Analysis of Mio-Pliocene pollen in the Basin indicates that 10 palynological zones could be recognized as follows. Zone 1: *Pinus-Ephedra-Quercus* (deciduous) -*Betula* assemblage (10-9.5Ma), Zone 2: *Pinus-Tsuga-Quercus* (evergreen) -*Betula* assemblage (9.5-6.95Ma), Zone 3: *Polypodium-Pinus-Ephedra-Quercus* (evergreen) assemblage (6.95-6.7Ma), Zone 4: *Pinus-Picea-Cedrus-Ephedra* assemblage (6.7-6.0Ma), Zone 5: *Polypodium-Cedrus-Picea*-Chenopodiaceae assemblage (6.0-4.95Ma), Zone 6: *Cedrus-Picea-Quercus* (deciduous) - Chenopodiaceae assemblage (4.95-4.6Ma), Zone 7: *Polypodium-Abies-Cedrus-Ephedra* assemblage (4.6-3.3Ma), Zone 8: *Pinus-Picea-Ephedra-Quercus* (deciduous) assemblage (3.3-2.74Ma), Zone 9: *Cedrus-Picea-Abies-Quercus* (deciduous) assemblage (2.74-2.01Ma), Zone 10: *Ephedra-Abies-Betula-Juglans* assemblage (2.01-1.7Ma). Eight vegetation types can be distinguished as follows. Type 1: cool-arid deciduous broad-leaved and needle-leaved mixed forests (10-9.5Ma), Type 2: warm-humid evergreen and deciduous broad-leaved and needle-leaved mixed forests (9.5-6.95Ma), Type 3: cool-humid evergreen and deciduous broad-leaved and needle-leaved mixed forests (6.95-6.7Ma), Type 4: cold-damp deciduous subalpine needle-leaved forests (6.7-6.2Ma), Type 5: cool-arid deciduous subalpine needle-leaved forests (6.2-5.1Ma), Type 6: warm-humid

deciduous broad-leaved and needle-leaved mixed forests (5.1-4.35Ma), Type 7: cold-arid deciduous subalpine needle-leaved forests (4.35-3.3Ma), Type 8: cool-damp dry deciduous broad-leaved and needle-leaved mixed forests (3.3-1.7Ma). A remarkable cooling climate occurred between 6.7 Ma and 3.3 Ma, accompanied by a pronounced climatic warm-humid fluctuation from 5.1 Ma to 4.35 Ma. The records reflect changes of ice volume increase and the tectonic uplift of the Himalayas, accompanied by a East Asian summer monsoon intensification.

17: 2:00 PM, Booth 13
Presenter: AGENBROAD, LARRY D.

MAMMOTH SITE OF HOT SPRINGS, SOUTH DAKOTA: THE MAPPING OF A LONG-TERM EXCAVATION SITE.

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The Mammoth site is a Late Pleistocene, large population, death assemblage of Columbian mammoths (*Mammuthus columbi*) and associated fauna, discovered in 1974. An early decision was made to leave the majority of the specimens in situ, where they were deposited. Mapping of the faunal elements has undergone an evolution of techniques. Initially, a metric grid was established using an engineering transit, which was mapped via a 1m square string grid, manually mapping the bones to scale, on graph paper. Often mapping was conducted in small, sometimes disconnected units, frequently at different elevations. Added problems included the destruction, or replacement of bench marks, and the replacement and training of new cartographers. Improved surveying equipment in the form of a total station transit (Nikon EDM) was tried in 1988, coupled with ARCINFO and AUTOCAD computer programs which were not designed for such a project. Abandonment of the string grid mapping was accomplished in 1993, requiring mathematical calculations for the location of elements mapped in earlier years. Inherent to the system were errors in orientation calculations and the destruction of earlier benchmarks. In 2007 a total station robotic laser transit (Trimble 5600) was acquired and the in situ bone bed was mapped as a unit for the first time. The process for mapping the Mammoth Site bone bed is detailed here.

17: 2:00 PM, Booth 14
Presenter: STORRS, GLENN W.

IN THE FOOTSTEPS OF LEWIS AND CLARK - NEW ZOOARCHAEOLOGICAL EXCAVATION AT BIG BONE LICK, KENTUCKY

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Big Bone Lick, Kentucky is known as the birthplace of American vertebrate paleontology in honor of the first organized excavations conducted there in September, 1807 by William Clark at the behest of Thomas Jefferson. In 1803, Merriwether Lewis collected isolated bones at the lick for Jefferson (later lost) as the famous Corps of Discovery expedition to the Pacific began. Subsequent to BBL's discovery by Europeans in 1739, a variety of collecting activities has occurred there, most lacking in scientific rigor. A recent, serendipitous discovery of *Bison bison* bones was carefully excavated in 2008, the first such work at the lick in nearly 20 years. Preliminary analysis indicates a minimum of 5 sub-adult individuals present in the new excavation. Sedimentological and taphonomic evidence demonstrates no significant transport of preserved elements, these representing all parts of the skeleton. Notably, a dozen lithic artifacts were collected in close association with the remains, apparently confirming the suspicion that the discovery represents a Fort Ancient culture *Bison* kill and butchering site, an exceedingly rare occurrence in the Ohio Valley. Tallies of preserved skeletal elements and their apparent processing by Native American hunters add weight to this conclusion. The lithics have been identified as expedient tools, manufactured on-site from native materials and discarded after use. The recognition of human predation as a source of zoological remains at BBL suggests that this mechanism may also have played an important role in the accumulation of Pleistocene (Wisconsinan) paleontological specimens at the lick. This suggestion is at odds with the untested, anecdotal miring scenario oft repeated in the traditional view of Big Bone Lick bone accumulation. Indeed, it is now known that the first Paleoindian projectile points discovered in the Americas were acquired at BBL by Clark's 1807 expedition, suggesting human predation of Pleistocene megafauna at Big Bone Lick.

17: 2:00 PM, Booth 15
Presenter: CHONGLAKMANI, CHONGPAN

THAILAND PERMIAN-TRIASSIC BOUNDARY SEQUENCES

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The Permo-Triassic sedimentary sequences have been recognized in northwestern and northern Thailand. These sequences are within three separate terranes, namely the Shan-Mergui, the Inthanon, and the Sukhothai terranes respectively from west to east.The Triassic sequence of northwestern province (Shan-Mergui terrane) consists of platform calcareous sediments (Sri Sawat Limestone and its equivalence) and pelagic and synorogenic siliciclastics (Mae Sariang Formation). The basal part of the Sri Sawat Limestone contains Early Anisian conodont and it overlies disconformably on Middle to Late Permian limestones of the Ratburi Group. The slope facies of the Mae Sariang Formation (Spathian to Carnian) overlies the basal redbed of presumably Earliest Triassic age. The underlying Middle to Late Permian carbonates are overlain by a sequence of shale, mudstone and sandstone of Late Permian to Early Triassic age based on palynological evidence. The Fang Chert is distributed in isolated outcrops north of Chiang Mai within the Inthanon terrane of northern province. The Late Permian and Early Triassic radiolarian faunas have been distinguished in the bedded chert sequence. Sediments of the Lampang Group were accumulated in rift basins of the Sukhothai terrane. They overlie partly on the Late Permian Huai Thak Formation or Middle Permian Pha Huat Formation or older strata. The Phra That Formation is the basal unit of the Lampang Group. It is 100-650 m. thick and is characterized by a sequence of siliciclastics and volcaniclastics with limestones intercalated in the upper part. Thin-shelled bivalves (*Claraia* sp.) and *Ophiceras* ammonoid recorded from the lower part of this unit indicate a Late Griesbachian age. The Late Permian Huai Thak Formation is more than 250 m. thick and consists of calcareous shales, siltstones and limestones containing brachiopods (*Oldhamina* sp.), ammonoids and fusulines (*Palaeofusulina* sp., *Reichelina* sp.) of Changhsingian age.

17: 2:00 PM, Booth 16
Presenter: CIAMPAGLIO, CHARLES N.

AN OVERVIEW OF RESEARCH ON COLEOID CEPHALOPODS FROM TERTIARY ROCKS OF SOUTHERN NORTH AMERICA

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To date, studies of coleoid cephalopods from Tertiary rocks of southern North America have yielded guard-like sheaths of three species of belemnosellids, from the Eocene of Mississippi, Alabama, and Louisiana; of two genera of belosaepiids, from Alabama, Louisiana, Texas and North Carolina; of two genera of spirulids, one from the Miocene of Mexico, the other from the Oligocene of Alabama; and one other coleoid cephalopod of uncertain family affinity from the Oligocene of Alabama. Workers have also recovered phragmocone steinkerns of *Beloptera*? sp. and *Anomalosaepia* sp. from the Eocene of North Carolina.Weaver and Ciampaglio (2003), erected a new genus of belosaepiid, *Anomalosaepia* based on guard-like

sheaths that were in some ways similar to *Belosaepia*, but markedly different. They described four species from the Eocene of North Carolina and moved *Belosaepia jeletzkyi* from Louisiana to *Anomalosaepia*. Weaver et al. (2007), after acquiring several phragmocone steinkerns from the Eocene of North Carolina, recognized two different types, those with low angle, almost parallel septae as *Beloptera*? sp., and those with very strongly oblique septae as *Anomalosaepia* sp. Recently, Ciampaglio and Weaver (2008) reported, two types of diminutive, guard like sheaths from the Oligocene of Alabama. One is most likely a spirulid, while the other is so unlike other coleoids they were unable to place it into a family. These specimens, though possibly juvenile, marked the first record of Oligocene coleoids from North America. Though the number of species of Eocene *Belosaepia* from North America are comparable to those from Europe, considerably more research is needed especially on Oligocene and younger coleoids to compare the North American fauna with that of Europe and to assist in determining phylogenetic linkages with the modern.

17: 2:00 PM, Booth 17
Presenter: LIU, YUSHENG (CHRISTOPHER)

APPLYING PALEONTOLOGICAL EDUCATION OF THE GRAY FOSSIL SITE TO TENNESSEE SCIENCE EDUCATION STANDARDS

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Changes in scientific thinking often cause our educational systems to adjust in order to keep pace with new methods and theories. One such adjustment has been the application of paleontological teaching. By teaching paleontology, educators can cover a good portion of the science requirement set up by the state and federal education boards. An example of applying paleontology to K-12 classrooms is from the Gray Fossil Site, located in Gray, northeastern TN. The Gray Fossil Site was discovered during highway construction in late 2000, and has expanded into a nearly five acre site, consisting so far of a unique Latest Miocene- Earliest Pliocene biota (7-4.5 Ma). An education-based museum is located on site that was completed in late August of 2007 and has since seen over 120,000 visitors. By complying with educational standards, as shown by the Tennessee Department of Education, Gray's Natural History Museum and Fossil Site has cooperated with area schools to help shape k-12 education. Most of GFS's information deals with a large portion of the Life Sciences and a moderate portion of the Earth Sciences curriculum. By grouping classes into sections, such as kindergarten through second grade, third through fifth grade, sixth through eighth grade, and ninth through twelfth grade, we can start with a base program and expand on this as the class stages progress. By beginning with the basics of fossil formation in kindergarten, we can expand on the site's ecology and geology in first grade and introduce evolution and extinction

in second grade. Third through fifth grade deals with geology and the fossil record, while sixth through eighth grade discusses the chemistry of lab work and species classifications. High school students will cover paleontology in courses such as Biology, Geology, Ecology, Environmental Sciences, Life Sciences, Earth Sciences, and Scientific Research studies.

17: 2:00 PM, Booth 18
Presenter: RIYAHI, KUMARS

THE CREATIONISM/EVOLUTION CONTROVERSY: POSSIBLE SOLUTIONS FOR A WORKABLE AGREEMENT BETWEEN SCIENCE AND RELIGION?

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The creationism/evolution controversy is an important issue in the realm of science and society, as well as in the relationship between science and religion. In society, science plays a crucial role both for practical purposes and in understanding the world we live in. Religion is also a major factor in the lives of a significant part of humanity all over the world. The crude division into 'scientists' and 'religious people' is an oversimplification, since people can be both scientific and religious. This fact is elegantly explained by The Paleontological Society's position statement on evolution.I will highlight some main issues that underlie this debate for both creationists and evolutionary scientists. I explore possible solutions to this debate. How can creationists, come to accept evolution, in view of the compelling evidence that life has evolved over a vast time period? Exploring the relationship between science and religion, I describe an unusual and astonishing historical case study from two Persian scholars who, hundreds of years ago discussed evolution by very similar processes we now call Natural Selection. They were influential in all sciences as well as being theologians. They are Abu Rayhan al-Biruni (Biruni) (973-1048 AD), and Nasir al-Din al-Tusi (Tusi) (1201-1274 AD). For example, Tusi referring to hereditary variability, wrote “The organisms that can gain the new features faster are more variable. As a result, they gain advantages over other creatures.” Biruni for example, in his geological work realized that regions that were once seas, became dry land, based on the observation of fossils. He furthermore explained that geological changes on earth take a long time, with the origin of the earth so distant that they could not measure it. In time we may agree that evolution is as wonderful as the endless forms we see.

17: 2:00 PM, Booth 19
Presenter: PARK, LISA E.

EXTINCTION! THE GAME THAT TEACHES EARTH SCIENCE TO K-12 STUDENTS

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A board game emphasizing the history of Earth and the fossil record that is based on the state and national science benchmark teaching and learning standards has been developed and is ready for dissemination. This game involves two to six players who roll a die and travel through geologic time from the Hadean to the Quaternary and answer questions based on the science standards. If they get the answer correct, they move forward additional spaces according to what is on the question card. Along the way, they may fall victim to an "extinction event" that sends them back in time or may benefit from a "land bridge" which advances them to another time period. The questions for the game are divided into four levels: K-2; 3-5; 6-8 and 9-12 grade levels and each question has the benchmark and academic content standard information in the corner so that teachers can assign the game to their students, knowing that they will be reviewing these competencies. In addition, the board itself is designed using the geologic time scale, so each square represents an epoch. Extinction events are located on the squares corresponding to the time in which they occurred and the player that lands on one has to go back to the beginning of that geologic period. The winner is the player who reaches the Holocene first! Initial testing on students from different grade levels indicates that this game is both fun to play and effective in teaching and reinforcing concepts on Earth history. This game could easily be utilized in classrooms of all grade levels.

17: 2:00 PM, Booth 20
Presenter: HULBERT, RICHARD C., JR.

BIOCHRONOLOGIC AND TAPHONOMIC IMPLICATIONS OF RARE EARTH ELEMENT CONCENTRATIONS IN MIXED TERRESTRIAL/MARINE FOSSIL VERTEBRATE ASSEMBLAGES: A CASE STUDY FROM THE NEOGENE OF FLORIDA

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Episodic high sea level stands through the Neogene resulted in a series of nearshore marine and coastal formations in southwestern Florida. These frequently contain mixed assemblages of terrestrial and marine vertebrate fossils. Mineralized vertebrate skeletal tissues incorporate rare earth elements (REEs) from local pore waters during early diagenesis for an interval of 10 to 30 thousand years, after which there is neither significant gain or loss of REEs. We measured REE patterns from fossil bones and teeth from southwestern Florida and seven time intervals (15, 12.5, 11, 4.5, 3.8, 2.5, and 1.3 Ma). Each interval included samples of marine vertebrates, both sharks and mammals, while terrestrial mammal bones were analyzed from

all but one interval (3.8 Ma). Marine and terrestrial fossils collected from the same deposits had no significant differences in relative proportions and overall concentrations of REEs, indicating a lack of significant reworking, for all but one time interval. Shark teeth from the 1.3 Ma Leisey Shell Pit had ten times the REEs of its land mammals, and identical to REE levels from the 2.5 Ma shark teeth. Some intervals had distinctive REE patterns that will allow dating of specimens of uncertain provenance. Most importantly, fossils from the Upper Bone Valley (4.5 Ma) clearly differ from those of the lower Bone Valley (15, 12.5, and 11 Ma), although the REE patterns of the latter three are indistinguishable. Within the region the most dramatic change in REE patterns occurs between the 3.8 and 2.5 Ma intervals, with 2.5 Ma and younger fossils characterized by relatively greater proportions of middle and heavy REEs. This could be the result of new oceanic circulation patterns caused by the closure of the Panamanian Seaway or changes in mid-continental erosion patterns caused by continental glaciation.

17: 2:00 PM, Booth 21
Presenter: SCHEMM-GREGORY, MENA

THE OLDEST SPECIES OF *CYRTOSPIRIFER* (BRACHIOPODA, MIDDLE DEVONIAN)

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A brachiopod faunule from Givetian-age carbonate and clastic rocks on the southeast flank of the Tindouf Syncline in the Western Sahara (northwestern Africa) has yielded the oldest species of *Cyrtospirifer*. It is proposed that the origin of cyrtospiriferid brachiopods lays in North Africa instead of western Europe as hitherto assumed. The new species of *Cyrtospirifer* differs in its smaller number and coarser medial and flank plications and equibiconvex shell profile from the other Givetian species of *Cyrtospirifer* that all occur in Europe and, to which the new species is given rise. The new implications of the proposed phylogeny of the earliest cyrtospiriferids and their origin of the Western Sahara are discussed. The palaeogeographic distribution of the cyrtospiriferids during the Givetian and Frasnian is shown as well as its migration routes in relation to global transgression and regression cycles, first from North Africa to Europe and later to North America and Asia.

17: 2:00 PM, Booth 22
Presenter: HENDY, AUSTIN J.W.

QUANTITATIVE ANALYSIS OF GLOBAL CRETACEOUS AMMONOID PALEOBIOGEOGRAPHY

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Incomplete and inconsistent data are among the most significant challenges for paleontologists undertaking the kinds of global analyses necessary for testing and developing concepts of paleobiogeography. Such analyses require adequate sampling of globally distributed fossil assemblages and an internally consistent and systematic source of data; the Paleobiology Database (www.paleodb.org) provides such a resource. The database presently comprises over 15,000 occurrences of Cretaceous Ammonoidea, derived from 4,000 faunal assemblages. Significant effort has been made to increase geographic coverage and density of sampling for Cretaceous ammonites, in addition to the development of a sound taxonomic framework. This resource now permits adequate analyses of spatial relationships between faunal assemblages throughout the Cretaceous.The purpose of this investigation is primarily to demonstrate the utility of the database for analyzing patterns of distribution among marine invertebrate taxa. Specifically, these data are used to quantify changes in latitudinal diversity gradients and provincialism throughout the Cretaceous. Biogeographic units (realms and provinces), defined with both genus- and species-resolution data in the context of tectonic reconstructions, are shown for eight geologic intervals across the Cretaceous using consistent quantitative protocols (similarity measures and endemism metrics) for each time interval. The study succeeds in identifying key features of previously published analyses of Cretaceous faunal provincialism, in particular in identifying Boreal, Tethyan, and southern high latitude realms (coarse biogeographic areas), in addition to established provinces (geographically and taxonomically distinct faunas). These data contribute to a greater understanding of the role that biogeographic gradients (beta diversity) play in varying biodiversity through Earth's history.

17: 2:00 PM, Booth 23
Presenter: GARCIA, JOSEPH A.

CYCLIC SEDIMENTATION AND FAUNAL DEGRADATION IN THE CRETACEOUS HELL CREEK FORMATION, PRIOR TO THE KPG BOUNDARY

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Field observation in the Upper Cretaceous Hell Creek Formation were conducted in McCone County, eastern Montana, by a team assembled in 2007 and 2008 for the “Paleo Exploration Project” (PEP) and later, Fort Peck Paleontology Inc. (FPPI). Each site investigated revealed a repetition of stratigraphic units characterized by distinct differences in lithology, sedimentology, and paleontology. Each cycle includes lacustrine, fluvial, and terrestrial environments. Lacustrine units include packed mudstone, sandstone and shale with macerated plant material. Fluvial channel deposits consist of cross-bedded sandstone and

gravel with iron and packed mudstone concretions. Terrestrial deposits are primarily sandstone and shale. Cyclic units are also characterized by distinct differences in faunal and floral content that show evidence of gradual community degradation as the cycles repeat. From the evidence, it appears that the fauna and flora were experiencing signs of increasing stress prior to the KPg event.

17: 2:00 PM, Booth 24
Presenter: SANDY, MICHAEL R .

BRACHIOPOD-BIVALVE FAUNA FROM THE EARLY JURASSIC (PLIENSBACHIAN), PENINSULAR TERRANE, SOUTHERN TALKEETNA MOUNTAINS, ALASKA - PALEOBIOGEOGRAPHIC SIGNATURE AND TECTONIC SIGNIFICANCE

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Contrary to popular belief brachiopods are occasionally abundant in the marine Mesozoic of North America. Bivalves are of course more commonly found. Here we investigate a Jurassic locality where brachiopods and bivalves co-occur. The fauna is from the Talkeetna Formation, Hicks Creek area, southern Talkeetna Mountains, Alaska which is tectonically part of the Peninsular Terrane. Ammonites from the locality indicate an early late Pliensbachian age (Kunae Zone; Caruthers and Smith, 2009). The associated fauna at the Hicks Creek locality includes gastropods, ammonoids, and scleractinian corals (both solitary and colonial). The brachiopod fauna is of high diversity for a Mesozoic North American brachiopod fauna and includes four taxa: terebratulids referred to *Lobothyris*; ovate zeillerids comparable to *Cincta*; medium-sized biplicate terebratulids; and spiriferids referred to *Callospiriferina tumida* (Von Buch). Sandy and Blodgett (2000) recorded *Callospiriferina tumida* (Von Buch) from the Talkeetna Formation, Peninsular Terrane, south-central Alaska. Rhynchonellids have not been recorded from this locality. Eighteen bivalve taxa are identified, representing fifteen genera and subgenera: Parallelodontidae: *Grammatodon costulatus* (Leanza); Ostreidae: *Gryphaea dilobotes* Duff, *Gryphaea* sp.; Neitheidae: *Weyla alata* (Buch) and *Weyla (Lywea) unca* (Philippi); Pachycardiidae: ?*Trigonodus* sp. (probably gen. nov.) and *Cardinioides* sp. (probably nov. sp.); Kalenteridae: *Kalentera* sp. (nov. sp.); Trigoniidae: *Trigonia (T.) cf. prora* Fursich & Heinze, *Vaugonia literata* (Young & Bird); Family Astartidae: *Coelastarte excavata* (J. de C. Sowerby); Cardiniidae: *Cardinia hybrida* (J. Sowerby), *Protocardia cf. truncata* (J. de C. Sowerby), *Protocardia striatula* (J. de C. Sowerby); Quenstedtiidae: *Quenstedtia* sp., Tancrediidae: *Tancredia (T.) gibbosa* Lycett; Pholadomiidae: *Pholadomya* sp., Pleuromyidae: *Pleuromya uniformis* (J. Sowerby).The brachiopod-bivalve fauna is consistent with a mid-

latitude paleogeographic setting for the Peninsular Terrane during the Pliensbachian supporting the conclusions of other tectonic and paleontological studies.

17: 2:00 PM, Booth 25
Presenter: FELDMAN, HOWARD R.

BIOGEOGRAPHY AND TAXONOMY OF THE MIDDLE JURASSIC ZEILLERID BRACHIOPODS EUDESIA AND SPHRIGANARIA

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Mesozoic workers are generally of the opinion that the common European zeillerid brachiopod genus *Eudesia* King, 1850 also occurs along the southern Tethyan margin. Recent research in the Jurassic Ethiopian Province of Jordan, Israel and Saudi Arabia, however, indicates that Cooper's (1983) genus *Sphriganaria* has been misidentified over past decades as *Eudesia*. *Eudesia* is a strictly European taxon that, according to Muir-Wood (1965), has a cardinal process that is complicated in structure, hollow, with two small cavities, trilobed, prominent, and elevated above fused thickened hinge plates that are commonly pierced by 3 small cavities. *Sphriganaria* does not have a cardinal process but superficially resembles *Eudesia*. Similar genera include *Xenorina*, a eudesiod with a long, massive, bilobed cardinal process and *Apothyris*, with its distinctive ornamentation consisting of three generations of intercalation and eudesiid cardinalia similar to *Sphriganaria*. *Sphriganaria* is abundant in the Jurassic of Saudi Arabia (Dhruma Formation), Jordan (Mughanniyya Formation) and Gebel El-Maghara, Sinai Peninsula, Egypt (Masajid Formation). However, it is rare or absent in correlative strata in Israel (Hamakhtesh Hagadol, Makhtesh Ramon), Somalia (Bihen Limestone, Gahodleh Shale, Wanderer Limestone, Daghani shales) and Ethiopia (Antalo Limestone). *Eudesia* is confined to the Bathonian according to Muir-Wood (1965:830) whereas *Sphriganaria* ranges from the Bajocian to the Kimmeridgian. After sectioning numerous specimens from the Middle Jurassic (Callovian) of Jordan we were able to reconstruct and illustrate the loop of *Sphriganaria* Cooper, 1983 for the first time.

17: 2:00 PM, Booth 26
Presenter: MCCOY, VICTORIA E.

BIOGEOGRAPHIC ASSOCIATIONS OF SILURIAN BRYOZOAN GENERA IN NORTH AMERICA, BALTICA AND SIBERIA

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Silurian bryozoan faunas in North America, Baltica and Siberia belong to six geographic assemblages determined by Parsimony Analysis of Endemicity and Simpson's Index of Faunal Similarity of their generic compositions. In the Llandoverian, the Brassfield assemblage occupies most of the three continents except for a smaller region occupied by a Mongolian assemblage. In the Wenlockian, the Brassfield and Mongolian assemblages both persist, but the former becomes restricted within Baltica. The Visby and Rochester Assemblages replace the Brassfield in North America, by processes involving both vicariance and geodispersal. In the Ludlovian/Pridolian, the Rochester assemblage persists in North America, and the Visby Assemblage is replaced in eastern North America and England by the Keyser assemblage. The Keyser includes endemics common to the Mongolian assemblage. A new Estonia-Ukraine assemblage replaces the Visby in Baltica. Both the Brassfield and the Mongolian assemblages have endemic associations completely congruent with their overall faunal composition. Incongruent Visby endemics are found in the Waldron fauna of Indiana and Tennessee, whose overall affinity is with the Rochester assemblage. Incongruent Rochester endemics are found in the Henryhouse fauna of Oklahoma, whose overall affinity is with the Keyser assemblage. Incongruent Estonia-Ukraine endemics also are found in the Malinovetskie fauna of Podolia, whose overall affinity is with the Keyser assemblage. All of these disjunct associations can be attributed to limited dispersal of otherwise endemic genera.

17: 2:00 PM, Booth 27
Presenter: ZELLERS, SARAH D.

CHARACTERIZATION OF LATE NEOGENE BENTHIC FORAMINFIERA IN A FJORD TO SLOPE TRANSECT, NORTHERN GULF OF ALASKA

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The Integrated Ocean Drilling Program (IODP) is considering drilling in the Gulf of Alaska, where cause and effect relationships among climate change, mountain building processes (tectonics), erosion, and deposition can be examined. Benthic foraminiferal faunas obtained from a series of multicores and jumbo piston cores in a fjord-to-slope transect provide insight

into paleoenvironments of this margin. In Disenchantment Bay (cores AH04YB MC No. 1, 2 and EW040872JC), *Textularia earlandi* and *Elphidium* dominate low diversity benthic foraminiferal assemblages that occur in muddy layers indicating a strong influence of seasonal meltwaters in a glacier proximal fjord. Outer shelf muds (core EW040879JC) yielded *Epistominella pacifica* and species of *Uvigerina*, *Cassidulina*, *Islandiella*, and *Cibicides*. Shelf assemblages also contain common *Elphidium clavatum*, an inner shelf species, which indicates transport into shelf settings. The slope location (core EW040885JC) contains three distinct sedimentological assemblages. From 680 to 1124 cm depth, samples consists of a sandy diamicton with a mixture of the inner shelf to outer shelf taxa listed above, indicating transport into deep water by ice rafting and/or turbidity currents. Two samples from a short interval (640 to 680 cm) in the slope core contain a calcareous ooze dominated by *Bolivina* spp. which may indicate an oxygen minimum zone. Above this zone (0 to 640 cm) are bioturbated, silty muds that produced low abundances of *Gyroidina*, *Bolivina* and the shelf taxa listed above, along with planktic foraminifera and abundant radiolarians and sponge spicules. The three assemblages show a change from glacially influenced deposition at the base, to low oxygen conditions bottom waters, to conditions favoring silica production at the top.

17: 2:00 PM, Booth 28
Presenter: STROTHER, PAUL K.

SPORE MASSES FROM MIDDLE SILURIAN ROCKS IN WESTERN VIRGINIA, USA

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Isolated spore masses and plant fragments containing spores were recovered from shaley and silty horizons within the top four meters of the McKenzie Fm, and lower half of the Williamsport Fm at Bluegrass, Virginia. Their age is Homerian based on UK sporomorph zones or Ludfordian (based on conodonts). The spore masses include fused and unfused permanent spore tetrads, loose dyads and monads, and clusters of alete spores or “leiospheres.” These largely laevigate to finely scabrate tetrads, if dispersed, would be classified as species of *Tetrahedraletes*, *Rimosotetras*, or *Ambitisporites*. Spore masses containing dyads and monads correspond to species of *Dyadospora*, *Artemopyra* and *Laevolancis*. Individual masses contain less than ten to several hundred spores, all at the same state of maturation. Several spore masses are associated with attached tissue fragments interpreted to be the remains of enclosing sporangia. Fragments of nematophytes (*Nematothallus*) and possible plant-like thalli that appear to be at a liverwort grade have been recovered through careful acid maceration. These micro- and meso-fossils provide direct evidence of embryophytic land plants from the

Silurian of the Appalachian basin, adding to the palynological record that begins in the middle Cambrian.

17: 2:00 PM-6:00 pm, Booth 29
Presenter: SHAFIEEARDESTANI, MEYSAM

PALAEOECOLOGY AND PALAEOGEOGRAPHY OF ABDERAZ FORMATION AT TYPE SECTION USING FORAMINIFERA AND PALYNOMASERAL

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Abderaz Formation at its type section with an age of Turonian-early Campanian and a thickness of 300 m contains light grey shale and marls. The study of the planktonic foraminifera in isolated form resulted in differentiating three morphotype groups. Also the planktonic to benthic ratio and infaunal to epifaunal and clear structureless organic matter(SOM) explains that at the end of Turonian the water depth increased in the area and then in Coniacian decreased to less than 100 meters. Increasing the water depth at the Coniacian-Santonian boundary has been observed as well as a deep diminishing trend to the end of the formation. This study was intended to explore the marine sedimentation of the Abderaz Formation in (outer neritic -upper bathyal) restrict and the provided curves from morphotypes changes are in full agreement with the curves of the sea level changes and planktonic foraminifera to benthic ratio. Planktonic foraminifera of Abderaz formation in comparison to the Cretceous biogeographical provinces are very close to the Tethyan provinces.

17: 2:00 PM, Booth 30
Presenter: REZAEI, ZEINAB

WATER-LEVEL FLUCTUTIONS AND SEQUENCE STRATIGRAPHY OF THE AB-TALKH FORMATION AT THE TYPE SECTION IN THE KOPEH-DAGH SEDIMENTARY BASIN (NORTHEAST OF IRAN)

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The Ab-Talkh Formation (Lower Campanian-Lower Maastrichtian) is in one of the lithostratigraphic units of the Kopeh-Dagh sedimentary basin. So far no high resolution

sequence stratigraphy has been done on this formation. In this study, we use the fossil evidences to analyse the formation in the sequence stratigraphy framework. For this purpose, after field studies 39 samples were collected and processed for palynology and palynofacies studies. Accordingly three palynofacies(V:Distal shelf , ?:Proximal shelf , ?:Marginal shelf) were determined. Based on the palynofacies and changes in percentages of the three majour constituents of organic matter and correlation of all data, three second-order sequences were differentiated. The abundance of warm water dinocysts, the presence of fungal spores and the ratio of Peridinioids / Gonyaulacoids indicate dominance of warm climate during depositional course of the Ab-Talkh Formation.

Session No. 18, 8:00 AM; Thursday, 25 June 2009
Plenary Session P2. Evolution and Society

18: 8:00 AM-8:30 AM
Presenter: TERRY, MARK

THE WEDGE IN THE CURRICULUM: EVOLUTION EDUCATION FOR THE SCHOOL BOARD MEMBERS OF TOMORROW

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The Discovery Institute, headquartered in Seattle just a few blocks from my school, has had a disproportionate effect on science education around the country, causing confusion and leading teachers and school boards to waste precious time and resources. Its efforts are tireless, its “Wedge Strategy” to make supernatural causation central in society by opening up curricular space for it in public education, is well conceived and well targeted. Anyone concerned with science education needs to recognize its ever-changing disguises and to publicly identify its true aims. I take this on in part as a matter of civic duty, since my hometown is routinely identified with the Institute as it wedges its way into science curriculum discussions in Texas, Louisiana, Ohio, Pennsylvania and beyond. Marcus Ross's 2005 paper in the Journal of Geoscience Education provides an instructive example of the Wedge at work. How might it have been recognized by its reviewers prior to publication as part of the effort to acquire a cloak of scientific respectability for this politico-religious movement? The Wedge and the Discovery Institute need to be studied, not ignored. Northwest School's interdisciplinary approach to evolution provides an example of how the Institute's campaign, if studied in historical context, can enhance students' understanding of the nature of science and evolution. Our goal is not only to graduate students excited by and knowledgeable about science and evolution, but also aware that they'll need to bring their

understanding to the table to defend and promote science education as future local and state school board members.

18: 8:30 AM-9:00 AM
Presenter: MILLER, KENNETH R.

RECLAIMING “DESIGN”: A STRATEGY FOR SUCCESS IN THE EVOLUTION WARS

MILLER, KENNETH R, Molecular Biology, Cell Biology, & Biochemistry, Brown University, 142 Martin Street, Rehoboth, MA, 02769, United States, kenneth_miller@brown.edu

The scientific and legal failings of the “intelligent design” (ID) movement stand in sharp contrast to its substantial gains in public support. The popular support the ID movement has received points to a profound failure on the part of the scientific community to articulate its message in the public square. ID's intentionally vague use of the word “design” has been at the heart of its successes. This has led to a needless aversion to design-based explanations in the biological sciences, paving the way for still further advances on the part of the anti-evolution movement. The great irony of this situation is that members of the scientific community know very well that the concept of design is at the heart of their explorations of nature. Quite specifically, there is indeed a design to life - but it's not the clumsy, interventionist one in which life is an artificial injection into nature, a contradiction of its physical laws. Rather, it is a design in which life emerges from the laws of nature themselves. Our elegant universe is a universe of life. And the name of the grand design of life is evolution. I will suggest ways in which the scientific community can reclaim this term and publicly place the anti-evolution movement in its proper context outside the scientific mainstream.

18: 9:00 AM-9:30 AM
Presenter: SCOTT, EUGENIE

STRATEGIES FOR DEFENDING EVOLUTION EDUCATION

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Creationists have preferred to seize the imprimatur of science and its cultural power by claiming that their views are supportable through science. Creation science and intelligent design are examples of this. Because of legal decisions that recognized the inherent religious advocacy of both of these positions, the current creationist strategy emphasizes attacking evolution – though certainly the “creationism as science” approach is not yet dead. However,

creationists today are more apt to argue that evolution should be presented as unsupported science, with many “weaknesses.” A corollary approach is to contend that students should “critically analyze” (i.e., criticize) evolution as a critical-thinking exercise. Creationists are applying this “evidence against evolution” approach in various ways. One focus is to water down the teaching of evolution in state science-education standards, or to include “weaknesses of evolution.” Another approach involves bills that would protect teachers from prosecution if they bring the “full range of views” on origins into the classroom. The “full range of views” language springs from an amendment that Senator Santorum of Pennsylvania attempted to add to the No Child Left Behind education act of 2001. How can these attacks on evolution education be countered? They must be countered both at the grassroots and the national level. As such, there are roles for professional scientists and the societies to which they belong, and there are also roles for scientists as community members, parents, and voters. Scientists must realize that helping decision-makers (such as school board members or legislators) understand science, and the importance of evolution in the curriculum is necessary, but insufficient. Success depends on thinking and acting politically – it is not sufficient merely to be right.

18: 10:00 AM-10:30 AM
Presenter: JACKSON, JEREMY B. C.

WHY DON'T THEY LISTEN?

JACKSON, JEREMY B C, Oceanography, UCSD, Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla , CA, 92093-0244, United States, jbjackson@ucsd.edu

Can you explain to your mother what you do and why you do it so that she can brag about you to her friends? Or do her eyes glaze over before she says: “That's nice dear” and turns on the TV? Do your students in required science courses love your lectures or cut class? Too many scientists cannot pass these simple tests and feel no compulsion to try. So why is it so surprising that we fail miserably at explaining what science is about and why it matters to the wider world?There is no best way to communicate science and its importance for modern life. Public lectures, popular books, op-eds, films, science cafes, testifying before Congress, and going on the Daily Show are all potentially great ways to communicate science. But they are a waste of time if we are boring, arrogant, or preachy. Carl Sagan and Stephen Jay Gould were the greatest scientific communicators of my lifetime, not least because they were great storytellers, which made them fascinating and fun no matter what they were talking about. The dark side has terrified scientists into being afraid to open their mouths for fear of being branded as advocates. But scientific information is not advocacy, and scientists have an obligation to explain to their fellow citizens what they have learned at public expense. None of this comes easily and it takes a lot of time and hard work - especially for entire generations of scientists who have shut themselves up in an ivory tower. But no one else can communicate

science for us if we cannot do it ourselves. So if we really want to make a difference lets get on with it.

18: 10:30 AM-11:00 AM
Presenter: SMITH, FELISA A.

OF MICE AND MEN: WHAT LONG DEAD RATS REVEAL ABOUT ANTHROPOGENIC PROBLEMS

SMITH, FELISA A., Department of Biology, University of New Mexico, Albuquerque, NM, 87131, United States, fasmith@unm.edu; HARDING, LARISA, Biology, University of New Mexico, Albuquerque, NM 87131; MURRAY, IAN W., Biology, University of New Mexico, Albuquerque, NM 87131

Numerous pressing environmental issues face society today. In coping with anthropogenic challenges, policy makers require robust and high quality scientific data, yet many issues such as global change have few analogs in human-recorded history. The increasing availability of fine-scale paleoclimate data has led to greater appreciation for the rapidity and frequency of past shifts in the earth climate system and focused attention on the historical record as a means of assessing likely biotic responses. Analysis of the pollen record, for example, has proved invaluable in estimating the migration ability of plants. Yet, movement is just one way that organisms can respond to anthropogenic change; the historical record documents the entire gamut, including tolerance and local extirpation, as well as adaptive changes in genetics or morphology. Here, we review recent work examining responses of mammals to late Quaternary climate fluctuations. In particular, we focus on Neotoma (woodrats), a taxa with arguably the best-resolved paleorecord of the late Quaternary. Neotoma construct middens (debris piles) that are ubiquitous in the western US and which under appropriate conditions are preserved for thousands of years. Paleomiddens yield information on woodrat morphology, genetics and diet; analysis of chronosequences from mountain gradients allow investigation of responses to climate change over temporal and spatial scales. Moreover, because woodrats are extant, we integrate paleohistory with modern work on physiology, life history and ecology. Our results document the entire range of responses possible to past climatic shifts - in situ phenotypic adaptation, migration, species replacements and when climatic thresholds were exceeded, extirpation. Responses were excerbated at elevational/latitudinal range boundaries where animals already faced enhanced abiotic stress. Estimates of evolutionary capacity based on paleomiddens were compared with that necessary to adapt to predicted levels of anthropogenic warming; results suggest we may be underestimating the ability of organisms to adapt.

18: 11:00 AM-11:30 AM
Presenter: TRAPANI, JOSH

COMMUNICATING BIODIVERSITY SCIENCE TO POLICYMAKERS

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Biodiversity relates to many areas of public policy, from climate change and endangered species protection to transportation and foreign policy. Scientists, including paleobiologists, have important roles to play in communicating with Congress (which develops policy) and the Executive Branch (which implements policy) to help decision-making on policies that have biodiversity impacts. To communicate effectively, scientists must understand both policymakers' motivations and their own. Scientists must also understand how policymakers learn about and think about science. Science is only one of many inputs into the formulation of policy. Policy objectives frame the role of science, and science alone rarely dictates specific policy outcomes. Three valuable roles for scientists are: 1) synthesizer: survey scientific information related to various policy issues; 2) translator: explain technical concepts and place science in policy-relevant context; and 3) fact-checker: assess the quality of scientific information. Scientists must also be flexible about the roles they play. For example, ever since climate change first garnered Congressional attention, scientists have played important roles in steering discussion on Capitol Hill. But these roles have evolved over time, and will continue to transform as Congress moves toward establishing national climate change policies. In particular, policymakers have become progressively more interested in understanding projected effects of climate change at different scales and consequences of various policy options. Paleobiologists can make unique and valuable contributions to biodiversity policy development and implementation. I will mention several anecdotes from my own experiences, and then discuss three specific areas where paleobiologists can contribute to discussions of climate change policy: 1) impacts (climate change and extinction); 2) mitigation (offsets policies); and 3) adaptation (public lands management). I will conclude by reviewing the many resources available for scientists to engage with the policy process - ranging from hour-long commitments to year-long (and potentially career-altering) fellowship experiences.

Session No. 19, 1:30 PM; Thursday, 25 June 2009
Topical Session T6. Dynamics of Extinction and Radiation in the Phanerozoic

19: 1:30 PM-1:45 PM
Presenter: MELOTT, ADRIAN L.

A 62 MYR PERIODICITY IN FOSSIL BIODIVERSITY

MELOTT, ADRIAN L., Physics and Astronomy, University of Kansas, 1251 Wescoe Dr. No. 1082, Lawrence, KS, 66045-7582, United States, melott@ku.edu; BAMBACH, RICHARD K., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, PO Box 37012, MRC 121, Washington, DC 20560-0121 USA

A 62 Myr periodicity is superimposed on other longer-term trends in fossil biodiversity. This cycle can be discerned in marine data based on the Sepkoski compendium, the Paleobiology Database, and the Fossil Record 2. The signal also exists in changes in sea level/sediment, but is much weaker than in biodiversity itself. A significant excess of 19 previously identified Phanerozoic mass extinctions occur on the declining phase of the 62 Myr cycle. Given the appearance of the signal in sampling-standardized biodiversity data, it is likely not to be a sampling artifact, but either a consequence of sea-level changes or an additional effect of some common cause for them both. In either case, it is intriguing why both changes would have a regular pattern.

19: 1:45 PM-2:00 PM
Presenter: SADLER, PETER M.

FALSE COINCIDENCES OF TAXON RANGE-ENDS - A PERVASIVE CHARACTERISTIC OF THE UNEVENLY UNDER-SAMPLED FOSSIL RECORD?

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Locally observed taxon ranges under-represent the duration of true local and global ranges. The short-fall between true and observed range ends varies by taxon and may include random components. Consequently, range ends that should truly coincide, as at a mass-extinction horizon, are more likely to be observed across a range of horizons - the Signor-Lipps effect. Mitchell et al. drew attention to an inverse Signor-Lipps effect in which apparent range ends tend to coincide at species-rich horizons that result from unusually favorable preservation or large sample size. This uneven sampling is part of a more pervasive phenomenon that likely swamps the Signor-Lipps effect: taxon range charts are typically under-sampled in the sense that they are based on many fewer fossil-bearing horizons than the number of range ends to be resolved. A corresponding proportion of observed range-ends are forced to coincide. Thus, the detailed fossil record, as we know it, probably includes more false clustering than smearing of true range ends. Increased sampling does not simply resolve more range ends, it tends to find more taxa. These traits emerge from analysis of more than 1500 range charts for a variety of fossil clades: readily visible macrofossils (ammonites in sand), fossils revealed by splitting bedding planes (graptolites in shale), and microfossils extracted in the lab (conodonts and chitinozoans). The inevitable clustering of range ends worsens where the record of many locations is summarized by biozone, of course, but is ameliorated in composite sections built

by graphic and numerical correlation methods. Using a map of more than 250 end-Cretaceous ammonite finds, in homoclinal strata extending approximately 7km along strike, it is possible to assemble hypothetical range charts based on different sampling intensities and reveal how the proportion of coincident range ends scales with the width of the sampling swath.

19: 2:00 PM-2:15 PM
Presenter: MILLER, ARNOLD I.

EPICONTINENTAL SEAS VERSUS OCEAN-FACING SETTINGS: FUNDAMENTAL DIFFERENCES IN THE KINETICS OF ORIGINATION AND MASS EXTINCTION

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A defining transition of the Phanerozoic was a change in the central locus of benthic marine diversity from epicontinental seas to ocean-facing environments associated primarily with continental margins. Whereas a large percentage of preserved Paleozoic marine life was focused in epicontinental seas, the relative contribution of these environments and their associated biotas to the geologic record declined thereafter, and, by the mid Cenozoic, they were virtually absent. Despite this trend, and the attendant hydrodynamic and environmental differences between the two regimes, its effect on secular patterns of diversification has never been investigated. Here, we present a comparative analysis of origination and extinction in these settings for the Permian through Cretaceous periods, when both were well represented in the geological record. Genus-level data were downloaded from The Paleobiology Database (http://paleodb.org/), and global paleogeographic maps were used to assign occurrences to the two regimes based on their proximity to the open ocean. Genera were then characterized as preferring one regime over the other in cases where a statistically-significant preponderance of their occurrences were located in that regime. Stage-by-stage comparisons of per-taxon origination and extinction rates for the two groups of genera demonstrated: no clear distinction in extinction rates through the study interval, EXCEPT during the mass extinctions at the ends of the Permian, Triassic, and Cretaceous, when ocean-facing genera exhibited significantly higher extinction rates than their epicontinental-sea counterparts; and a tendency for origination rates to be higher in epicontinental seas than ocean-facing settings prior to the mid Jurassic, with the OPPOSITE being the case for the remainder of the Mesozoic. The origination-rate transition coincided with an increase in geographic differentiation of open-ocean but not epicontinental faunas. Collectively, these results suggest that, indeed, there were fundamental differences between the two regimes that should be incorporated into future assessments of Phanerozoic diversification.

19: 2:15 PM-2:30 PM
Presenter: GREEN, WALTON A.

THE INTERACTION OF PHYLOGENY AND ECOLOGY IN DETERMINING EXTINCTION SEVERITY

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Extinctions are defined and measured by the disappearance of lineages, but caused by environmental and ecological change. If the ecological preferences of species are weakly related to phylogeny, even large ecological perturbations are unlikely to drive major clades extinct; on the other hand, if phylogenetic relatedness and ecological preferences correspond, then ecological perturbations and lineage extinctions will occur together. In order to quantify this effect, we used a computer model to simulate the diversification and extinction of clades based on ecological criteria. By varying the parameters of the model, we show how the probability of going extinct for a clade of a given size (number of terminals) is related to the overall intensity of extinction (the proportion of the terminals that go extinct), the ecological coherence (the correspondence between ecological traits and the phylogeny), and the dimensionality of the ecological morphospace in which the extinction occurs. The disappearance of large clades is observed in the fossil record, but based on our model, it is very improbable without high overall extinction intensities and high values of ecological coherence. Data from two extinctions (Eocene-Oligocene planktic forams and Westphalian-Stephanian land plants) show phylogenetic clustering of both ecological traits and extinction probability, and demonstrate the interaction of these factors in fossil data.

19: 2:30 PM-2:45 PM
Presenter: SIMPSON, CARL

AN ORGANISM-LEVEL TRADE OFF IN GROWTH AND REPRODUCTION AFFECTS THE MACROEVOLUTIONARY STABILITY OF REEFS

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Reef habitats are characterized by being formed and inhabited by organisms of various levels and degrees of individuality. Poorly individuated and usually colonial sponges, algae, corals, and bryozoans are all reef builders, while highly individuated members of other phyla live among the reef builders. The variation of individuality within reef dwelling organisms has consequences for reefs themselves. The degree of individuality is largely determined by the strategy of partitioning of energy into growth and reproduction. Poorly individuated organisms like corals dedicate more energy to growth than they do to reproduction and are therefore dedicated to occupying and competing for space. Conversely, highly individuated organisms dedicate more energy to reproduction and the expense of growth. Since individuality is observable in the fossil record, and a good proxy of the energy partitioning strategy, we can investigate the short- and long-term consequences of each strategy. A major short-term consequence of an organism specializing in growth is an increased ability to compete for and control space. Unfortunately, we predict that as a side effect of specializing on growth, poorly individuated organisms will have a low success rate of larval settling which in turn leads to patchy distributions and an increased risk of extinction. Since reef builders tend to be poorly individuated, this prediction is confirmed by the observation that reef habitats are more stable when the diversity of reef builders is high. This high diversity buffers reefs from the stochastic extinction of constituent reef builders. Furthermore, we observe that reef builders tend to have higher extinction rates than reef dwellers of the same taxomonic class based on an analysis of dynamic survivorship curves. This pattern is observed even in primitively highly individuated organisms like rudist bivalves. We infer that the life history demands of reef building organisms consequently increase their risk of extinction.

19: 2:45 PM-3:00 PM
Presenter: DORAN, NEAL A.

PASSPORTS TO SURVIVAL

DORAN, NEAL A., Classical Liberal Arts, Patrick Henry College, 1 Patrick Henry Circle, Purcellville, VA, 20132, United States, nadoran@phc.edu

Age-dependent extinction is an observation with obviously important biological implications. Van Valen's Red Queen hypothesis triggered three decades of research testing its primary implication: that age is independent of extinction. In the first report of the application of the Cox Proportional Hazards model to paleontological data, planktonic foraminiferal morphospecies were shown to have age-dependent extinction across two major boundaries: K-P and C-T (Doran et al, 2004, 2006). For these studies, planktonic foraminiferal morphospecies were chosen on the basis of their precise stratigraphic range data and finely-documented phylogenetic relationships. As morphospecies, they also qualify as Darwinian “individuals”, macroevolutionary units of selection a la Gould, 2002, characterized by birth, stability, death, and production of daughters. Well-defined first and last appearance dates on foraminiferal morphospecies likewise make them candidates for use in the Cox model in a way

analogous to patient survival in medical survivorship studies. In this case, the variable under study is extinction time, and morphological features play the role of covariates. The result is that the Red Queen hypothesis appears to be a time-averaged oscillation between extinction and recovery episodes, resulting in the well-known age-independent signal. Close analysis of species populations surviving the extinction episodes show the effect is attributable to the presence of shorter-ranged species (range < 4 Ma). Since the Cox Model equation allows for covariates, morphological parameters from the database were tested in addition and revealed further intriguing observations. Species survival (or lack thereof) correlates to various types of seemingly unrelated test morphology. Since hydrodynamic forces on organisms of this scale would seem to preclude a selective advantage for such subtleties of morphological change, other factors appear more likely. Shorter-ranged, smaller foraminiferal morphospecies seem to exhibit extinction “immunity” and leave morphological imprints that are discernable in a carefully-crafted survival analysis.

19: 3:00 PM-3:15 PM
Presenter: MYROW, PAUL M.

BIOMERE EXTINCTIONS: POTENTIAL CAUSES AND LINKS TO SEA LEVEL

MYROW, PAUL M, Geology, Colorado College, Dept. of Geology, Colorado College, 14 E. Cache La Poudre, Colorado Springs, CO, 80903, United States, pmyrow@coloradocollege.edu; TAYLOR, JOHN F., Geosciences, Indiana University of Pennsylvania, Indiana, PA, USA 15705; RIPPERDAN, ROBERT L., Earth and Atmospheric Sciences, Saint Louis University, St. Louis, MO, U.S.A., 63108; ETHINGTON, RAY L., Dept. Geological Sciences, University of Missouri, Columbia, MO, U.S.A., 65211

Cambrian biomeres and their associated stage boundaries represent systematic and repeated patterns of trilobite extinction within Laurentia. Sedimentological and biostratigraphic data from marine successions are used to propose process-response models to explain biomere extinction patterns. Many invoke sea level change as a forcing mechanism, although in some cases flooding and in others regression. Eustasy is sometimes linked to changes in temperature or levels of dissolved oxygen. We provide a detailed description and high-resolution (decimeter-scale) analysis of strata that span the critical interval at the top of the Ptychaspid Biomere, the last of the Cambrian Biomeres, and the base of the Ibexian Series. This includes an integrated sedimentological, biostratigraphic, and carbon-isotope chemostratigraphic analysis of numerous measured sections from the inner detrital belt of western North America. These sections contain well-developed, meter-scale, deepening-upward, subtidal cycles of shale and limestone that correlate across a broad area of the inner detrital belt. Deposition of shale is linked to the introduction of mud from reactivated rivers during lowstand conditions, and upward replacement by carbonate reflects reduced terrigenous input and enhanced carbonate saturation state of seawater. Sub-meter-scale resolution of the biostratigraphic data establishes that the horizons of faunal change (subzonal

boundaries) from within the critical interval at the top of the Ptychaspid Biomere do not coincide with the cycle boundaries. Instead, faunal turnover occurs within the upper parts of the upward-deepening cycles. Although the biomere occurs within a third-order lowstand, precise biostratigraphic data indicate that each component extinction occurred during the late stages of fifth-order highstand deposits. Thrombolitic microbial mounds, which are absent from the critical interval, reappear precisely at the top of the Ptychaspid Biomere. We interpret these not as disaster taxa but as a reflection of increased saturation state of seawater linked with rising sea level.

19: 3:15 PM-3:30 PM
Presenter: TAYLOR, JOHN F.

FAUNAL CHANGE AT THE BASE OF THE STAIRSIAN STAGE: DEATH RATTLE OF THE BIOMERE PHENOMENON

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A rapid turnover of trilobite faunas through the Skullrockian-Stairsian Stage boundary interval represents the first “biomere-type” crisis that affected Laurentian platform faunas in the Early Ordovician. The pattern of faunal change resembles that documented at Cambrian biomere stage boundaries in several respects: there is a thin “critical interval” (the *Paraplethopeltis* Zone) dominated by a survivor of the stage-boundary extinction that decimated the diverse fauna of the underlying Bellefontia trilobite Zone, proliferation of brachiopods and trilobites produced dense bioclastic lags, and a cosmopolitan, open-ocean trilobite (*Kainella*) migrated onto the platform to join the survivors. However, the pattern at the top of the crisis interval (base of the *Leiostegium* trilobite Zone) differs from Cambrian biomere boundaries in two critical respects. The trilobite genera that dominate the *Paraplethopeltis* Zone do not disappear, but range upward into the *Leiostegium* Zone where they are joined by the species used to define the base of that zone. Consequently, a minimum-diversity, olenimorph-dominated replacement fauna comparable to those that typify Cambrian biomeres is not present. Unlike the Cambrian biomere boundaries, the base of the *Leiostegium* Zone does not mark the final stage in the extinction process, but records the beginning of the biotic recovery. Owing to less severe environmental stress and/or critical zone taxa with higher tolerances for stress, the effect was muted and the virtual depopulation of the platform that occurred during Cambrian biomere extinction episodes was not accomplished. Retrogradational stacking of meter-scale subaqueous cycles in the interval through which these changes were documented by decimeter-scale sampling in the El Paso Group in New Mexico indicates continuous deposition during rising sea level. Carbon isotopic analysis revealed a steady increase in

values from just below the base of the *Paraplethopeltis* Zone to the peak of a positive excursion just above the base of the *Leiostegium* Zone.

19: 4:00 PM-4:15 PM
Presenter: KRÖGER, BJÖRN

THE ORIGIN AND INITIAL RISE OF PLANKTONIC CEPHALOPODS

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Cephalopods are generally considered as swimming animals, and as such as organisms of the free water column. Cephalopods of today inhabit nearly the complete range of marine environments, they live in rocky intertidal zones, in the blue ocean, related to the sea bottom and fully planktonic. A global distribution in a wide variety of environments did not exist from the beginning of cephalopod evolution. The earliest cephalopods appeared in the latest Cambrian in North China, by then a shallow carbonate platform in tropical low latitudes. Cephalopods diversified rapidly in the latest Cambrian but where confined to paleoenvironments in low latitude carbonate platforms up to the middle Tremadocian. The subsequent Ordovician expansion of habitats into more open water paleoenvironments and higher latitudes was never thoroughly investigated. Here, we explore cephalopod occurrence data from offshore settings from the Paleobiology Database and from own new data.The earliest cephalopods from offshore depositional environments are known from few occurrences only, from high paleo-latitudes of the middle-late Tremadocian. Cephalopods are not common in offshore depositional environments before the Darriwilian. The occurrence data show that Orthocerida and Lituitida are clearly more common, and often dominant in offshore settings. These cephalopods are characterized by predominantly slender, straight shells, with a thin siphuncle, wide septal spacing and a spherical initial chamber.The diversification of lituitids and orthocerids peaked in the Middle Ordovician and lead to a Late Ordovician diversity plateau, a diversification pattern which is similar to that of other planktonic groups. The dramatic late Early-Middle Ordovician rise in abundance and diversity of cephalopods of the blue ocean indicates the establishment of complex and stable plankton food webs during this time.

19: 4:15 PM-4:30 PM
Presenter: CARRANO, MATTHEW T.

DIVERSITY PATTERNS OF LATEST CRETACEOUS DINOSAURS IN THE WESTERN INTERIOR OF NORTH AMERICA

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Contentious discussions have surrounded estimates of latest Cretaceous dinosaur diversity, focused on widely divergent opinions about both the actual pattern and its implications. At the local scale, within-formation sampling shows little evidence for a decline in dinosaur diversity immediately prior to the end of the Maastrichtian. Globally and regionally, diversity appears higher in the Campanian than the Maastrichtian, leading to suggestions of a longer-term decline. However, comparisons of global, stage-level diversity have often relied on temporal correlations, rather than stratigraphic ones, when separating and aligning data samples. This results in a tendency to lump taxa into a single "Campanian" bin, despite the fact that better resolution is available regarding taxon contemporaneity. It is especially important to recognize that superposed formations (e.g. Foremost, Oldman, Dinosaur Park) can provide genuinely sequential diversity estimates even within a single stage. Additionally, such comparisons must also examine variations in sampling method and density, paleoenvironment, and taxonomic resolution. I present a new analysis of North American dinosaur diversity that addresses these factors. The results show much less variation between formations and time intervals than has been documented by raw, stage-level diversity counts. A significant proportion of diversity tracks changes in paleoenvironment and sampling density. At least in North America, dinosaur diversity at the close of the Cretaceous likely reflects more complex biotic and anthropogenic patterns, rather than a drawn-out, pre-extinction decline.

19: 4:30 PM-4:45 PM
Presenter: BRALOWER, TIMOTHY

EXTINCTION AND RECOVERY OF NANNOPLANKTON AT THE CRETACEOUS-TERTIARY BOUNDARY

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Mass extinction events strongly influence the diversity of life throughout Earth's history. Paleontologists have compiled the taxonomic changes during these events in remarkable detail, yet we have a relatively poor understanding of the processes that led to the extinction of so many species. The Cretaceous-Tertiary (K/T) mass-extinction event left an extraordinarily detailed fossil record, especially of the plankton that filled a key niche at the base of the marine food chain. Here, we statistically analyze calcareous nannoplankton counts in 823 samples from 17 globally distributed K/T boundary sections representing all of the

major ocean basins. Our results reveal that the northern hemisphere oceans suffered high extinction and a biotic crisis that peaked 32 kyr after the impact and lasted for 334 kyr. By contrast, the southern hemisphere oceans served as a refuge with lower extinction rates and a nearly immediate recovery of a normal plankton population. These geographic patterns are consistent with darkness and suppression of photosynthesis as the main killing mechanism for nannoplankton. We propose a number of mechanisms that explain the duration and geographic patterns of the recovery.

19: 4:45 PM-5:00 PM
Presenter: FRIEDMAN, MATT

ECOMORPHOLOGICAL SELECTIVITY AMONG MARINE TELEOST FISHES DURING THE END-CRETACEOUS EXTINCTION: THE IMPORTANCE OF PHYLOGENY WHEN EXAMINING PATTERNS OF EXTINCTION RISK

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Despite the attention focused on mass extinction events in the fossil record, extinction dynamics in the dominant group of marine vertebrates""fishes""remain largely unexplored from a paleobiological perspective. Patterns of selectivity among marine teleosts during the end-Cretaceous extinction were investigated using a newly assembled, phylogenetically explicit genus-level dataset. For each genus, two ecologically relevant parameters were recorded: (1) body size (body size is a correlate of many important aspects of life history); (2) jaw closing mechanical advantage (jaw mechanics give clues about feeding ecology). In addition to genera that make their last appearance in the Maastrichtian and those known to have survived the extinction, this study also considers lineages implied to have crossed the Cretaceous-Paleogene boundary by phylogeny, but which have not been directly sampled. Characteristics of inferred boundary-crossers were estimated using models of character evolution based on Brownian motion. Two variants were considered: punctuated and gradual change. Extinction intensity is higher for taxa with large body sizes and jaws consistent with speed (rather than force) transmission; resampling tests indicate that victims represent a non-random subset of taxa present in the final stage of the Cretaceous. Logistic regressions of the raw data reveal that this pattern stems primarily from the larger body sizes of victims relative to survivors. Jaw mechanics are also a significant factor for most dataset partitions, but are always less important than body size. When data are corrected for phylogenetic nonindependence, jaw mechanics show a highly significant correlation with extinction risk but body size does not; this appears partly attributable to the clustering of the largest extinction victims in a few clades. Many modern large-bodied, predatory taxa currently suffering from overexploitation, such billfishes and tunas, first occur in the Paleocene, when they seem to have filled the functional roles vacated by some extinction victims.

19: 5:00 PM-5:15 PM
Presenter: HARRINGTON, GUY J.

THE PALEOCENE-EOCENE PALM-HOUSE ON THE US GULF COAST

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The biotic responses to rapid global warming in the Paleocene-Eocene Thermal Maximum (PETM) at c. 55.8 Ma are well understood from the marine realm. Extinction and origination in nannoplankton and foraminifera, and blooms of dinoflagellates are observed and well time constrained within this c. 100 Kyr period of transient warming. But the responses of terrestrial ecosystems, and especially plants, are known only at high latitudes and mainly from one region, the US Western Interior. Particular attention is focused on the responses of highly diverse vegetation types at middle and low latitudes because they are modeled as the most susceptible to suffer deleterious effects mediated by global warming. We present palynofloral and stable carbon isotope data from sites on the eastern US Gulf Coast that represent candidate sections for parts of the PETM. Our results from Lauderdale Co., Mississippi indicate a distinct environmental change in the upper Tuscahoma Formation from brackish, muddy strand lines with emergent swamps to marginal marine glauconitic facies. The sediments immediately above this change contain abundant Apectodinium spp. and a negative shift in $\delta^{13}C$ of bulk organics. Pollen is abundant and the first occurrence of *Brosipollis* sp. (Burseraceae) and *Interpollis microsupplingensis* are observed in the basal samples above the facies change: European immigrants are represented early in the Eocene. Araliaceae makes an early appearance as well together with *Retistrephanocolporites* sp. and a morphotype of *Quadricolporites* sp. Higher in the section *Nuxpollenites psilatus* (Loranthaceae) first appears before true *Platycarya* in the uppermost 10cm of the Tuscahoma Fm. At least 12 last occurrences are recorded together with a significant increase in palm and angiosperm abundance. Our results indicate that the PETM probably drives regional plant extinction. The abundance of Burseraceae and (probable) early successional plants confirm that seasonally dry and disturbed environments mark intervals within the earliest Eocene.

19: 5:15 PM-5:30 PM
Presenter: BURZYNSKI, GREG

BIVALVE SURVIVAL SELECTIVITY DURING THE LATE PLIOCENE: WAS HIGH METABOLISM A DETRIMENT?

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Survival of species across mass extinction events is of special interest in evolutionary study. Cenozoic molluscan faunas suffered several mass extinctions which offer insight into biological factors influencing survivorship. Previous studies have examined effects of morphological escalation on molluscan survivorship across extinction boundaries and generally found no relationship; few have focused on behavioral escalation, which includes anti-predatory burrowing or swimming. This behavioral escalation would lead to increased metabolism, which has a useful proxy in the fossil record.Using novel biogeochemical techniques, metabolic rates of fossil bivalves can be studied. Ratios of stable oxygen isotopes vary seasonally in marine environments; ^{18}O enrichment occurs during cooler periods and ^{16}O in warmer periods. As bivalves secrete their shells outward, the isotopic ratios are recorded. Stable isotope analysis of representative shells from selected taxa will be performed serially from umbo to commissure to produce sinusoidal growth curves. With these annual growth rate can be determined, which is intimately linked to metabolic rate. A major extinction of marine bivalves occurred during the upper Pliocene, straddling the Moore House Member of the Yorktown Formation and the Chowan River Formation. Bulk samples of bivalves from the upper Pliocene of Virginia and North Carolina were collected from these formations, and picked and sorted, where possible, to the species level. Several taxa, including Glycymeris, Mercenaria, and Pectinidae, have been identified as potential groups for isotope analysis. Comparison of relative abundance of each species at each stratigraphic level will demonstrate which were better able to endure the extinction. It is predicted that species with a higher metabolic rate will, due to higher nutrient demands, be preferentially decimated during times of lower food source abundance. This study will demonstrate the feasibility of the stable isotope method in evolutionary paleoecological studies, and shed new light on how biotic factors influence macroevolution.

Session No. 20, 1:30 PM; Thursday, 25 June 2009
Symposium S10. The Nature of Science and Public-Science Literacy

20: 1:30 PM-1:45 PM

Presenter: DODSON, PETER

VOYAGES OF DISCOVERY

DODSON, PETER, University of Pennsylvania, Dept Animal Biology, Vet School, University of Pennsylvania, Philadelphia, PA, 19104, United States, dodsonp@vet.upenn.edu

As we celebrate Charles Darwin's 200th anniversary, we can reflect on the role that paleontology played in his scientific life. Darwin was a well-trained natural historian and a keen observer. On the voyage of the Beagle he discovered important mammalian fossils (but missed an opportunity to discover spectacular Patagonian dinosaurs). He was disappointed at the failure of the fossil record to document evolutionary transitions. Paleontology was then in its infancy. Today, 150 years later, the fossil record, still incomplete, is incomparably richer and most definitely demonstrates transitions that would have delighted him. Spectacular examples include “fishapods,” “walking whales,” and the maniptoran-bird transition. Darwin made another voyage during his life, from religious belief to skepticism. Darwin never rejected belief in God; he explicitly disavowed atheism. His agnosticism did not follow from his scientific studies but rather from the death of his beloved daughter Annie in 1851. Despite the cacophony of best-selling scientific writers such as Richard Dawkins, evolution co-exists as comfortably with religious belief as with atheism. I went on a voyage of discovery myself after encountering evangelical atheist Will Provine in 1988. There were two results of this voyage: I discovered that although there are many atheists in the scientific community, there are also many persons of faith as well, most of whom toil quietly at their science without making a public issue of personal beliefs. I also discovered that I am able to discuss the issues of science and faith with students and the general public. The public is well served by balanced discussion not acrimonious debate.

20: 1:45 PM-2:00 PM
Presenter: GREER, PENNY

PRESENT DAY CHRISTIAN FUNDAMENTALIST REJECTION OF EVOLUTION: LEGACIES FROM THE PAST

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Darwin's Origin of Species was greeted with a variety of responses among 19th Century Protestants. Some enthusiastically embraced it, integrating it into the core of their faith. Others, such as many Evangelicals and most Fundamentalists, opposed evolution on what they considered to be scientific grounds. Their opposition has continued for at least three reasons. 1) Current opponents believe that evolution is a theory or a hunch, and therefore it is not factual. 2) Some current opponents cling to the “orthodox” text, as though it were the latest

word on the science, much as they might treat the Bible, ignoring 150 years of development in diverse areas of biology. 3) Still others believe that “godless, materialistic” science, as they characterize it, has eclipsed faith throughout society, and they have set out to create a new evangelistic tool, “Creation Science,” to encourage conversions to the faith (especially with youth). Influenced by the writings of Francis Bacon, a key proponent of Scientific Empiricism, and Thomas Reid, a Common Sense philosopher, these 19th Century opponents believed nature is governed by God's laws that are supported by facts. The facts of nature can be discovered by anyone who uses common sense. For these opponents, to do science, one would observe nature searching for facts. Then, one can discover, organize and classify those facts from which one could discover laws. Hypotheses and theories were considered to be speculative and therefore to be rejected. Further, they believed that God's laws were best articulated through the Bible whose revelations should guide any scientific research. Finally, building upon the 18th Century American Great Awakening religious movement and many revivals since, they believed successful methods that encourage personal faith conversions are paramount. The past is a key to the present for understanding current fundamentalist rejection of evolution.

20: 2:00 PM-2:15 PM
Presenter: DOMNING, DARYL P.

WHO SHOULD SPEAK FOR EVOLUTION: ATHEISTS OR THEISTS?

DOMNING, DARYL P., Dept. of Anatomy, Howard University, Washington, DC, 20059, United States, ddomning@howard.edu

The creation-evolution debate has been stalemated for decades, largely because the two sides talk past each other. Although creationists (including “intelligent design” advocates) claim scientific evidence for their views, they are mostly motivated by valid existential concerns such as the meaning and purpose of life, morality, the existence of God, life after death, etc. Since defenders of evolution usually confine themselves to scientific arguments like “creation scientists” do, the debate fails to come to grips with the underlying “crisis of meaning” in many people's minds. If the existential issues are brought into the discussion at all, it is usually by atheistic evolutionists who seek to delegitimize all religious thinking. This too plays into creationists' tactics, by corroborating their false claim that evolutionary science embodies metaphysical (not just methodological) materialism. In order to be helpful in support of science education, rather than just inflaming the controversy, atheists have to decide which they care about more: making our schools safe for evolution, or ridding the world of religion. Trying to do both at once alienates religionists who are their potential allies in supporting good science. I argue that persuading a clear majority of U.S. voters to accept the teaching of evolution will instead require allaying their fears of it, by showing them a theological understanding of evolution that they can live with and that might even help resolve their “crisis of meaning”. Some contemporary forms of “theistic evolution”, which hold that God

creates by means of evolution but without intervening in its mechanisms, are compatible with both science and mainstream Christian (and much other) theology. Atheists can't make this case or speak this language; only theists can. Theistic evolutionists should therefore step forward in greater numbers as prominent advocates for evolution, and not leave the public podium largely to antireligious extremists.

20: 2:15 PM-2:30 PM
Presenter: MATHESON, STEPHEN

WHY IS THERE NO CONTROVERSY SURROUNDING THEISTIC EMBRYOLOGY? DISSECTING CRITICAL RESPONSES TO THEISTIC EVOLUTION.

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Those who simultaneously express Christian belief and affirm evolutionary theory are said to espouse a position called “theistic evolution.” The view holds the peculiar distinction of being reviled by both hard-line creationists (who call it “appeasement”) and prominent atheist commentators (who deride it as fallacious). I argue that these critics typically fail to articulate objections that are specific to the view. Most creationist critics of theistic evolution object to one or both of these characteristics of the view: 1) its reliance on naturalistic explanation, a feature common to all scientific theorizing; or 2) its embrace of “random” causal events, a feature common to myriad scientific explanations. Most atheist critics of theistic evolution object to its openness to supernatural explanation, a feature of religious belief in general. Such criticisms, valid or not, fail to address anything specific to theistic evolution. In other words, attacks on theistic evolution are usually attacks on theism or attacks on evolution, but rarely represent specific criticisms of the theistic evolution position. To better understand the controversy surrounding theistic evolution, I propose that critiques of the position be considered in light of a lesser-known position we may (with tongue in cheek) call “theistic embryology.” Theistic embryology describes the thinking of those who simultaneously express Christian belief and affirm basic theories in human developmental biology. Although the logic is indistinguishable from that of theistic evolution, the view is uncontroversial and the term “theistic embryology” is practically non-existent. I suggest that critiques of theistic evolution be subjected to the “theistic embryology test.” Most critiques that claim to identify weaknesses in theistic evolution make arguments that are equally damaging to “theistic embryology” and so fail the test. Critiques that fail this whimsical test are likely to be arguments against belief, or against naturalistic explanation, and should be considered as such.

20: 2:30 PM-2:45 PM

Presenter: MILLER, KEITH B.

THE MEANING AND IMPORTANCE OF METHODOLOGICAL NATURALISM

MILLER, KEITH B., Geology, Kansas State University, 108 Thompson Hall, Manhattan, KS, 66506, United States, kbmill@ksu.edu

Science is a methodology that provides a limited, but very fruitful, way of knowing about the natural world. This method works only if science confines itself to the investigation of "natural" entities and forces. This self-limitation is sometimes referred to as "methodological naturalism." It is the basis for the testability of scientific propositions. Individuals on both sides of the public "creation - evolution" debate have promoted a warfare view of science and faith based on a fundamental confusion of methodological naturalism (MN) with philosophical naturalism or materialism. In reality, MN is entirely compatible with a theistic worldview, and the term itself was coined by a Christian philosopher who viewed science as compatible with other pathways to knowledge. One of the critical issues in the public debate is the distinction between natural and supernatural agency. The absence of references to supernatural cause in scientific description is not just an agreed philosophical limitation of science, but it is a consequence of the practical inability of science to detect divine action. The supernatural is unconstrained by natural law or by the capabilities of natural entities and forces, and thus can do anything. From the perspective of scientific inquiry, a supernatural agent is effectively a black box, and appeals to supernatural action are essentially appeals to ignorance. Understanding the methodological limits of science is key to diffusing much of the public resistance to the conclusions of modern science – particularly evolutionary science. There is no theistic or atheistic science. Scientific investigation has been so successful in large part because it is a trans-cultural enterprise embraced by individuals holding a wide range of religious and non-religious perspectives.

20: 2:45 PM-3:00 PM
Presenter: MURPHY, GEORGE L.

METHODOLOGICAL NATURALISM AND THE INTEGRITY OF SCIENCE AND THEOLOGY

MURPHY, GEORGE L., Trinity Lutheran Seminary, 538 Cynthia Lane, Tallmadge, OH, 44278, United States, gmurphy10@neo.rr.com

Recent arguments have challenged both the independence of science from religion and the legitimacy of theology as a study of anything real. Methodological naturalism (MN), as a criterion for scientific practice, helps to prevent erosion of either discipline. Intelligent Design proponents argue that action of a Designer (God) can be inferred from observations and should be part of scientific theories. Science would then no longer study the natural world alone. "New Atheists" maintain that scientific explanations rule out belief in a

God who acts in the world, so that theology is vacuous. MN means that science attempts to explain natural phenomena entirely in terms of natural entities. Thus a supernatural Designer is excluded from scientific theories. MN is, however, part of the definition of science, not a claim about what exists. Science cannot say that the natural world is all there is, for MN forbids scientific discussion of entities beyond nature. Thus scientific arguments for atheism fail. MN does not say that science will explain all phenomena. But scientists, qua scientists, stay within its limits, and cannot conclude that any given event was miraculous.
While MN is sometimes seen simply as a cease fire between science and theology or protection for religion, there are more fundamental reasons for it. Some Christian theologies hold that God's action in nature is generally hidden, and that we can understand the world "though God were not given." Such theologies thus insist not only on their own integrity but on that of science.

20: 3:00 PM-3:15 PM
Presenter: HAARSMA, LOREN

WHERE SCIENCE MEETS WORLDVIEWS

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Scientists of many different philosophical and religious worldviews typically work together and reach consensus on all sorts of scientific questions. But that doesn't mean that the practice of science is independent of the worldview of the scientist. Our worldviews form a philosophical basis for how and why we do science, how we interpret the discoveries of science, how we approach scientific puzzles, how we integrate scientific knowledge with other kinds of knowledge, and the ethics we practice when we do science. This talk will discuss examples of each of those. A scientist's worldview might not greatly influence how she works with a professional colleague, but it is much more likely to influence how she teaches students or speaks to the general public about her work. Because students and the general public hold a wide variety of religious worldviews, a scientist can be a better teacher or public advocate for science is she is candidly aware of how her own worldviews interact with her scientific knowledge.

20: 3:15 PM-3:30 PM
Presenter: PRINCEHOUSE, PATRICIA

ABUSING FOSSILS- CREATIONISTS & THE MEANING OF HISTORY

PRINCEHOUSE, PATRICIA, Biology, Institute for the Science of Origins, Case Western Reserve University, Cleveland, OH, 44106, United States, labrise@msn.com

Creationists capitalize on misperceptions of the nature of science –on the part of the public and also by many inside academia. The most interesting abuses may be ones regarding history –both the history of the earth/life, and the history of science and culture. Thus we encounter Young-Earth Creationist museums rejecting radiometric and carbon dating in one exhibit, only to embrace carbon dating in the next as a means of authenticating the antiquity of historical accounts of encounters with dinosaurish dragons. Creationists on the Ohio Board of Education have promoted materials for public school classroom instruction pretending that various fossils and geologic sequences contradict the expectations of evolutionary biologists. Even Ohio's state fossil Isotelus has fallen victim. On the cultural side of history, creationist materials exploit many examples from the history of science, and increasingly misuse terminology from scholarly History & Philosophy of Science. Many creationists reject evolution, big bang cosmology and other things they do not care for as "historical science" while promoting alternatives they claim are "empirical science." A recent trend attempts to recycle "Intelligent-Design" creationism from anti-evolution to anti-Modern Synthesis/neo-Darwinism. Criticisms of Darwin, Darwinians, and the Modern Synthesis are taken from German Synthesis stalwarts such as Goldschmidt and Schindewolf. But to do so, creationists must grossly misrepresent these evolutionary biologists, since they outspokenly opposed super-natural forces as part of scientific explanations. Their work is being misappropriated to the service of twenty-first-century religious politics.

20: 4:00 PM-4:15 PM
Presenter: RISSING, STEVE

PUBLIC PERCEPTION OF THE NATURE OF SCIENCE: TEN LESSONS LEARNED FROM THE OHIO INTELLIGENT DESIGN CREATIONISM BROUHAHA

RISSING, STEVE, The Ohio State University, 5735 Rushwood Dr., Dublin, OH, 43017, United States, rissing.2@osu.edu

Excursions from academia to help form science education policy provides insights into the public's perception of the nature of science. In response to the federal "No Child Left Behind" legislation, the Ohio state Board of Education prepared its first ever K-12 science content standards. A "Model Curriculum" addressing each content standard was also prepared and adopted. "Citizens panels" representing a "balance" of interests within the state prepared both resources. The process resulted in a content standard and model lesson that endorsed Intelligent Design Creationism. Throughout this process, several university-based scientists worked with the state Board of Education and local newspapers to increase the scientific integrity of the standards and Model Curriculum resulting eventually in the removal of the Creationism standard and lesson. The experience revealed a number of misconceptions about

the nature of science held by the public, including and especially policy makers. These will be discussed.

20: 4:15 PM-4:30 PM
Presenter: SPRINGER, DALE A

SCIENCE, FAITH, AND THE MEDIA: COMPLEX ISSUES IN THE AGE OF THE SOUND BITE

SPRINGER, DALE A, Geography and Geosciences, Bloomsburg University, Dept. Geography and Geosciences, Bloomsburg Univ, 400 E. 2nd St., Bloomsburg, PA, 17815, United States, dspringe@bloomu.edu

Paleontologists are acutely aware of the need to address the problem of public misunderstanding of the nature of science. This is nowhere more evident than when we discuss evolution. It is tempting to tune out the pseudoscientific/belief-based arguments set out ad nauseum by creationists; or decide not to read yet another article on the “debate” over evolution “versus” creationism/intelligent design. Unfortunately, we do an injustice to both science and faith when we ignore inaccurate or misguided reporting of these subjects by the media. We want the public and influential policy-makers to understand why evolutionary theory is science and why intelligent design is not—and why the particular political and social agenda of design proponents does a disservice to both science and faith. To accomplish this, we must step out of the comfort zone of our research and teaching and find effective methods of presenting the nature of science, and the complexity of evolutionary theory, to non-scientists. We have to learn how to use the media as effectively as do creationists. Our past performance indicates this is not easily accomplished. Scientific discussion is not amenable to classical or talk show debate formats, nor readily portioned into digestible sound bites. Journalists writing about evolution and intelligent design issues often have little or no scientific or theological training. Thus they may not have the tools to distinguish between scientific reasoning and professions of belief. We can change this, but it is imperative that experts from the scientific and faith communities work together to formulate a well-reasoned, comprehensive, and decidedly proactive plan to provide members of the media with the tools they need. The reward: we can create a ‘wedge’ of our own, helping the media become thoughtful, effective interpreters of science, especially evolution, for the general public.

20: 4:30 PM-4:45 PM
Presenter: PETTO, ANDREW J.

TEACHING AND LEARNING ABOUT THE HISTORY AND DIVERSITY OF LIFE

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The late 20th century saw two dramatic efforts to redesign the science curriculum in public schools in the USA. The main thrust of both these efforts was to align the curriculum more closely with the “big ideas” in contemporary scientific research and to emphasis science as a process of inquiry, rather than as a collection of facts. While curriculum reform swept the nation's schools, the re-invigoration of science teaching and learning also awoke a slumbering giant — anti-evolutionism. Beginning in the early 1960s — and continuing today — opponents of evolution mounted repeated efforts to remove evolution from the curriculum. Failing that, the secondary goal was to present “alternative theories” — such as biblical creation and “intelligent design” — as equivalent components of the science curriculum. Although these proposals have consistently been struck down — mostly on First Amendment grounds, the persistent effect has been to convince a significant plurality of US citizens that evolution is scientifically suspect. The evolution of anti-evolutionism has included political activism, media and public-relations success, and attempts to claim discrimination against valid scientific proposals. As a result, the sectarian foundations of these proposals are carefully hidden below many strata of rhetoric about “fairness”, “viewpoint discrimination”, and — most recently — “academic freedom”. In the future, attempts to secularize the rhetoric of anti-evolutionism may succeed in avoiding First Amendment obstacles, and successful promotion of valid scientific content in the curriculum will require a general public that is much more familiar with the nature and process of scientific inquiry as practiced in the 21st century.

20: 4:45 PM-5:00 PM
Presenter: GLYMOUR, BRUCE

SCIENCE, VALUES AND PRAGMATISM: THE VALUE OF OPTIMISM IN PUBLIC COMMUNICATION

GLYMOUR, BRUCE, Dept. of Philosophy, Kansas State University, Manhattan, KS, 66506, United States, glymour@ksu.edu

Science aims to discover true theories that correctly predict natural phenomena. These aims are not unique to science; what is unique is the method by which these aims are pursued. That method privileges a particular value, truth, and seeks to insure success in respect of it by testing theory against empirical data. Scientific tests compare predictions with observations. Auxiliary assumptions beyond the theory being tested are required both in order to generate predictions and to ground inferences from successful predictions to the truth of the predicting theory. Some auxiliary assumptions can not be justified by appeal to background theories, independent test, or experimental design; instead they must be justified pragmatically. A pragmatic justification shows that if an assumed auxiliary is true, the data suffice to identify a true theory, while if the auxiliary is false, it is not possible to draw warranted inferences from data. Such auxiliaries are therefore justified by the aim of reliable discovery itself: if false,

successful inference is impossible, while if true, success is possible only if one assumes the auxiliary is true. In this respect, science is constitutively optimistic. In contrast, pseudo-science, such as creation science and versions of intelligent design, trades on pessimism. Pseudo-scientific critiques of science turn on pragmatically justified auxiliary assumptions, e.g. vera causa presuppositions, which are then rejected by the pseudo-science. To the extent that one seriously entertains the possibility that such auxiliaries are mistaken, it becomes impossible to learn from experience: all possible data underdetermine the truth. The essentially optimistic nature of the scientific enterprise provides a natural way to frame discussions of science and the scientific method with public audiences.

20: 5:00 PM-5:15 PM
Presenter: SCOTCHMOOR, JUDITH

SHIFTING THE PARADIGM: MOVING TOWARD A MORE REALISTIC PORTRAYAL OF HOW SCIENCE WORKS

SCOTCHMOOR, JUDITH, Museum of Paleontology, University of California, Berkeley, 1101 Valley Life Sciences Building No. 4780, Berkeley, CA, 94720-4780, United States, jscotch@berkeley.edu; CALDWELL, ROY L., Museum of Paleontology, University of California, Berkeley, 1101 Valley Life Sciences Building No. 4780, Berkeley, CA 94720-4780; LINDBERG, DAVID R., Museum of Paleontology, University of California, Berkeley, 1101 Valley Life Sciences Building No. 4780, Berkeley, CA 94720-4780; THANUKOS, ANASTASIA, Museum of Paleontology, University of California, Berkeley, 1101 Valley Life Sciences Building No. 4780, Berkeley, CA 94720-4780

Most Americans do not understand the scientific process, nor can they distinguish between science and non-science (National Science Board, 2006). Given the impact of science on society, the lack of public understanding of science should be a concern to us all. In large part, the current confusions about evolution, global warming, stem cell research, and other aspects of science are symptomatic of a general misunderstanding of what science is and what it is not. Too few of our citizens view science as a dynamic process through which we gain a reliable understanding of the natural world. As a result, the public becomes vulnerable to misinformation and the very real benefits of science become obscured. In response, several initiatives have emerged from the science research community to engage the public and improve public understanding about how science works, why it matters, and who scientists are. One such initiative is “Understanding Science”- an NSF-funded resource that has at its heart a public re-engagement with science that begins with teacher preparation. To this end, its immediate goals are to (1) improve teacher understanding of the nature of the scientific enterprise and (2) provide resources and strategies that encourage and enable K-16 teachers to incorporate and reinforce the nature of science throughout their science teaching.This collaborative project, developed by the UC Museum of Paleontology, accurately portrays how science really works and serves to both inspire and engage students in the dynamic nature of

science. Whereas the “scientific method” within our text books stresses the destination (conclusion), this project stresses the journey - the unique paths by which the natural universe is understood. It includes the creative aspects of scientific research, the influence and diversity of the scientific community, the applications, the joys, and the frustrations.

20: 5:15 PM-5:30 PM
Presenter: WANG, WEI

KNOWLEDGE COMMUNICATION ABOUT FOSSILS: INVESTIGATION AND PRACTICE IN THE CYBER WORLD

WANG, WEI, Nanjing Institute of Geology and Paleontology, CAS, 39 East Beijing Road, Nanjing, Jiangsu, 210008, China, weiwang@nigpas.ac.cn

At the end of June 2008,the number of Chinese internet users had reached 253 million, and around 20% of the Chinese population uses the Internet for learning and knowledge searching. China is rich in fossils but the general Chinese public lack basic knowledge in paleontology. Fossil Web, a cyber bridge between science and the public, aims to meet the public needs for the understanding of life and earth, and to attract teenagers to learn about fossil, the mysteries of life and our planet.”Fossil Web” is the heaviest popular science web in China, has 11000 more pages includes online museum, knowledge of nature history, showing and discussing news, pictures and stories about fossils and paleontology. In response to the public needs for understanding life and earth, Fossil Web draws teenagers away from endless games and unsuitable websites. For e-Science, Fossil Web has put in effort in “interactive learning”, “knowledge pushing”, “society assembling,” and “opinion leader training” so that it may become a favorite world for people who are interested in nature and life. As it has gathered 7000 more active members, “Fossil Web” has organized field trips for amateurs to help them gain hands-on experience in fossil hunting and prepared them for further research. Some participants have published papers in professional journals. The “Fossil Web” popular monthly e-Magazine from 2008, “Fossil@NET”, written mainly by amateurs, has published 12 issues. Some novel techniques developed by website members have already been applied by professionals. Many new findings discovered by them have drawn the attention of paleontologists and geologists.”Fossil Web” has engaged in amateurs' activities, and has successfully held the Fossil Amateurs' Conference of China twice, which provides a stage for amateurs to have face-to-face communication and academic discussions with paleontologists in person.

20: Poster
Presenter: RIYAHI, KUMARS

THE CREATIONISM/EVOLUTION CONTROVERSY: POSSIBLE SOLUTIONS FOR A WORKABLE AGREEMENT BETWEEN SCIENCE AND RELIGION? Fur full abstract, see *17: 2:00 PM, Booth 18*

Session No. 21, 1:30 PM; Thursday, 25 June 2009
Symposium S11. Paleontology in K-12 Education

21: 1:30 PM-1:50 PM
Presenter: SANDY, MICHAEL R.

"CLAM CHOWDER, SHARK SOUP, AND ECHINODERM SANDWICHES" VIRTUAL FIELD TRIP TO THE HIGHLY FOSSILIFEROUS MIOCENE OF LEE CREEK, AURORA, NORTH CAROLINA: AN INQUIRY-BASED PALEONTOLOGICAL ACTIVITY THAT CAN BE READILY ADAPTED FOR EARLY CHILDHOOD, MIDDLE, ADOLESCENT/YOUNG ADULT, OR UNDERGRADUATE CLASSES

SANDY, MICHAEL R., Geology, University of Dayton, 300 College Park, Dayton, OH, 45469-2364, United States, michael.sandy@notes.udayton.edu; WRIGHT , JASON, Science, Ansonia High School, 600 East Canal Street, Ansonia,OH 45303; HOLLIDAY, CANDACE, 765 Main Street, Aurora,NC 27806; MCKINNEY, FRANK K., Geology, Appalachian State University, Boone, NC 28608

In this session we will take a "virtual" field trip in the classroom or laboratory by investigating fossiliferous marine sediment collected from waste piles from the PCS Phosphate Mine, Lee Creek, Aurora, Beaufort County, North Carolina. This area has a rich and famous fossil fauna comprising many vertebrates including sharks (myriads of teeth!), rays, whales, porpoises, reptiles and rich invertebrate faunas including molluscs, echinoderms, and barnacles. The material we are using here is from the Pungo River Formation of Miocene age. This formation is interbedded with other famously fossiliferous units such as the unconformably overlying Pliocene Yorktown Formation. We will discuss an activity based on the use of this richly fossiliferous sediment and how it can be easily adapted for your class depending on your needs. Uses can range from: a "fossil hunt" and differentiating vertebrates from invertebrates; identifying shark teeth, ray plates, clams, snails, coral and echinoderm fragments and barnacle plates that are usually common to very abundant in samples and the subtleties of telling them apart discussed; to a more systematic treatment of the fossils, identifying them to genus and species level where possible; estimating shark body length;to a discussion of the environments and lifestyles of the organisms represented.This activity can be adapted to address a number of indicators in Life Science, Earth Science, and Scientific Inquiry at a variety of grade levels. The fossiliferous sediment used for this activity is actually the waste from phosphate processing at the Aurora Phosphate Mine operated by Potash Corporation of Saskatchewan: http://www.mining-technology.com/projects/aurora/. The local Aurora Fossil Museum

maintains a website with information on the locality: http://www.aurorafossilmuseum.com/. In addition other informative sites can be easily located online. Available resources will be discussed. Thanks to Curtis Ormond, PCS Phosphate for support and access.

21: 1:50 PM-2:10 PM
Presenter: BOESCHE-TAYLOR, ELIZABETH

INQUIRY-BASED HIGH SCHOOL SCIENCE LAB: USING FOSSILS TO DEMONSTRATE TYPES OF FOSSILIZATION AND RELATIONSHIPS OF PLANTS

BOESCHE-TAYLOR, ELIZABETH, Science, Scottsburg High School, 500 S Gardner St., Scottsburg, IN, 47170, United States, btaylor@scsd2.k12.in.us; TAYLOR, DAVID W., Biology, Indiana University Southeast, 4201 Grant Line Rd., New Albany, IN 47150

Students of all ages, even high school, enjoy looking at and interacting with fossils. A variety of fossils were shared with high school science students. The students where placed into groups and assigned roles. The groups, in a control exercise, were first asked to describe the organism, identify the fossilization type, and to determine the amount of information about the organism that might be preserved. This included whether original organic material was preserved and cells could be observed. Each group then presented the results of their study to the class. The second phase had the groups examine a selection of living plants showing the major groups of green land plants. These plants were preserved as flattened herbarium specimens (more similar to fossils). A data collection sheet allowed a uniform record of their observations. The students shared their results with the class. Based on their data the class then created a simple phylogenetic relationships and placed the plants on an evolutionary tree. This produced a hypothesis of the relative age of the groups. In the third phase, the groups examined a selection of plant fossils. As they did with the first group of fossils, they described them in detail, and then identified the major living group of plants to which they belonged based on the shared characters. These fossils and their ages were used to test the previous hypothesis of the phylogeny of the living plant groups. This hands-on, inquiry-based project supports several of the Indiana (and other) State and National standards. With a focus at the national level of science as a process, this project was created as a means of moving from teacher centered to learner directed inquiry. A variety of assessments were used to gauge student learning. Standards alignment, assessment tools, and data collection techniques will be shared.

21: 2:10 PM-2:30 PM
Presenter: TERRY, MARK

THIRTY YEARS OF PALEONTOLOGICAL SCIENCE AT NORTHWEST SCHOOL

TERRY, MARK, Science, Northwest School, 1415 Summit Avenue, Seattle, WA, 98122, United States, mark.terry@northwestschool.org

Paleontology has been a vital part of Northwest School's curriculum for high school students for thirty years. The history of paleontological thought is used to underscore the nature of science itself. Paleontology's crucial role in the development of Darwin's ideas is highlighted each year in our interdisciplinary study of Evolution. We've introduced our students to the local major museum collection (Burke Museum) via field trips, and have also brought a series of working paleontologists into our courses. Our senior life science elective includes an examination of the primate fossil record using the students' background in comparative skeletal and dental anatomy. For twenty years we've made an annual spring expedition to the John Day Fossil Beds National Monument, where the paleontology staff has introduced us to prospecting, preparing, curating and interpreting fossils. We judge the success of these curricular strategies by the interest our students express in pursuing more science and by the career paths of some of our graduates.

21: 2:30 PM-2:50 PM
Presenter: SCOTCHMOOR, JUDITH

WHAT CAN WE REALLY LEARN FROM DINOSAURS?

SCOTCHMOOR, JUDITH, Museum of Paleontology, University of California, Berkeley, 1101 Valley Life Sciences Building No. 4780, Berkeley, CA, 94720-4780, United States, jscotch@berkeley.edu

Far beyond the remembering that “tri” means three and “ceratops” means horn face, dinosaurs have the potential to open the scientific world to students of all ages. From evolution to biogeography, behavior, physiology, paleoecology, and the nature of science, dinosaurs provide an opportunity for students to understand how we know what we know about past life. This session will focus on specific activities to engage students in science as science is done.

21: 2:50 PM-3:10 PM
Presenter: FISHERKELLER, PEGGY

PALEONTOLOGISTS AND THE PUBLIC: AN AWKWARD CONVERSATION

FISHERKELLER, PEGGY, Natural History, Indiana State Museum, 650 West Washington Street, Indianapolis, IN, 46204, United States, pfisherkeller@dnr.in.gov; BROWN, GAIL W., Performing

Arts and Education, Indiana State Museum, 650 West Washington Street, Indianapolis, IN 46204

Members of the general public often lack the awareness of a concept that to paleontologists is as fundamental as breathing. The basic, often unsaid notion that not all fossil bones are dinosaurs often makes communication between interested lay people and scientists stunted and difficult. Add to that other misperceptions that non-scientists hold about geologic and biologic topics and the task of transmitting ideas appears monumental. Paleontologists share responsibility for these awkward conversations. As a museum that deals in natural history, the Indiana State Museum attempts to act as a bridge between large scale scientific concepts and the public's preconceived notions. Museum staff and volunteers address this challenge through development of core topical galleries, an active dig program, special exhibits, public festivals, summer camps, and school workshops.

21: 3:10 PM-3:30 PM
Presenter: GOLDSTEIN, ALAN

UTILIZING LOCAL RESOURCES TO IMPROVE PALEONTOLOGY KNOWLEDGE OF K-12 EDUCATORS

GOLDSTEIN, ALAN, Falls of the Ohio State Park, 201 West Riverside Drive, Clarksville, IN, 47129-3148, United States, agoldstein@dnr.in.gov

Most science teachers do not get in-depth training in paleontology prior to reaching the classroom. Professional development opportunities to get fossils for the classroom are primarily restricted to dinosaur digs located hundreds or thousands of miles away. Learning about the paleontology in an educator's own backyard is often more difficult. Fifteen years ago the Falls of the Ohio State Park has developed two workshops that allow educators to not only learn about fossils using local examples, but also go out in the field to both observe and collect them. This presentation will describe the goals and objectives of the three-day Field Paleontology Institute and one-day F.P.I. Discovery Day and how they fulfill a professional development need. Participants are able to return to these sites to resupply their classroom whenever necessary, saving tight dollars used to buy pre-packaged expensive collections with fossils that are lost, stolen or broken within a few years. This workshop could be duplicated in many parts of North America.

21: 4:00 PM-4:20 PM
Presenter: SMRECAK, TRISHA A.

PALEONTOLOGICAL TEACHING INITIATIVES AT THE PALEONTOLOGICAL RESEARCH INSTITUTION

SMRECAK, TRISHA A., Paleontological Research Institution, 1259 Trumansburg Rd, Ithaca, NY, 14850, United States, trish.smrecak@gmail.com; KISSEL, RICHARD A., Paleontological Research Institution, 1259 Trumansburg Rd., Ithaca, NY, USA, 14850; ROSS, ROBERT M., Paleontological Research Institution, 1259 Trumansburg Rd., Ithaca, NY, USA, 14850; CRAWFORD, BARBARA A., Department of Education, Cornell University, Ithaca, NY, USA, 14850

The Paleontological Research Institution (PRI) has a rich history of paleontology and evolution-based research. PRI has received a number of NSF education grants that focus on bringing real science into the classroom. We highlight the Teacher-Friendly Guides and Fossil Finders programs, which increase inquiry-based Earth system science literacy by introducing local and regional geology into the classroom.PRI's Teacher-Friendly Guides (TFGs) complement existing Earth science curricula by encouraging educators to introduce local geologic history and features into the classroom. The series consists of seven regional guides. Guide development will proceed through planned interaction with educators before, during, and after guide completion, and content is approved by geoscientists in each region. A critical extension of the guides is the Virtual Fieldwork Experience (VFE). VFEs bring the field to the classroom, and TFGs provide educators with the resources necessary to understand local geology, who may then produce VFEs for their classroom. Both TFGs and VFE's will be posted online as they are completed.Fossil Finders engages learners in an authentic investigation of Devonian fossils while helping paleontologists understand fine-scale faunal change. Students answer the question “Do organisms in the Devonian sea stay the same during environmental changes?” This program, a collaboration with Cornell University, focuses on 5-9th grade classrooms and, using online databasing, allows teachers to compare their sample data with other classes' sample data from adjacent horizons. These data include fauna, size, fragmentation, and color, all used to answer real paleontological questions. The project will also serve as a prototype for other educational institutions wishing to encourage inquiry through classroom research. Both projects provide learners with more active experiences with concepts that can be applied to their own lives. It is through a successful relationship between paleontologists and teachers that these collaborations can be achieved.

21: 4:20 PM-4:40 PM
Presenter: GREB, STEPHEN F

FOSSILS AND PREHISTORIC LIFE AT THE EARTH SCIENCE EDUCATION NETWORK, KENTUCKY GEOLOGICAL SURVEY

GREB, STEPHEN F, Kentucky Geological Survey, 228 MMRB, University of Kentucky, Lexington, KY, 40506, United States, greb@uky.edu

The Kentucky Geological Survey's Earth Science Education Network is a web-based tool for K-16 earth science education (www.uky.edu/KGS/). The Fossils and Prehistoric life page includes information on the types of fossils found in Kentucky, illustrations and photographs of common fossils and the organisms they represent, fossil identification keys, online publications of fossils in Kentucky, links to more information about fossils and earth history. A fossil photo database is under construction. A Classroom Activities section includes (1) Its About Time, which provides activities for demonstrating geologic time and earth history using adding machine paper, clocks, etc.; (2) How Fossils Form, a group of activities to illustrate the different ways in which fossils form; (3) The Geologic and Paleontologic Cookbook, which includes tasty activities including corn chip coral reefs and celery cephalopods; (4) Trilobite Masks in which students use paper plates to make their own exoskeleton cephalon (head) mask; (5) Can You Find on the Progression of Life Poster, in which students examine a poster mosaic of life through time, are given definitions of major divisions of life, such as invertebrates, vertebrates, mammals, dinosaurs, etc., and then try to find those types of life on the poster; (6) Fossils at the Library, in which students are shown photographs of fossils from the polished floor of the University of Kentucky library, group similar fossils together, and then try to interpret what types of organisms may have left those fossil remains; and (7) Draw T-rex, in which students combine science and art to flesh out the soft parts on a T-rex and bring this famous dinosaur back to life.

21: Poster
Presenter: PARK, LISA E.

EXTINCTION! THE GAME THAT TEACHES EARTH SCIENCE TO K-12 STUDENTS. For full abstract, see *17: 2:00 PM, Booth 19*

21: Poster
Presenter: LIU, YUSHENG (CHRISTOPHER)

APPLYING PALEONTOLOGICAL EDUCATION OF THE GRAY FOSSIL SITE TO TENNESSEE SCIENCE EDUCATION STANDARDS. For full abstract, see *17: 2:00 PM, Booth 17*

Session No. 22, 1:30 PM; Thursday, 25 June 2009
Symposium S12. Global Change and Biotic Response: Perspectives From the Quaternary, Windows to the Future

22: 1:30 PM-1:45 PM
Presenter: GRIMM, ERIC C.

NEOTOMA: A MULTIPROXY, COMMUNITY DATABASE FOR THE PLIOCENE, PLEISTOCENE, AND HOLOCENE

GRIMM, ERIC C., Botany, Illinois State Museum - RCC, 1011 East Ash Street, Springfield, IL, 62703, United States, grimm@museum.state.il.us; GRAHAM, RUSSELL W., Earth & Mineral Sciences Museum, Pennsylvania State University, University Park, PA, USA 16802-5000; JACKSON, STEPHEN T., Department of Botany, University of Wyoming, Laramie, WY, USA 82071; ALLAN ASHWORTH, ALLAN C., Department of Geosciences, North Dakota State University, Fargo, ND, USA 58105

Neotoma is a multiproxy database that includes fossil data for the past 5 million years (the Pliocene, Pleistocene, and Holocene epochs). Initially, the database is merging the Global Pollen Database, FAUNMAP, the North American Plant Macrofossil Database, and a fossil beetle database into a single integrated database. NEOTOMA is a community database that provides underlying database cyberinfrastructure for a variety of disciplinary database projects. In contrast with a federated database system, which integrates multiple autonomous constituent databases into a single virtual database with a uniform front-end user interface, NEOTOMA is a centralized database with virtual constituent databases, which can develop individualized front ends for their portions of the data. Constituent databases can retain their own identities, maintain control over data input and quality, and have their own Web interfaces. On the other hand, the centralized database structure facilitates cross-disciplinary, multiproxy analyses and common tool development. NEOTOMA is exposed to outside developers via Web Services, whereby either standalone or Web based applications can acquire data from NEOTOMA over the Internet in real time. This access should facilitate the development of a wide range of graphic and analysis tools, and research projects can focus on tool development and data analysis rather than database development and maintenance. NEOTOMA is designed so that multiple “data stewards” from different database projects can remotely input and update data. NEOTOMA offers database infrastructure to specialists in various taxonomic groups, who will not need to develop or even necessarily understand the core information technology, but who learn to input, update, and extract data through a user-friendly interface and to have control over disciplinary taxonomic issues. NEOTOMA also offers a potential solution for out-year sustainability of individual paleodatabase projects, which typically have been funded for discrete, often single, time periods.

22: 1:45 PM-2:00 PM
Presenter: BREWER, SIMON C.

CONTINENTAL SCALE VEGETATION DYNAMICS IN EUROPE DURING THE LATE QUATERNARY

BREWER, SIMON C., Botany, University of Wyoming, 1000 E University Avenue, Laramie, WY, 82071, United States, sbrewer2@uwyo.edu

One of the major efforts in the paleosciences over the last 15 to 20 years has been the development of continental scale databases of fossil records. Amongst these, pollen databases have been a particular focus, with development for most large regions of the world. These databases provide a unique long term dataset for the reconstruction of past ecosystems and the controlling environmental factors at large spatial scales, and over long time periods (10^3 to 10^6 years). With the move away from single or small-scale studies, there has been a development of new methodologies to improve our understanding of these changes. These approaches have relied heavily on both statistical and mechanistic modeling, and parallel the development of ecoinformatics. The careful design of these databases allows these data to be integrated with other studies, such as phylogeographic studies or climate modeling studies, and may allow much of the data to be used in ways that were not originally expected. Two examples of integrated studies will be presented. The first concerns the changes in the distribution of European deciduous oak forests (*Quercus* spp.) following the end of the last glacial period. The study combines the dynamical information available from fossil pollen data with spatially precise information available from a comprehensive phylogeographical study to provide highly detailed information about the behavior of this taxon in response to the changing climate. A second example will present the reconstruction of synoptic-scale climate patterns in the past, and the use of vegetation models to account for biases resulting from changes in atmospheric CO_2 concentration during the glacial period. These results are used to test the predictive abilities of a set of coupled general circulation models, run under past forcing conditions. In conclusion, some perspectives for future research directions will be discussed.

22: 2:00 PM-2:15 PM
Presenter: WILLIAMS, JOHN W.

QUANTITATIVE LATE-QUATERNARY TREE COVER RECONSTRUCTIONS FOR THE NORTHERN HEMISPHERE

WILLIAMS, JOHN W., Department of Geography, University of Wisconsin, , Madison, WI, 53706, United States, jww@geography.wisc.edu; TARASOV, PAVEL, Institute of Geological Sciences, Palaeontology Department, Free University, Malteserstr. 74-100, House D, Berlin, 12249, Germany; BREWER, SIMON, Department of Botany, University of Wyoming, 1000 E. University Ave., Laramie, WY 82071

Accurate, global land-cover datasets are essential to earth-system science. For the last several decades, a wealth of publicly available and highly resolved land-cover datasets, derived from remote sensing sources, have revolutionized earth system science, enabling e.g. detailed studies of the patterns and drivers of tropical deforestation, interannual variations in

terrestrial carbon uptake, and urban expansion. However, the brief duration of the remote-sensing window limits studies of land-use and land-cover dynamics prior to ca. 1980AD. Here we present a series of quantitative land cover reconstructions for the Northern Hemisphere and last 21,000 years, in which we synthesize fossil pollen records with remotely sensed datasets of percent woody cover (%WC). Modern-analogue methods are applied to reconstruct %WC for the late Quaternary, and are calibrated using the contemporary spatial relationship between relative pollen abundances in surficial sediments and %WC datasets created from Advanced Very High Resolution Radiometer (AVHRR) observations by the Global Land Cover Facility at the University of Maryland. We map both %WC and two components - broadleaved woody cover and needleleaved woody cover - for most of North America and Eurasia, for five time periods: 21ka, 9ka, 6ka, 1ka, and 0ka (1ka=1000 calendar years before present). We apply these datasets to track shifts in the position and steepness of the forest-tundra and forest-steppe ecotones.

22: 2:15 PM-2:30 PM
Presenter: MCDONALD, H. GREGORY

SITE SPECIFIC CLIMATIC MODELING AS A MEANS OF UNDERSTANDING THE PALEOECOLOGY OF PLEISTOCENE MAMMALS

MCDONALD, H. GREGORY, National Park Service, 1201 Oakridge Drive, Fort Collins, CO, 80525, United States, Greg_McDonald@nps.gov

In order to better understand how a species responds to environmental change, it is necessary to determine the limiting factors of its ecology, whether biotic or abiotic. Abiotic factors such as seasonal temperature ranges and patterns of precipitation have only been roughly estimated for extinct Pleistocene species, often based on proxy species, often extant taxa of plants and animals, found associated with the extinct species, or more recently by stable isotope values. Site specific computer modeling of climatic parameters using the Macrophysical Climatic Model for a single taxon with good radiocarbon dates from multiple sites and different times permits us to look at consistency of climatic parameters such as the seasonal amounts of precipitation and the temperature range that may have determined the species distribution and habitat preferences. Since the climatic model for each site can cover the range of radiocarbon dating ca. 40,000 years, it also permits an examination of the long term climatic history of the site, both before and after the presence of the species and allows us to look at how changes in climatic parameters may have resulted in its subsequent local extirpation or based on data from multiple sites, perhaps its extinction. Comparisons of the calculated climatic parameters for different taxa allows us to better understand the role of climate in each species distribution and changes in its distribution during the Pleistocene in response to changes in those parameters. It also shows what climatic parameters permitted the co-occurrence of taxa in a fauna or their mutual exclusion. Application of the model for Megalonyx, Nothrotheriops, Paramylodon, Camelops, Platygonus, and Mylohyus from

multiple sites and times identified consistent patterns with regard to seasonal temperature and precipitation patterns for each and allows us to better understand the potential individual response of each taxon to climatic change.

22: 2:30 PM-2:45 PM
Presenter: LYONS, KATE

COMMUNITY BODY SIZE DISTRIBUTIONS OF MAMMALS DIFFER AMONG TROPHIC GROUPS, BUT NOT ACROSS TIME

LYONS, KATE, Department of Paleobiology, National Museum of Natural History, Smithsonian Institution [NHB, MRC 121], P.O. Box 37012, Washington, DC, 20013, United States, lyonss2@si.edu; BOYER, ALISON G., Ecology, Behavior & Evolution Section, Division of Biological Sciences,University of California- San Diego, 9500 Gilman Drive, MC 0116, La Jolla, CA 92093-0116, USA; RESEARCH COORDINATION NETWORK, IMPPS, Department of Biology, University of New Mexico, MSC03 20201, University of New Mexico, Albuquerque, NM 87131-0001

Understanding and predicting the effects of current climate change is one of the fundamental questions in ecology today. The late Pleistocene and Holocene provide a record of changes in biodiversity as a result of climate change associated with glaciation and can be used as a model system to determine a baseline for understanding the effects of natural, as opposed to, human-caused climate change. At the local scale, there was significant turnover in community composition likely related to the megafaunal extinction and climate change. Here we discuss changes in community structure of mammals across the last 40 kya using a variety of different metrics. Specifically, we evaluated the body size distributions of all mammals in a community and compared that to the body size distributions of three different trophic groups: animalivores, herbivores, and omnivores. Community body size distributions before and after the extinction do not show significant changes in overall shape during the expansion and contraction of the glaciers. However, within communities, the different trophic groups show significant differences in their body size distributions across all time periods. Regardless of taxonomic identity or time period, body size distributions of the different trophic groups have different shapes. Herbivores have a more peaked body size distribution than do animalivores or omnivores. In addition, body size distributions of herbivores and omnivores tend to have a more positive skew than animalivores. Finally, omnivores have lower mean and median body sizes than do either herbivores or animalivores. The similarities in body size distributions of trophic groups across the last 40 kya suggests that there are fundamental rules structuring communities and these rules operate consistently during times of major climate change.

22: 2:45 PM-3:00 PM

Presenter: PROTHERO, DONALD R.

STASIS IN LATE PLEISTOCENE BIRDS AND MAMMALS FROM LA BREA TAR PITS OVER THE LAST GLACIAL-INTERGLACIAL CYCLE

PROTHERO, DONALD R., Dept. Geology, Occidental College, Los Angeles, CA, 90041, United States, prothero@oxy.edu; RAYMOND, KRISTINA R., Sundquist Center for Excellence in Paleontology, East Tennessee State University, Johnson City, TN 37614; SYVERSON, VALERIE, Divison of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125; MOLINA, SARAH, Earth Sciences, Univ. California, Riverside, CA 92521

One of the great puzzles of evolutionary biology is how organisms remain static in the face of dramatic climatic changes, contradicting the “Galapagos finch” model of organisms as constantly changing in response to their environment. Such stasis was documented in Pleistocene mammoths as early as 1863 by Darwin's friend, Hugh Falconer, and is widely recognized among most Pleistocene large mammals. We examined all the common birds and mammals from the Rancho La Brea tar pits in the Page Museum in Los Angeles. The studied taxa included the horse, bison, camel, the ground sloth, the sabertooth and the Ice Age lion, as well as the golden eagle and the ancestral California condor. We measured large samples (usually more than 100 of each element) of several dimensions of the most common bones (typically leg or foot bones) from all the pits with good radiocarbon dates. Even though there was dramatic climatic and vegetational change from the previous interglacial (40 ka-20 ka) to the peak glacial (20 ka-15 ka) to the glacial-interglacial transition (15 ka-10 ka) to the Holocene (as documented by pollen, plants, snails, and isotopic studies), none of these taxa show any statistically significant differences in size or shape of their bones from one level to the next. Such dramatic stasis among all the common mammals and birds over the late Pleistocene-Holocene, despite dramatic climatic changes, casts doubt on the responsiveness of birds and mammals to environmental variables, and suggests that intrinsic rather than extrinsic factors are more important in evolution.

22: 3:00 PM-3:15 PM
Presenter: PARDI, MELISSA I.

STRUCTURE OF LATE PLEISTOCENE NON-ANALOG MAMMAL COMMUNITIES ALONG THE LAURENTIDE ICE FRONT OF NORTH AMERICA

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Late Pleistocene faunas from North America have been characterized by the presence of non-analog, or disharmonious, associations of taxa - that is the co-occurrence of extant taxa in fossil deposits that do not occur together today. The legitimacy and biological significance of these associations has been a subject of debate for many decades. The issue at hand is if these faunas are an artifact of random processes like taphonomic mixing or stochastic biotic response, or whether they are a reflection of species adjusting to their biological tolerance limits within the climatically-dynamic late Pleistocene North American landscape. If non-analog faunas form as a result of environmental parameters, then their distributions should be structured around recognizable environmental gradients. Here we present the results of a multivariate analysis of mammal faunas across the Laurentide Ice Front of North America. Our results focus primarily on trends along North-South temperature and East-West precipitation gradients. This analysis also includes a new data set from a complete full glacial-middle Holocene cave faunal sequence in the Black Hills of South Dakota.

22: 3:15 PM-3:30 PM
Presenter: GRAHAM, RUSSELL WM.

MAMMAL RESPONSE TO FIVE MILLION YEARS OF ENVIRONMENTAL FLUCTUATIONS IN NORTH AMERICA

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Climates of the last five million years have ranged from warmer than today in the Pliocene and Sangamon Interglacial to much colder than today in the glacials and stadials of the Pleistocene. The periodicity of glacial fluctuations have varied from 40 ka in the early Pleistocene to 100 ka intervals during the last 0.8 ka. In addition, there are a variety of hierarchical cycles of climate change in the Pleistocene (e.g., DansgaardOeschger events, Bond Cycles and Heinrich events). Finally, the Holocene may be an anomalous stable climate interval compared to those of the Pleistocene. Data derived from FAUNMAP II in the new NEOTOMA interdisciplinary paleoecology database have been used to quantitatively document mammal response to these various climate fluctuations in order to assess the applicability of the fossil record to modern global change.

22: 4:00 PM-4:15 PM
Presenter: SHAW, CHRISTOPHER A.

ENVIRONMENTAL IMPLICATIONS OF EARLY TO MIDDLE IRVINGTONIAN BIOTA FROM EL GOLFO DE SANTA CLARA, SONORA, MEXICO

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The early to middle Pleistocene Colorado River Delta deposits exposed in the upper Gulf of California, Sonora, México are host to a diverse paleo-fauna and -flora (El Golfo local paleobiota) of Irvingtonian Land Mammal Age. The fossiliferous exposures are found in badlands developed in fluvio-deltaic sediments that have been mildly deformed during late Pleistocene doming along the Cerro Prieto Fault. The El Golfo Project is part of the resource inventory for the Upper Gulf of California and Colorado River Delta Biosphere Reserve and includes salvage efforts along new highway construction crossing the fossil-bearing badlands. Through joint efforts by Arizona Western College, the George C. Page Museum, and the Biosphere Reserve, about 20% of the region has been prospected and mapped. To date, over 5200 mapped vertebrate fossil localities are documented, including important microvertebrate sites. New mammalian, avian, and fish taxa have been recently added to a growing paleofaunal list that now numbers over 80 taxa. The preserved paleobiota suggests the existence of four ecologic communities: freshwater aquatic, riparian galleria forest, shrub and brush woodland, and savannah-like grassland. The recovery of fan palm, giant tortoise, boa constrictor, and giant anteater remains further suggest that the annual regional temperature supported tropical to subtropical climates, and that areas existed within the region where at least partial shade prevailed.

22: 4:15 PM-4:30 PM
Presenter: SCHUBERT, BLAINE W.

THE EXCAVATION AND RESEARCH HISTORY OF LATE PLEISTOCENE MEGAFAUNA IN SALTVILLE, VIRGINIA

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Although megafaunal remains were known from the valley sediments of Saltville by the 1700s, research on the fossils did not occur until O.A. Peterson of the Carnegie Museum began excavations in the early 1900s. Research ensued again in the mid 1960s after geologists from Virginia Polytechnic Institute (VPI) investigated fossils exposed by construction. VPI and the Smithsonian collaborated and published some of their results in a 1967 paper headed by C.E. Ray; this still represents the most comprehensive report on the fauna. In the late 1970s and early 1980s C.S. Bartlett, Jr. conducted salvage operations and spearheaded the excavation of a musk-ox skeleton. J.E. McDonald was brought in to assist and went on to supervise excavations and conduct research until the late 1990s. The focus of his work was in two areas

in the southwestern part of the valley. A series of abstracts, notes, reports, and articles were produced on these extensive excavations, culminating in a paper published in 2000 that describes bones and stones interpreted to be Pre-Clovis artifacts, as well as associated features surmised to be the result of a butchered and cooked mastodon. During the summers of 1999 - 2002, R.E. Eshelman conducted a series of excavations for the Museum of the Middle Appalachians at other nearby localities in the valley. In 2003 and 2004, S.C. Wallace of East Tennessee State University continued excavations in one of Eshelman's localities (SV-10) as part of a paleontology field school. Excavations are now continuing at SV-10 under the direction of the author, with the current focus on a heavily carnivore-scavenged mammoth and associated taxa. As one of the richest and most extensive late Pleistocene megafauna localities in eastern North America, continued excavations and research are needed to better understand the paleoecology of the deposits.

22: 4:30 PM-4:45 PM
Presenter: MEAD, JIM I.

THE NORTHWARD EXTENSION OF TROPICAL ENVIRONMENTS IN SONORA, MEXICO DURING THE PLEISTOCENE

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Sonora in northwestern Mexico holds an important position on the continent - the ecological transition from more tropical environments of Mexico to the temperate semi-arid and arid regions of the American Southwest. Dispersing vertebrates traveled to and from these regions and therefore traversed Sonora. Changing regional climate caused Sonora to experience varying intensities of north-south movements of boundaries. These changes are reflected in fossils in sediments. Fifty-seven fossil localities can be assigned to the Rancholabrean land mammal age. Most are isolated fossils of Mammuthus, Bison, and Equus. Rarely are the stratigraphic context understood, sediments sampled for microfauna, or the chronology adequately established. The climate regime and local environment at time of deposition have not been determined. Grazers moved south and tropical elements dispersed north but the timing and mechanism of this interchange is not clear. Tropical habitats likely moved north along coastal Sonora and traveled inland only within major river corridors. We speculate that this northward coastal movement did not extend north of the Rio Yaqui, as larger tropical species are not present at the two best sampled sites, Rancho la Brisca and La Playa, which lie on the Rio Sonora and Rio Concepcion respectively. The mixture/interface of grassland and woodland habitats was likely patchy. Rancholabrean-age fossils have been recovered from Terapa, 350 km up the Rio Yaqui-Moctezuma from the coast. Terapa today is a semi-arid

Sonoran Uplands community. Eleven meters of fluvial sediments contain marsh units with 70+ animal species. Temperate species include *Mammuthus* and *Bison*. Tropical/semi-tropical species include birds, *Glyptotherium*, *Pampatherium*, *Hydrochoerus* and *Crocodylus*. Geochemical analyses indicate an age of 43,000-40,000 years ago, MIS 3, pre-full Last Glacial Maximum. Continued research seeks to define the climate and environment that permitted tropical species north of where they exist today.

22: 4:45 PM-5:00 PM
Presenter: SCOTT, ERIC

NATIVES, IMMIGRANTS, AND PRODIGALS: EVOLVING *EQUUS* AND *BISON* IN AMERICA

SCOTT, ERIC, Division of Geological Sciences, San Bernardino County Museum, San Bernardino County Museum, 2024 Orange Tree Lane, Redlands, CA, 92374, United States, escott@sbcm.sbcounty.gov

Horses (*Equus*) and bison (*Bison*), two well-known American icons today, often shared the stage throughout North America in the late Pleistocene. Fossils of these animals are commonly found together in many Ice Age faunas across the continent. Despite this relative ubiquity, the evolutionary pathways of these animals remain enigmatic. The primary challenge is one of taxonomy; *Equus* and *Bison* exhibit strong inter- and intraspecific variability, and so both genera are replete with dozens of species names having questionable validity. Lacking consensus on how many species actually existed and how these species are defined, systematists have long struggled to frame a coherent, consistent, and demonstrable evolutionary narrative for these animals. Recent molecular studies have challenged traditional, morphology-based studies, proposing that the evolutionary trajectories of *Equus* and *Bison* are more straightforward than previously proposed. For both genera, the multiplicity of named species is reduced, and the relationships of these species are clearly elucidated through genetic rather than morphologic similarity. These molecular studies have powerful potential to clarify systematics and evolutionary relationships among extant and extinct organisms. However, in some cases the same challenges faced in classic morphological studies - particularly assessing inter- and intraspecific variability - can also plague molecular investigations. These difficulties are compounded by the lack of useful genetic material in many fossils.Paleontology and molecular biology should not be treated as rival camps, but rather as complementary tools. Understanding the evolution of iconic American animals such as Equus and Bison - an understanding critical for establishing effective wildlife management practices - remains a challenge to be resolved using all such tools at our disposal.

22: 5:00 PM-5:15 PM
Presenter: WALLACE, STEVEN C.

WHO CARES ABOUT LEMMINGS? CURRENT GENETIC DIVERSITY AND THE FOSSIL RECORD OF COLLARED AND BROWN LEMMINGS (*DICROSTONYX* AND *LEMMUS*): THE IMPORTANCE OF SOUTHERN REFUGIA DURING THE PLEISTOCENE

WALLACE, STEVEN C., Geosciences, East Tennessee State University, Department of Geosciences, Box 70357, Johnson City, TN, 37614, United States, wallaces@etsu.edu

Today, *Lemmus* and *Dicrostonyx* prefer tundra-like environments and are sympatric over much of their Holarctic range. In North America however, *Dicrostonyx* is restricted to arctic tundra; whereas Lemmus also occupies alpine tundra and subalpine forests, and therefore has a slightly more southern distribution. Recent genetic studies have shown that there are three species of *Dicrostonyx* (*D. groenlandicu*, *D. hudsonicus*, and *D. richardsoni*), but only one species of *Lemmus* (*L. trimucronatus*). Fossils of both *Lemmus* and *Dicrostonyx* have been found south of the Pleistocene ice sheets (well outside of their current geographic range); however the role of these refugial populations in re-colonization after deglaciation and/or speciation remains unclear. Moreover, *Dicrostonyx* is at least an order of magnitude more common in Pleistocene fossil deposits (though still rare compared to other Arvicoline taxa), coming from sites spanning the entire southern limit of the Pleistocene ice sheets, as well as Canada and Alaska. *Lemmus* on the other hand, has only been recovered from roughly 7 fossil localities, with the only records occurring in the contiguous United States being a single record from Michigan and three from Iowa. Because lemming population dynamics are tied directly to the environment in which they live (specifically the vegetation), it appears that displaced *Dicrostonyx* populations were able to find the taxon's preferred habitat, consequently benefiting from the glacial cycles through adaptation and allopatric speciation, whereas *Lemmus* clearly was unable to find appropriate habitats leading to the existence/survival of only a single species. Interestingly, the exact opposite situation is seen in Europe, with *Lemmus* being more common in the fossil record and having more species than *Dicrostonyx*. This dichotomy highlights the role of glacial cycles to the diversification of Holarctic rodents, but also emphasizes the need for caution when assuming similar (Pleistocene) ecological requirements for currently sympatric mammals.

22: 5:15 PM-5:30 PM
Presenter: JASS, CHRISTOPHER N.

PERSPECTIVES ON PALEONTOLOGICAL CHANGE IN ICE AGE ALBERTA: PAST, PRESENT, AND FUTURE

JASS, CHRISTOPHER N., Royal Alberta Museum, 12845 - 102 Ave., Edmonton, AB, T5N 0M6, Canada, chris.jass@gov.ab.ca; BEAUDOIN, ALWYNNE B., Royal Alberta Museum, 12845 - 102 Ave., Edmonton, AB, Canada, T5N 0M6; BURNS, JAMES A., The Manitoba Museum, 190 Rupert Avenue, Winnipeg, MB, Canada, R3B 0N2

Considerable research effort has been devoted to the examination of the distribution and dating of late Quaternary mammal assemblages in Alberta. Radiocarbon dates on fossils in the Edmonton region show a distinct hiatus between 22,200 and 10,650 yr BP, corresponding to the last (late Wisconsinan) glacial episode. These data suggest that most mammals were likely extirpated from Alberta during that period. Although glacial ice likely produced comparable ecosystem disturbance elsewhere in North America, the varied topography of Alberta offers an opportunity to explore mammalian response to the reopening of both lowlands and uplands following deglaciation. As a baseline for interpreting regional faunal change, we began a project that summarizes the chronologic and spatial distribution of late Quaternary mammals throughout Alberta. Using published data and the collection of Quaternary vertebrates housed at the Royal Alberta Museum, we mapped geographic distributions of Quaternary fossils from Alberta, and summarized radiocarbon records of individual taxa. Initial summary data show interesting patterns of bias. Certain megafauna are represented in high numbers from gravel deposits along fluvial systems. While there appear to be taxonomic similarities in both pre- and post-glacial gravel deposits, assessing how these assemblages reflect past community structure is difficult. The assemblages are likely biased by depositional processes because they are dominated by robust elements from megafauna. They possibly represent accretion from a wide geographic area; therefore, the degree to which they accurately reflect past local faunal composition is unknown. Fossiliferous cave deposits provide information regarding upland habitats and contain mostly microfaunal records. Again, these probably reflect factors influencing accumulation, because many will have been produced by raptors or other predators. Future work will focus on the identification of additional localities, clarification of the impact of taphonomic bias on faunal assemblages, and examination of the timing of re-colonization of deglaciated Alberta.

22: Poster
Presenter: STORRS, GLENN W.

IN THE FOOTSTEPS OF LEWIS AND CLARK - NEW ZOOARCHAEOLOGICAL EXCAVATION AT BIG BONE LICK, KENTUCKY. For full abstract, see *17: 2:00 PM, Booth 14*

22: Poster
Presenter: AGENBROAD, LARRY D.

MAMMOTH SITE OF HOT SPRINGS, SOUTH DAKOTA: THE MAPPING OF A LONG-TERM EXCAVATION SITE. For full abstract, see *17: 2:00 PM, Booth 13*

Session No. 23, 1:30 PM; Thursday, 25 June 2009

Symposium S13. Whole-Organism Paleoecology in Deep Time: Influences on Evolution and Applications to Modern Ecology

23: 1:30 PM-1:45 PM
Presenter: DIETL, GREGORY P.

ON THE RELATIONSHIP BETWEEN DRILLING FREQUENCY AND PREDATION RISK

DIETL, GREGORY P., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca , NY, 14850, United States, gpd3@cornell.edu

Predators affect prey through direct predation and through risk effects, that is, the costs of antipredator behavioral and morphological responses. For prey, the costs of these responses may be severe, including reduced survival, growth and reproduction. In the fossil record of predator-prey interactions, drilling frequency, the ratio of the number of successful attacks to the total number of prey, has been used widely as a proxy for relative predation intensity and selection pressure - a high frequency of drilling is thought to reflect intense selection pressure from drilling predators. This view assumes that direct predation effects on prey are greater than risk effects, and that risk effects correlate positively with direct effects. Here I review a simple model introduced by Lima and Dill (1990) as a heuristic to explore the relationship between drilling frequency and the components of predation risk. From the prey's perspective, a simple representation of predation risk, or the probability of being killed by a drilling predator during some time period, is: P(death) = 1 - exp(-adT), where a equals the probability of encounter between predator and prey, d is the probability of death given an encounter, and T is the time interval over which predation risk is being integrated. Empirical studies have indicated that the correlation between direct predation and risk can be either positive or negative. An implication of this result is that a low drilling frequency does not necessarily reflect weak selection pressure from predators on their prey. Modeling and integrating risk effects into studies of the direct effects of drilling predators on prey evolution is an open challenge for future research.

23: 1:45 PM-2:00 PM
Presenter: NAGEL-MYERS, JUDITH

MISSING PREDATORY DRILLHOLES IN DEVONIAN BIVALVES: REALITY OR BIAS?

NAGEL-MYERS, JUDITH, Paeontological Research Institution, 1259 Trumansburg Rd. , Ithaca, NY, 14850, United States, jn226@cornell.edu; DIETL, GREG, P. , Paleontological Research Institution, 1259 Trumansburg Rd.Ithaca, New York, 14850; BRETT, CARLTON, E., Department

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Drilling predation in the Paleozoic is dominated by reports of drillholes in brachiopods and echinoderms, but little unequivocal evidence is available for bivalves until the Permian. This paucity of data ("missing holes") for bivalves throughout most of the Paleozoic reflects: 1) an ecological reality, 2) an observer bias, or 3) taphonomic bias. We examined nearly 350 specimens of the pterineid genus *Ptychopteria* from the Middle Devonian Hamilton Group of western and central New York for traces of drilling predation. *Ptychopteria* was an abundant, immobile, epifaunal suspension feeder that lived side by side with a number of brachiopod taxa in nearshore marine environments. Given their similar lifestyles we expected that *Ptychopteria* and brachiopods would be equally vulnerable to drilling predators. The well-preserved nature of these bivalve specimens also eliminated potential for taphonomic bias. We focused our attention on the presence of 1.5-3.5 mm, parabolic-shaped Type 3 drillholes (Brett, 2003), which commonly have been found on Middle Devonian Hamilton Group brachiopods, such as *Athyris*, *Rhipidomella*, *Pseudoatrypa*, and strophomenids (Buehler, 1969; Smith et al., 1985). Surprisingly, given the available evidence for drilling in co-occurring brachiopods, we found no Type 3 drillholes in *Ptychopteria*. At least for our case study, the missing holes reflect an ecological reality - predators did not drill bivalves. Ultimately, however, even such "negative" results have important implications for our understanding of the transition from the brachiopod-rich Paleozoic Fauna to the mollusc-rich Modern Fauna.

23: 2:00 PM-2:15 PM
Presenter: KELLEY, PATRICIA H.

EVOLUTIONARY EFFECTS OF CRETACEOUS - PLEISTOCENE NATICID GASTROPOD PREDATION: DRILLING FREQUENCY, PREY DIVERSITY, AND PREDATOR DIVERSITY

KELLEY, PATRICIA H., Department of Geography and Geology, University of North Carolina Wilmington, Wilmington, NC, 28403-5944, United States, kelleyp@uncw.edu; HANSEN, THOR A., Geology, Western Washington University, Bellingham, WA 98225

The role of ecological interactions in evolution remains controversial. Some previous studies have suggested that predation is important in evolution, influencing rates of evolution or diversity of prey. In this study we examined the role of naticid gastropod predation in evolution by determining the relationship between drilling frequency and diversity of prey and predators. Data come from the Kelley-Hansen database of naticid gastropod predation derived from bulk samples (>140,000 mollusc specimens) of 28 Cretaceous-Pleistocene US coastal plain assemblages. We hypothesized that assemblage-level drilling frequency should be positively correlated with both prey and predator diversity. Prey diversity for each assemblage was determined using raw species richness, Margalef index, and rarefied species richness; bivalve sample sizes were rarefied to 460 specimens and gastropod samples to 200 specimens

using Analytic Rarefaction 1.3 (http://www.uga.edu/strata/software/). To determine the relationship between predator diversity and drilling frequency, assemblages dominated by a single naticid species were compared to those containing multiple naticid species. Diversity measures were compared to frequency of successful and unsuccessful drilling.In contrast to previous work comparing predation intensity to prey diversity at the resolution of geologic period, none of the correlations between drilling frequency and prey diversity was significant (most R squared values = 0.01). Nor were any correlations of unsuccessful drilling and prey diversity significant. Predator diversity, however, was inversely related to drilling for gastropods and the total fauna. Counterintuitively, assemblages dominated by a single naticid species exhibited greater drilling than those with multiple naticid species. This result may indicate an emergent effect of multiple predators; intraguild (interference) competition or predation may have decreased the combined effect of multiple naticid predators. However, samples dominated by a single predator species had greater frequencies of multiple drilling and no significant difference in incomplete drilling, an unexpected result if interference competition occurred between predators.

23: 2:15 PM-2:30 PM
Presenter: VISAGGI, CHRISTY C.

LATITUDINAL VARIATION IN DRILLING FREQUENCY, SHELL THICKNESS, AND MICROSTRUCTURAL LAYERS OF RECENT *HEMIMACTRA* FROM THE U.S. EAST COAST

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The history of predation can be explored using paleontological assemblages; however, understanding the effect of spatial variation on apparent evolutionary patterns poses a greater challenge due to limited fossil exposures. Modern communities provide an excellent platform in which to examine latitudinal variation in predation; contemporary spatial patterns have implications for patterns of evolution in the fossil record. This investigation explores latitudinal variation in drilling frequency (DF), shell thickness, and microstructural layers of *Hemimactra* (formerly *Spisula*) from four biogeographic provinces along the Eastern U.S.Thickness, length, and DF were recorded for 820 shells from beach collections by Visaggi and Kelley & Hansen (2007). A minimum of four localities containing ~200 shells per biogeographic province were used (10-80mm in length). DF was highest in the Carolinian Province (91%) and lowest in the Gulf Province (4%), both significantly different from all other provinces ($p<0.001$). These results are consistent with previous work documenting a peak in DF at mid-latitudes and minimal drilling in low latitudes. No significant difference existed for intermediate levels of drilling between the Nova Scotian (39%) and Virginian (35%) provinces

(p=0.533).Thickness was regressed on length for each province and compared among provinces at a length of 37.91mm (mean for all provinces). Thickness at this standard length was highest (0.65mm) in the Nova Scotian Province and lowest (0.43mm) in the Virginian Province. Other provinces ranged between 0.56-0.57mm. Thickness and DF did not show an inverse relationship as might be expected. Because microstructural layers within shells differ in resistance to drilling predation, latitudinal variation in thickness was analyzed further at the microstructural level using acetate peels (60 shells: 15 per province). Ontogenetic variation within a province was assessed initially; no pattern was observed. Although latitudinal variation was noted, taphonomic differences between samples from different provinces may be influencing this pattern.

23: 2:30 PM-2:45 PM
Presenter: STAFFORD, EMILY S.

TRENDS IN GASTROPOD SHELL ORNAMENT FROM THE MIDDLE CRETACEOUS THROUGH THE MIDDLE EOCENE

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Shell ornament in gastropod mollusks is widely believed to have evolved as a defense in response to increased predation pressure. Many shell crushing predators, such as decapod crustaceans and teleost fish, radiated during the Mesozoic. Decapod crustaceans have shown a trend of increasing shell crushing ability and specialization from the Mesozoic to the Recent. If gastropod shell ornament (ribs, varices, spines, etc.) is indeed a response to increasingly powerful crushing predators, the proportion of ornamented gastropod species is expected to increase throughout the Mesozoic and Cenozoic. The fossil gastropods from Baja California, Mexico to southern British Columbia, Canada have been catalogued in detail over the past 150 years. We collected gastropod species occurrence data from 51 sources for a database spanning the middle Cretaceous (Albian stage) through the middle Eocene (“Tejon” molluscan stage). Species were assigned to three ranked categories according to the degree of shell ornament exhibited: no ornament (0), low ornament (1), or prominent ornament (2). The proportion of species in each category, and the mean ornament (average rank), were calculated for each stage.During study interval, the North American Pacific coast was shifting northward; for a given geographical location, earlier faunas lived in more tropical environments than later faunas. Additionally, most material from Baja California is Cretaceous, adding to a tropical bias earlier in the interval. In modern oceans, gastropod ornament decreases toward higher latitudes. Based solely on the tropical-temperate shift in the interval, ornament should decrease from the Cretaceous to the Eocene.With the exception of one stage, mean ornament was slightly but consistently greater during the Cenozoic stages than

during the Cretaceous stages. In the Cenozoic interval, the proportion of “low ornament” species increased, due in part to an absolute decrease in the number “no ornament” species.

23: 2:45 PM-3:00 PM
Presenter: LEIGHTON, LINDSEY R.

EXPLORING NEUTRAL THEORY IN THE FOSSIL RECORD

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Currently, two prominent ecological hypotheses endeavor to explain community/guild diversity and taxonomic composition. Traditional Niche Theory ascribes a primary role to local processes, especially biotic interactions, for influencing community diversity. Therefore, species' traits are of great importance. In contrast, Neutral Theory argues that species are “neutral” - that community composition is not a function of differences between species, and that community assembly is controlled more by extrinsic, or regional, factors, such as immigration and geographic distance between communities. Questions exist, however, regarding the effects of such influences over long time-scales, and the fossil record provides a means of examining this issue.One of the primary predictions for Neutral Theory and for the influence of regional processes is that community composition or community taxonomic-distance will vary positively with the log of geographic distance. We test Neutral Theory in the Ordovician, using the extensive Nashville Dome dataset of Patzkowsky and Holland, supplemented by our own data from the Cincinnati Arch. Four stratigraphic sequences (Mohawkian 3, Mohawkian 5, Cincinnatian 2, Cincinnatian 5) had sufficient localities with adequately robust samples within the same facies to employ the test. We used Relative Sorensen distance to measure the taxon-abundance differences between samples of brachiopods.For all four sequences, the linear-, log-, and rank-correlations of taxonomic-distance and geographic distance were all non-significant and close to zero ($0.15 > R > -0.15$). These results suggest that either (a) Neutral Theory does not explain these communities; regional processes did not play a major role in influencing community composition, or (b) with enough time, communities within the region became sufficiently homogenized such that the influences of dispersal and geographic range were mitigated or possibly masked.

23: 3:00 PM-3:15 PM
Presenter: OLSZEWSKI, THOMAS D.

ORGANIZATION OF ECOLOGICAL COMMUNITIES BY COMPETITION: IMPLICATIONS FOR CHANGE IN FOSSIL ASSEMBLAGES

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One of the fundamental principles of community ecology is Gause's Law, which states that two species competing for the same resources cannot stably coexist under constant conditions. This principle predicts that the diversity of communities and the similarity of member species should be limited due to competitive exclusion. Nevertheless, high diversity communities composed of similar species competing for a small number of resources are common in nature (i.e., Hutchinson's “paradox of the plankton”), both in the present day and in the fossil record. Explanations for such high diversity communities include: 1) neutral dynamics in which there are no competitive differences among species, 2) the rescue effect in which populations of inferior competitors are subsidized by immigration, 3) environmental volatility through time, 4) competitive trade-offs for different limiting resources, and 5) life-habit trade-offs between resource exploitation and colonization ability. All of these models circumvent the limits to diversity imposed by competitive exclusion by either making species competitively indistinguishable (the neutral model) or by allowing them to subdivide their environment in order to avoid exclusion by competition. Recent theoretical results, however, suggest that competition among many species with distinct but overlapping niche requirements can result in a dynamic of competitive accommodation, permitting coexistence of many ecologically differing species without resulting in competitive exclusion. Further, communities can switch between alternative steady states when perturbed, a pattern resembling that of brachiopod assemblages from the Permian Basin of west Texas. Competitive accommodation can be further tested by examining changes in species/taxon rank abundance distributions through time. In this case, fossil data provide a critical source of information for testing alternative models of diversity maintenance in ecological communities, with implications for community response to major environmental perturbations.

23: 3:15 PM-3:30 PM
Presenter: TYLER, CARRIE L.

SATURATION, DIVERSITY AND COMPETITION IN THE ORDOVICIAN FOSSIL RECORD

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Saturation and diversity (richness) are commonly used to analyze whether competition or the regional species pool structures communities. A community is considered unsaturated (i.e. competition is not a driving force in the community) if a linear relationship exists between

local and regional diversity. Multiple methods can be used to correlate local and regional diversity, each yielding different interpretations, for example, it is often assumed that if the community were saturated, then there would be a flat (r ~0) regression line between regional and local diversity because increasing regional diversity would have no effect on the saturated local community. Thus, a significant linear relationship between local and regional diversity (i.e. a trend different from a flat regression line) is sufficient to demonstrate that a community is unsaturated. However, in any set of communities, there will be some communities that have been recently disturbed and consequently have low diversity; these immature communities will not have had sufficient time to become saturated. Regardless of whether the mature communities are saturated or not, immature communities will indicate a linear relationship between local and regional diversity. Thus, a better model for saturation might be a logarithmic, rather than a flat curve because the logarithmic curve will flatten for mature communities that are saturated. Thus, both linear and logarithmic analyses must be performed when testing for saturation. Many of these issues are illustrated by re-examining saturation and diversity in the Nashville Dome using diversity data published by Patzkowsky and Holland (2003). Using this dataset, both types of correlations produce significant results; thus, in this case, the relationship between local and regional diversity supports both the saturation and non-saturation models. Given these equivocal results, an exploration of competition using data other than diversity, such as morphological data, might circumnavigate many of these issues.

23: 4:00 PM-4:15 PM
Presenter: WEBB, AMELINDA E.

MEASURING THE EFFECT OF PAST CLIMATE CHANGE ON MARINE MICROORGANISMS: HOW DO COMMUNITIES CHANGE IN RESPONSE TO GLOBAL WARMING?

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The impact of global warming on biodiversity has been the subject of many studies, and predictions about the effects of global warming on modern taxa are varied and sometimes contradictory. Past episodes of rapid global warming provide an ideal opportunity for investigating the ecological impact of climate change. This study examines the changes in microfossil communities by using assemblage data for four common groups (ostracodes, calcareous nannoplankton, benthic and planktic foraminifera) from three thermal maxima (Paleocene-Eocene thermal maximum, mid-Paleocene biotic event, and the late Maastrichtian thermal maximum). Ecological impact is assessed in two ways: 1) changes in diversity, measured using a series of meta-analyses to investigate whether the species diversity of the four groups of microfossils increases or decreases, and 2) changes in community structure, measured by quantifying changes in the shape of rank-abundance curves which allow inference of the relative level of stress on communities. When all of the taxa from all of the

events are combined, the overall effect on diversity is positive, i.e., there are more species during thermal maxima than during the intervals preceding these events. A significant increase in diversity was also observed within fossil assemblages from the Paleocene-Eocene thermal maximum and separately from within the late Maastrichtian thermal maximum, although no significant change was observed for the mid-Paleocene biotic event. Both planktonic groups showed increased diversity during the three thermal maxima, while the benthic foraminifera and ostracodes lost diversity. Changes in community structure (relative stress) also differ across the groups, with relative stress increasing or decreasing irrespective of changes in species richness. The results of this study show the effects of global warming on communities are varied between groups and highlight the importance of understanding an ecosystem before making conservation decisions or predictions about changing biodiversity in response to climate change.

23: 4:15 PM-4:30 PM
Presenter: SCHNEIDER, CHRIS L.

RESPONSES OF EPIBIONT FAUNA DURING THE LATE DEVONIAN MASS EXTINCTION AND INSIGHTS INTO THE MODERN BIODIVERSITY CRISIS IN PUGET SOUND (WASHINGTON, USA AND BRITISH COLUMBIA, CA)

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The current biodiversity crisis shares several features with prior mass extinctions: global environmental perturbation, the permanent loss of taxa, and conspicuous changes in ecosystem composition and structure. During extinction events, epibiont faunas dependent on substrates must respond to changes wrought on host composition and abundance. The marine ecosystem in Puget Sound is in crisis from anthropogenically-induced environmental degradation, affecting primary producers to top predators. The epibiont fauna on brachiopods, sampled from the same locality in 1984 and again in 2006, reveals severe declines in biodiversity and evenness, but also a doubling of epibiont abundance per brachiopod individual. In addition, four brachiopods were sampled in 1984 (*Terebratalia transversa*, *Terebratulina unguicula*, *Laqueus californianus*, *Hemithiris psittacea*), but *Hemithiris* (which bore a high proportion of epibionts in 1984) was absent in four sampled localities by 2006. Comparisons between encrusted brachiopods sampled in 2006 reveal an increase in biodiversity in a marine preserve relative to unprotected localities, but even there does not approach diversity of 1984 samples. Similarly, Devonian epibionts were diverse and abundant, but experienced a marked decline across the Frasnian-Famennian extinction. Simultaneously during this extinction, the brachiopod fauna underwent a major alteration in surface textures. Devonian brachiopod faunas were dominated by ribbed brachiopods, whereas common Mississippian brachiopods were smooth or spinose. Epibionts frequently

encrusted the ribbed Devonian brachiopods, but post-extinction, attached to smooth brachiopods and rare coarsely-ribbed brachiopods, avoiding spinose brachiopods. Observations made on epibionts and their responses to host substrates through the Late Devonian extinction suggests potential changes to be expected in modern epibiont communities with continued biodiversity loss. In Puget Sound, the decline in epibiont biodiversity and evenness, coupled with the increase in epibiont abundance on encrusted brachiopods, may in part arise from declines in some or all host taxa, including the loss of *Hemithyris*.

23: 4:30 PM-4:45 PM
Presenter: PLOTNICK, ROY E.

MOVEMENT PALEOECOLOGY AND THE TAPHONOMY OF BEHAVIOR

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Numerous difficulties plague the behavioral interpretation of trace fossils. First, there are the long-recognized difficulties of identifying a tracemaker, highlighted by the recent discovery by Matz et al. (2008) of tracks made by giant protists which closely resemble those made by putative Ediacaran bilaterians. Even more troubling, it is also becoming apparent that morphologically similar traces can result from different behaviors (Martin and Rindsberg, 2006; Gingras et al., 2008). Finally, the classic ethological classification of trace fossils developed by Seilacher (1964) has no counterparts in the behavioral literature of neontology, which also has numerous idiosyncratic classifications. Nathan et al. (2008, PNAS) have called for a new “movement ecology paradigm for unifying organismal movement research.” This approach views movement as resulting from the interactions of the organism's internal state (“why move?”), its biomechanical ability to move (“how to move”), and its navigation capacity (“where to move?”) with each other and with the external environment. The adoption of this paradigm would have significant implications for the study of ichnofossils and has the potential for placing these studies in a far wider common context for the study of movement, while adding the dimension of the evolution of movement behavior in deep time. For this integration to occur, paleontologists need to first consider what are the range of behaviors exhibited by organisms and what are the controls on these behaviors, and then what is the preservation potential of these behaviors and controls in the fossil record.One possible schema for such a “taphonomy of behavior” is the theoretical ecospace of Novack-Gottshall (2007). Among the characters in this framework are many that describe behavior. This construct can be used not only to ask what potential behaviors can occur, but what their potential for producing a diagnostic trace is.

23: 4:45 PM-5:00 PM
Presenter: AUSICH, WILLIAM I.

ASSEMBLY OF THE MISSISSIPPIAN CRINOID FAUNA: INVASION, ENDEMIC ORIGINATION, AND EXTINCTION

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Following the late Devonian demise of reefs, crinoid faunas expanded onto the carbonate ramps that characterized much of the earliest Mississippian. Patterns of origination and invasion are examined with generic, range-through data. Sea level rise during the early Osagean (time step 3) resulted in maximum generic diversity. The North American fauna during time 3 was comprised of existing North American genera and a significant radiation of new endemic North American genera. In contrast, the European time 3 (Ivorian) fauna was comprised of approximately 50 percent genera invaded from North America and 50 percent from the origination of endemic European genera. Genera continued to migrate between North America and Europe, but invasion was not important again in shaping either regional fauna. North American crinoid richness declined slightly to the end of time 6 (late Osagean), then dropped by approximately 50 percent from times 6 to 7 (late Osagean to early Meramecian) and from times 7 to 8 (early to late Meramecian) until increasing again into time 9 (early Chesterian). In contrast, the peak richness of European genera was during time 9 (Brigantian), and this rise in richness was driven by high European endemic origination during both time 8 (Asbian) and time 9. Crinoid richness collapsed at the close of time 9 in Europe and the close of time 10 (middle Chesterian) in North America. The time 9 decline in Europe was driven primarily by extinction of European endemic genera, and the time 10 demise in North American was driven primarily from the extinction of more widespread and typical Mississippian crinoid genera.

23: 5:00 PM-5:15 PM
Presenter: JANEVSKI, G. ALEX

COULD A STALKED CRINOID SWIM? A BIOMECHANICAL MODEL OF STALKLESS CRINOID SWIMMING AND ITS EVOLUTIONARY IMPLICATIONS

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Modern stalked crinoids represent a relict fauna of once considerably higher diversity, as seen in their extensive fossil record. Comatulid crinoids, which lack a stalk and dominate modern crinoid diversity, have been interpreted as an evolutionary success story due to the increased mobility afforded by stalk loss. This mobility includes effective crawling and also swimming, often interpreted as anti-predatory escape strategies. Until recently it was assumed that stalked crinoids were incapable of active locomotion, but observations of modern extant isocrinids demonstrated that some can crawl relatively rapidly, perhaps in order to escape from benthic predators. Because the mechanics of crawling in stalked crinoids resembles the mechanics of swimming in comatulids, it is worth considering whether isocrinids might be capable of swimming. The feasibility of this scenario is tested using a biomechanical model of swimming in a stalkless crinoid and by applying the model to a stalked crinoid. The model demonstrates that the stalk imposes a heavy burden that prevents stalked crinoids from swimming. Evolutionarily, this suggests that stalk loss may have been a key innovation that allowed crinoids to swim. Applying these observations to the fossil record of crinoids suggests that swimming may be plesiomorphic for comatulids. Swimming would have allowed greater capability for escape from benthic predators than afforded by crawling. Non-swimming comatulids may represent lineages in which the ability to swim was lost.

23: 5:15 PM-5:30 PM
Presenter: BAUMILLER, TOMASZ K.

PRELUDE TO THE MESOZOIC MARINE REVOLUTION - TRIASSIC DIVERSIFICATION OF CRINOIDS

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Predation is considered an important, though not uncontroversial, factor in evolution. A variety of trends characterizing crinoids have been interpreted in the context of predator-prey interactions, including increased armoring of Paleozoic crinoids, offshore displacement of stalked crinoids in the Late Mesozoic, and morphological and behavioral traits of comatulids. Here, we provide data for predation on Triassic crinoids and suggest that it was causally connected to the appearance of most of the post-Paleozoic crinoid body plans at this time. Data for fossil and Recent forms indicate that crinoids suffer from predation by fishes, arthropods, asteroids, and echinoids. Using samples from numerous Triassic localities in Poland, we found many crinoid skeletal elements with scratches and pits similar to those made by Recent cidaroids. The scratches are relatively shallow cuts on the ossicle surface; pits are usually perpendicular to the surface and oval to circular in outline. Marks occur on lateral

facets of ossicles, suggesting that they were made while elements were articulated. Given the rapid rates of post-mortem disarticulation of crinoids, this suggests that the crinoids were alive when the marks were made, and we treat it as evidence of predation.The Triassic represents a critical phase of crinoid evolution. Following their near demise at the Permo-Triassic, crinoids rebounded rapidly in the Triassic expanding rapidly through morphospace and attaining great ecological diversity that included the planktonic microcrinoids (roveacrinids), pseudoplanktonic stalked crinoids (traumatocrinids), stalk- and arm-shedding benthic crinoids (holocrinids, isocrinids), free moving crinoids (paracomatulids), and pseudoplanktonic isocrinids (pentacrinids). It is highly probable that the evolution of morphologies and behaviors of the above mentioned groups was stimulated by their interactions with benthic predators.

Session No. 24, 1:30 PM; Thursday, 25 June 2009
Symposium S14. Crisis in Reefs: Is the Past the Key to the Present?

24: 1:30 PM-1:45 PM
Presenter: COPPER, PAUL

REEFS UNDER GLOBAL CLIMATE STRESS: A PALEOZOIC PARADOX FROM THE LATE ORDOVICIAN THROUGH DEVONIAN

COPPER, PAUL, Department of Earth Sciences, Laurentian University, Sudbury, Ontario, P3E 2C6, Canada, pcopper@laurentian.ca

The Mid-Paleozoic coral-sponge reef community flourished uninterruptedly in shallow tropical waters for ca. 100 million years (Katian 0.460- Frasnian 0.376 Ga), surviving the O/S Mass Extinction Events, but crashing at the F/F (Late Devonian) MEEs. Both mass extinctions are generally agreed to have been the result of multiple polar glaciations. The Wenlock-Ludlow and Emsian-Givetian were marked by high atmospheric CO2 concentrations at levels 12-24x the Recent, and tropical SSTs averaged 30°. During the Emsian-Givetian, sealevel highstands drowned continental shelves, producing vast infracontinental sealanes and regional evaporite basins with strong tidal pulses and high salinities. Middle Devonian GBR-sized tracts were at their maximal development, covering far greater carbonate platforms than the Holocene, reaching latitudes 50°N and 45°S. After the F/F MEE, reefs virtually disappeared for nearly 27 myr, with high generic losses of 80%: all stromatoporoid reef builders vanished at the close of the Famennian, and during the Famennian rugose corals were virtually exclusively solitary forms. Glacial events produced MEEs at the O/S and F/F boundaries, confining reefs to lower latitudes such as during the Quaternary: global warming stimulated reef growth and coral diversity during the supergreenhouse, an apparent contradiction to the dire predictions for modern global warming. The advent of the first tropical Late Devonian rainforests stimulated

icehouse O_2 production, and changed continental runoff: cold advective currents exacerbated P upwelling during the Famennian, lowering $CaCO_3$ production by 90% in the tropics. There is no evidence for losses of low-Mg calcite corals and high Mg- calcite or aragonite stromatoporoids during the Devonian supergreenhouse, as postulated for the Holocene aragonitic scleractinians.

24: 1:45 PM-2:00 PM
Presenter: STANLEY, GEORGE D., JR.

REEF COLLAPSE AND REORGANIZATION DURING EARLY MESOZOIC TIME

STANLEY, GEORGE D., JR., The University of Montana Paleontology Center, , Missoula, MT, 59812, United States, george.stanley@umontana.edu

Following the end-Permian extinctions and reef collapse, the first metazoan reefs of the Middle Triassic initiated the long-lived, evolutionary “modern fauna”. Reef evolution reveals expansion-collapse –recovery episodes during a critical part of the Mesozoic. Scleractinians likely arose from “naked corals” progenitors surviving the lengthy Early Triassic extinction aftermath. In the Anisian-Ladinian recovery, corals were joined by organisms (problematica, calcified sponges, bryozoans, and algae) dissimilar from those of Permian reefs but with similar reef cements. After Anisian-early Ladinian reef recovery was a Ladinian-Carnian expansion with mounds and patch reefs of sponges, coral and algae, mostly centered in the Tethys. A continued expansion, interrupted by a second-order mass extinction between the late Carnian-early Norian, produced high taxonomic turnover, resulting in new communities of reef sponges and corals. It was followed by a lengthy mid-late Norian reef expansion when large-scale platform reefs, dominated by corals and sponges, attained wide geographic and latitudinal ranges. Larger, coral-constructed reefs and the coral radiation characterizing the Norian-Rhaetian, was likely facilitated by photosymbiosis. An adaptive radiation among corals in both the Tethys and more distant, island-arc terranes of Panthalassa, occurred during a time of reef expansion, ocean circulation and global warming. Rhaetian extinctions suggest step-wise diversity drops before the end of the Triassic. The end-Triassic collapse appears sudden with worldwide carbonate reduction. High levels of CO_2 and gas hydrate release would have been inimical to reefs, promoting ocean acidification, lowering the saturation of carbonate and promoting breakdown of coral photosymbiosis. Low coral-sponge diversity and general reef reduction characterized the earliest Jurassic (Hettangian-Sinemurian). Survival likely was facilitated by island refuges and calcification responses of corals and other organisms. Sponge-coral reefs recovered and reorganized in Middle Jurassic time but corals did not reach the previous diversity or reef building roles during the Oxfordian reef bloom of the Late Jurassic.

24: 2:00 PM-2:15 PM
Presenter: LIPPS, JERE H.

REEFS THROUGH TIME ARE PHOTOSYNTHETICALLY DRIVEN, INTEGRATED ECOSYSTEMS

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Photosymbiosis is a powerful evolutionary strategy among marine organisms since the early Proterozoic. With the advent of metazoans, the metabolic advantages and enhanced calcification rates conferred by photosymbiosis allowed reefs to flourish. Through time, photosymbiosis accounts for both successes and failures of reefs. Reefs are traditionally regarded as fragile and calcified metazoans as their masters, but reefs are amazingly tough and resilient as evidenced by their Cenozoic record. Adaptability and robustness of the reef organisms may be due to the diversity of single-celled algal symbionts available to the host pool. Today corals, clams and protists living at different depths, light and temperatures possess seven or more clades of zooxanthellae (*Symbiodinium*). Reef bleaching, commonly regarded as a breakdown of symbiosis, may be a positive adaptive force. Reacquisition of new clades of symbionts, better adapted to conditions following any environmental change, likely explains successes of most reefs through geologic time. At least six episodes of major mass extinction are associated with global reef collapse during Phanerozoic reef history. The causes are debated but effects include global sudden warming-cooling, sunlight reduction, sea-level change, acidification and eutrophication all of which were inimical to host-symbiont relationships. These were followed by recovery intervals ranging from two to 20 million years during which photosymbionts likely re-evolved independently in a wide spectrum of unrelated reef-building organisms. Possible examples include Cambrian archeocyathids, Devonian calcareous sponge/coral associations, a variety of Late Permian shelly organisms, Late Triassic coral/sponge reefs, Late Jurassic and Cretaceous coral, sponge and rudistid bivalve associations as well as late Paleogene-Neogene coral-dominated reefs. Photosynthetically-driven reefs are complex, integrated ecosystems selected for resistance to shallow-water disturbances and variations and likely driven by photosynthetic symbionts. One-celled photosymbionts, not metazoans, are the real masters of most reefs through time.

24: 2:15 PM-2:30 PM
Presenter: KIESSLING, WOLFGANG

ON THE POTENTIAL FOR OCEAN ACIDIFICATION TO BE A GENERAL CAUSE OF ANCIENT REEF CRISES

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Current concerns on the ecological impacts of ocean acidification have let some authors to assume that acidification also played a large if not dominant role in ancient mass extinctions and reef crises - we call this the ocean acidification hypothesis (OAH). Reefs are thought to be especially sensitive to ocean acidification because their existence depends on the rapid calcification of sessile organisms. We tested two predictions of the OAH with data in Sepkoski's compendium, the Paleobiology Database and the PaleoReefs database: 1. Hypercalcifying organisms such as reef builders should be affected more strongly than other organisms, especially those without calcareous skeletons. - A rigorous comparison of extinction rates in hypercalcifying sponges and corals with extinction rates of all other or just non-calcifying organisms confirms this prediction for just two mass extinctions: Late Devonian and end-Triassic. 2. Reefs should decline during times of rapidly rising pCO_2. Although both proxy and model data are limited, they do suggest profound increases in the latest Permian, latest Triassic, and in the Paleocene-Eocene thermal maximum, but not in the Devonian. We are thus left with just one mass extinction where ocean acidification may have played an important role: the end-Triassic mass extinction. Therefore, the OAH is currently not convincingly supported by the fossil record.

24: 2:30 PM-2:45 PM
Presenter: JOHNSON, CLAUDIA C.

REEF'S FUTURE INHABITANTS: SELECTED CORAL DEVELOPMENT ON ARTIFICIAL SUBSTRATES

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A critical yet often overlooked component of research in the reef ecosystem is the recruitment, survival and ecological development of selected corals on artificial substrates. Although species such as *Acropora cervicornis* and *A. palmata* now form massive dead zones in shallow waters throughout the Caribbean, species of Faviidae and Fungiidae are thriving in these same localities on artificial substrates. Structures such as cannons and cannonballs - archaeological artifacts from shipwrecks - as well as petroleum barrels and cement blocks that serve as mooring buoy anchorage contain coral recruits. These substrates are modified and converted to calcium carbonate by normal marine processes, and are documented sites upon which corals develop into communities. These colonizers, survivors and incipient constructors

of future reef communities require analysis, for they thrive in the sites of A. cervicornis and *A. palmata* destruction, and are apparently advancing the constructor guild of the reef community landward at a time when sea level is rising and reefs are in decline regionally and globally. Preliminary bio-environmental data collected from Bonaire National Marine Park from 44/115 underwater mooring anchor sites indicate that the dominant corals growing on the mooring anchors are of the Faviidae and Fungiidae lineages, specifically *Diploria labyrinthiformis* and D. strigosa, Colpophyllia natans, Porites astreoides, *Montastrea cavernosa*, *Agaricia agaricites* and *Favia fragum*. Temperatures ranged from 82-84oF from November 2007 data and 80-82oF from May 2008. pH by litmus was 8 and by colorimetric 8.0-8.5. Salinity ranged from 36 -40 ppt. Cations and anions are within normal range. Nitrites and nitrates are above background levels at specific sites, whereas phosphates are above background levels and sulfates below at almost all sites tested from 11/07. These empirical data form the basis of future geochemical models for aragonite saturation and thermal tolerances of coral species from site-specific locations in the Caribbean.

24: 2:45 PM-3:00 PM
Presenter: LAGOMARCINO, ANNE

A TAPHONOMIC SIGNATURE FOR WHITE BAND DISEASE AND/OR BLEACHING IN *ACROPORA PALMATA*, BUCK ISLAND NATIONAL MONUMENT, ST. CROIX, USVI

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Over the past few decades Caribbean reefs have experienced severe reductions in coral cover and a phase shift to macroalgal-dominated communities. Monitoring has indicated that *Acropora palmata*, a dominant reef builder in the Caribbean, has been devastated by both White Band Disease (WBD) and bleaching. However, direct monitoring can obviously not be used to diagnose the effects of these agents in the longer-term history of reef communities. Both bleaching and WBD leave *A. palmata* colonies in life-position, subject to increased grazing and encrustation post-mortem. By contrast, destruction by storms reduces colonies to pieces of rubble that either grow anew or die and become part of the substrate. Our goal was to determine whether differences in grazing and epibiont encrustation might be used to distinguish between these two distinct causes of *A. palmata* degradation in the historical reef record. Over 150 colonies of standing, dead colonies of *A. palmata* were collected from two sites off Buck Island, near the island of St, Croix, where WBD was first described. At the same sites, samples were recovered from 1-2 meter deep pits that were dominated by broken, toppled and encrusted branches. A subset of 15 “standing-dead” and 15 “pit” samples was chosen randomly from the larger group at one site. The relative importance and microstratigraphy of epibionts were quantified along ten randomly chosen transects for each sample. Multivariate analysis reveals distinct differences between standing-dead and pit

samples. In particular, vermetid gastropods and thick, conformable coralline algae tended to be abundant on standing dead-samples. Two encrusting foraminiferans, *Carpenteria utricularis* and *Biarrititzina carpenteriaetermis* were more abundant on pit samples. Differences between the tops and bottoms of standing-dead samples were also investigated, and bottoms are encrusted by constituents that tend to be intermediate in composition between the tops and pit samples.

24: 3:00 PM-3:15 PM
Presenter: HUBBARD, DENNIS K.

CORAL REEFS OF THE PAST, PRESENT AND FUTURE - DO WE NEED A TRANSLATOR?

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Reefs have changed dramatically in recent decades, and much of this is probably anthropogenically driven. Effective mitigation faces the challenge of identifying, to paraphrase Wendell Berry, “what nature would be doing if we were doing nothing.” While it has been long understood that both taphonomy and the different temporal and spatial scales of geological versus biological change can create incompatible data sets, the two are often conflated. For example, backstepping off Barbados during massive melt-water releases led to the linking of rapid sea-level rise and the demise of reefs. However, this spatial migration was not particularly unique, except for its verticality; comparable reefs, dominated by *A. palmata*, remained after each melt-water event. Thus, backstepping provided “stepping-stones” for the reef and eventual “reassembly” following the sea-level lowstand was unnecesary. In contrast, *A. palmata* suffered at least two millennial-scale periods of decline over the past 6,000 years, but reefs continued to build at similar rates despite the absence of this traditional reef-crest dominant. A possible fingerprint for disease and/or bleaching in *A. palmata* is emerging, but whether or not this signature is ultimately linked to the periodic demise of Holocene *A. palmata*, its role as a “keystone species” is in question if either accretion or spatial heterogeneity is any measure of a reef's success or ecological value. Preliminary compilations of Holocene core data indicate that lapses in Caribbean acroporids are not shared by other corals. Thus, what may be new about the recent decline is more the involvement of massive species and less the disappearance of *Acropora*. None of this identifies the best mitigation strategy, but it does highlight the need to be very careful as we try to use a uniformitarian approach to either understand fossil reefs or to develop effective management strategies for the future.

24: Poster
Presenter: KAUFFMAN, ERLE G.

THE FIRST DIVERSIFICATION OF METAZOAN LIFE: BIOGEOCHEMISTRY AND COMPARATIVE MORPHOLOGY OF 1.9 – 2.5 BILLION YEAR OLD TRACE FOSSILS TO PHANEROZOIC COUNTERPARTS. For full abstract, see *8: 2:00 PM, Booth 1*

Session No. 25, 2:00 PM; Thursday, 25 June 2009
Poster Session PS3. Taphonomy and Paleoecology

25: 2:00 PM, Booth 1
Presenter: ANDERSON, BRENDAN

ESTIMATING THE DIVERGENCE TIMES OF "MISSING" OPEN-OCEAN TAXA OF THE PALEOZOIC: A MOLECULAR CLOCK APPROACH

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Ever since Sepkoski's classic depictions of Phanerozoic marine diversity taxa it has been appreciated that the richness of the Modern evolutionary fauna was limited in the Paleozoic Era, and showed a dramatic increase in the post-Paleozoic. However, because of a possible tendency of elements of the Modern Fauna to occur in open-ocean facing settings, which are underrepresented to at least some extent in Paleozoic strata, the true first occurrences of at least some of these elements might be underestimated significantly in the fossil record. We conducted an initial test of this possibility by tabulating the occurrences of the crown groups of the Arcoidea and Veneroidea (bivalves), Buccinidae s.l., Conoidea and Muricoidea (gastropods), and eubrachyuran crabs. The fossil records of these major elements of the Modern fauna are associated primarily with open-ocean facing marine rocks in the Cretaceous and Early Cenozoic, when both ocean-facing and epicontinental environments are preserved. We therefore hypothesized that at least some of these groups originated earlier than indicated by available records on fossil occurrences. We used a molecular clock to estimate the divergence times of Buccinidae s.l., and Veneroidea, and noted that although the fossil record of Buccinidae s.s. appears to be robust, Veneroidea appears to have a deep Paleozoic history arising sometime in the Silurian or the Devonian (440-353 Ma). In contrast the Mytilidae, which have a deep Paleozoic fossil record are not as strongly associated with ocean-facing environments. Our preliminary analyses therefore suggest that at least some Modern faunal elements may have significantly deeper histories than suggested by the fossil record.

This, in turn, opens up the possibility that Paleozoic biodiversity is underestimated because of the preferential loss of open-ocean records and elements of the Modern Fauna, in particular, that may have resided in them.

25: 2:00 PM, Booth 2
Presenter: SHIINO, YUTA

COMPUTATIONAL FLUID DYNAMICS SIMULATION ON THE SPIRIFERIDE BRACHIOPOD *PARASPIRIFER BOWNOCKERI*

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The mechanism of passive feeding flow generation in the Devonian spiriferide brachiopod *Paraspirifer bownockeri* was theoretically elucidated through fluid dynamics simulations for flow around rigid shells. The k-e model along the RANS equations was used as a turbulence model, and the unsteady incompressible flow was solved using the finite volume method. The fluid dynamics simulations were performed under the condition that fluid flow directed from ventral and dorsal sides, during which little exchange of flow occurred inside the shells. The digital shell model was constructed using image processing of X-ray CT images of a shell replica of a well-preserved fossil specimen made by molding a polycarbonate plate. To examine the effect of flow velocity, three conditions of ambient flow velocity were adopted for both the ventral and dorsal flows. The pressure distribution along the gape showed that a relatively high pressure occurred around the sulcus in all simulated cases. This high pressure generated inflow from the sulcus and subsequent spiral interior flow, especially in fast ambient flows. This means that the sulcus generated the considerable pressure gradient around the gape passively and generated the stable intake of seawater and a spiral flow of water inside the shell for feeding. We conclude that the shell form of certain spiriferides could generate spiral flows so as to promote passive feeding.

25: 2:00 PM, Booth 3
Presenter: BUDIL, PETR

FEEDING STRATEGIES OF TRILOBITES OCCURRING IN THE KRALUV DVUR FORMATION (UPPER ORDOVICIAN, PRAGUE BASIN, CZECH REPUBLIC)

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All supposed feeding strategies as defined by Fortey and Owens (1999) were recognized within each of five trilobite associations (Budil et al., herein) in the Kraluv Dvur Formation (Katian of the Prague Basin). Their absolute and relative frequencies, however, strongly differ from association to other in time and space. Numerous small benthic scavengers-predators (acastoids, calymenids, diversified illaenids, cheirurids, rare lichids) accompanied by rare large scavengers/predators (*Birmanites*), common filter-feeders (*Nankinolithus*, *Cerampyx*, *Lonchodomas*, *Raphiophorus*), minute particle feeders (*Phillipsinella*, very rare *Harpidella*), and common pelagic/nectic ?predators (*Amphytrion*, cyclopygids, odontopleurids, rare *Telephina*) constitute the deeper-water trilobite-dominated *Nankinolithus granulatus* Association, which occur in the gray and green claystones. Minute filter feeders (*Tretaspis*, *Lonchodomas*) and benthic and/or epi-planctic agnostids (*Arthrorhachis)* accompanied by cyclopygids prevail in the brachiopod-dominated *Dedzetina* and especially in the trilobite-dominated *Tretaspis anderssoni* associations (bound on siltstones and in olive green claystones, respectively). The *Marekolithus kosoviensis* Association is restricted to the bed of impure bioclastic limestones in the upper portion of the formation. Numerous small and medium-sized benthic scavengers-predators of this association probably used several different life strategies (dalmanitids, acastoids, calymenids, cheirurids, illaenids, very rare lichids and encrinurids). They are accompanied by filter feeders (common *Marekolithus*, very rare *Thorslundops*?) and rare, minute particle feeders (*Decoroproetus*). Active nectic/pelagic forms are represented by cyclopygids, rare odontopleurids and possibly also by some cheirurids. Only medium-sized scavengers-predators persisted as constituents of the youngest, monotypic *Mucronaspis* Association up to the onset of the early Hirnantian glaciation. The Grant Agency of the Academy of Science of the Czech Republic supported the contribution through the Project No IAA301110908.Budil, P., Fatka, O. Mergl, M. & Kraft, P. (2009, herein). Trilobite associations of the Kraluv Dvur Formation (Czech Republic, Prague Basin, Upper Ordovician, upper Katian) . Fortey, R. & Owens, R. (1999). Feeding habits in trilobites. Palaeontology, 42, 429-465.

25: 2:00 PM, Booth 4
Presenter: HUANG, YUNFEI

ECOLOGICAL SIGNIFICANCE OF THE EARLIEST TRIASSIC BIVALVE COMMUNITIES IN WEST GUIZHOU AND EAST YUNNAN

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The Zhongzhai and Tucheng sections in west Guizhou and east Yunnan, which was located at the east margin of Chuandian paleocontinent,deposited a suit of clastic rocks with abundant benthic faunas dominated by bivalves, brachiopods and gastropods. Based on the data of conodonts and bivalves from the study area, the Permian-Triassic boundary has been fixed and the ecological evolution of the bivalves has been discussed in the paper. The earliest Triassic marine community in Zhongzhai section is named *Claraia* community, and in Tucheng section *Promyalina-Pteria-Towapteria* community. The *Promyalina-Pteria-Towapteria* community appeared after first appearance of *Hindeodus parvus* and prior to that of *Claraia wangi*. *Promyalina and Pteria* are dominant and characteristic genera in surviving interval following the end-Permian mass extinction in Tucheng section while *Claraia* is the main genus in Zhongzhai section, Then their ecological respondings are analysed from life styles?food resources and ecological strategies. Through our finding, all these genera are epi-bysaate and suspension-feeding styles. The diversity of either *Pteria-Promyalina* community or *Claraia* community is very low. It can be conclude that the environment was likely unstable with high energy, hypoxia and lack of organic matters in the sediments, which may restrain survival of other species. Moreover, shell sizes were measured to distinguish mature individuals from juvenile individuals. We got the same result in two communities that the juveniles are dominant, reflecting the ecologic strategy of r-selection for the *Pteria*, *Promyalina*, and *Claraia* to adapt to the unfavoured environment.

25: 2:00 PM, Booth 5
Presenter: OPAZO, LUIS-FELIPE

CHANGES IN ECOLOGICAL TRAITS IN MARINE ORGANISMS THROUGH THE EARLY MESOZOIC

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Ecospace can be represented as a combination of the three axes of tiering, motility and feeding, each divided into six subcategories. From the Cambrian to Recent, ecospace utilisation has tripled, however the trend through the Phanerozoic remains unclear. We analysed stage-by-stage occupation of ecospace for the marine fauna from the Late Permian to Early Jurassic. 3181 genera were recorded from Sepkoski`s compendium, and each one classified according to the autecological information derived from the Paleobiology DataBase and published references. Finally, average relative abundance for each subcategory was

calculated and we evaluated the trends in tiering, predation and motility. 31 modes of life were recorded. Ecospace utilisation increases from the Guadalupian to Sinemurian. In the three main categories of tiering, motility and feeding, the most common subcategories (>15% of taxa) are, respectively, 'shallow infaunal', 'fast mobile' and 'predation'. Ecospace utilisation decreased 35% and 16% at the ends of the Permian and Triassic periods respectively. There was a significant, positive correlation between abundance of predators and both infaunalisation and prey motility. The appearance of marine reptiles and adaptations in the ichthyofauna to new trophic niches, like durophagy, presumably increased predation pressure and drove the increase in benthic infaunalisation.

25: 2:00 PM, Booth 6
Presenter: SAWYER, JENNIFER A.

INTENSITIES OF DRILLING PREDATION FROM MOLLUSCAN ASSEMBLAGES ALONG A SUBTIDAL TRANSECT THROUGH THE NORTHERN GULF OF TRIESTE (ADRIATIC SEA)

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Drilling predation is one of the most studied biotic interactions in the fossil record, but its history is debated: some report stable and high drill frequencies (DF) from the Eocene to the Recent, while others document variable predation frequencies. While patchiness in DF across environments has been documented, researchers have not consistently evaluated DF among paleoenvironments through time; such variation may confound temporal trends. Additionally, ecology of prey may play a role in predator food choices. To contribute to the overall understanding of drilling predation in the Adriatic, and to examine the roles of environment, patchiness, and ecology of prey organisms, >48,900 molluscs from 2 intertidal and 6 sublittoral bulk samples along a transect in the Gulf of Trieste were analyzed for DF and prey effectiveness (PE).DF across all samples was 20.6%, but varied considerably between the intertidal (1.4%) and sublittoral (27.4%) environments. Among the latter, DF differed strongly between the delta slope (18.1%) and sublittoral muds and sands (~28%). PE was low in the intertidal (1.1%) and sublittoral (4.5%). Suspension feeders had the highest DF amongst bivalves (24.3%) and gastropods (39.1%). Epifaunal bivalves (32.0%) were drilled nearly twice as often as infaunal bivalves (17.9%). DF on cementing (43.0%) and byssate (27.0%) bivalves were higher than on recliners (9.9%). Interestingly, parasitic gastropods (20.3%) and commensal bivalves (40.6%) had exceptionally high DF. PE was highest on suspension feeding (11.1%), infaunal (15.8%) and cementing (10.5%) bivalves, and on parasitic gastropods (11.9%).In summary, considerable differences in DF and PE occur within and between environments, and among ecological guilds. This study therefore supports the view that small-

scale patchiness and prey-ecology have to be considered in temporal analysis of drilling predation.

25: 2:00 PM, Booth 7
Presenter: CHRISTIE, MAX

CONFAMILIAL PREDATION ACROSS A BIOGEOGRAPHIC BOUNDARY AT CAPE HATTERAS, NORTH CAROLINA: NATICID ECOLOGICAL INTERACTIONS ACROSS A LATE PLIOCENE INTERVAL OF FAUNAL TURNOVER

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According to previous work along the western Atlantic Coastal Plain, 70% of molluscan species went extinct during a two pulsed event across the Plio-Pleistocene boundary; yet the nature of this extinction event is different north and south of the biogeographic boundary represented by Cape Hatteras, NC. North of this boundary extinction without origination is thought to have occurred while south of the boundary, paleocommunities experienced both. Although the evolutionary effects of this extinction have been studied, the community-level ecological effects are poorly understood. This research focuses on the confamilial predation of naticid snails, a family of shell-drilling predators, and seeks to determine changes in the degree of cannibalism, predator size, prey size, and naticid drill hole location across the biogeographic boundary during the late Pliocene.Float and museum collections of the Yorktown (Moore House Member) and Duplin Formations (sampling before the extinction) and the lower Waccamaw and Chowan River Formations (sampling after the first pulse of extinction) were used in this study. Measurements included: percent cannibalism per collection (cannibalized naticids/total naticids), naticid size, prey size (drilled specimens), predator size (drill hole size), and drill hole location. Naticid size was calculated using geometric mean of length and height. Drill hole location was determined using an eight sector grid. To date, eight samples (4 pre-first pulse, 4 post-first pulse; 5 north of Cape Hatteras, 3 south of Cape Hatteras) have been processed totaling 447 specimens and representing nine species. Current results indicate a non-significant increase in average size and maximum size and a non-significant decrease in percent cannibalism across the first pulse of extinction. Results were also non-significant when comparing naticids within 10mm size classes. These results suggest that there was no difference in the confamilial ecological interactions of naticids across the first pulse of the Plio-Pleistocene extinction.

25: 2:00 PM, Booth 8
Presenter: METZ, ROBERT

ICHNOLOGY OF PALEOZOIC ROCKS FROM THE DELAWARE WATER GAP NATIONAL RECREATION AREA, NEW JERSEY

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Lower Devonian barrier-bar or beach deposits of light- to medium-gray calcareous sandstones and medium-to medium dark-gray siltstones of the Oriskany Formation have yielded the trace fossils *Planolites beverleyensis*, *Skolithos linearis*, and a bivalve escape structure. *Skolithos linearis*, representing vertically-oriented feeding burrows within light-to medium-gray calcareous sandstones, denotes exploitation by opportunistic suspension feeders within a shallow marine environment during dominent high energy conditions. In contrast, *Planolites beverleyensis*, representing horizontally-oriented shallow burrows within medium-to medium dark-gray siltstones, records exploitation by opportunistic deposit feeders during relatively abrupt, short lived lower energy levels within the same environment. Marine deposits of medium-to dark-gray calcareous siltstones and clayey limestones of the Onondaga Formation (Middle Devonian), have yielded the trace fossils *Nereites missouriensis*, *Psammichnites isp*., as well as a trace fossil resembling *Psammichnites*. Both of these forms represent largely horizontal to slightly inclined deposit-feeding strategies occurring in relatively low-energy, well-oxygenated, moderately deep marine waters with a minimum sediment influx. This records the first occurrence of these trace fossils from the Delaware Water Gap National Recreation Area as well as New Jersey.

25: 2:00 PM, Booth 9
Presenter: BARRINGER, JOSHUA E.

MICROCONCHID-BRACHIOPOD RELATIONSHIPS FROM THE MIDDLE DEVONIAN OF THE MICHIGAN BASIN, USA

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Spiriferid and strophodontid brachiopods from the Middle Devonian (Givetian) Potter Farm Member of the Thunder Bay Limestone of Alpena County, Michigan, host more spirobiform encrusters (*Microconchus*) than brachiopods from other Middle Devonian strata of the Michigan Basin. Of the Potter Farm Member brachiopods, strophodontids were encrusted more often than spiriferids, though both the average number of microconchids per specimen

and the average microconchid shell diameter was similar between the two brachiopod hosts. Microconchids showed some settling preference: a greater number of microconchids settled on either side of the central region of the brachiopod valve (the fold and sulcus of spiriferids and similarly located central region of strophodontids) than settled on the central region of the valve or along the commissure. Microtopographically, microconchids preferred the grooves of the costae over all other regions. Preferred orientation of microconchid apertures with regard to the brachiopod host's commissure was evident on individual specimens but there was no preferred aperture orientation among microconchids from multiple brachiopod hosts. Dorsal/ventral brachiopod valve microconchid encrustation data support previous interpretations for the life position of the spirifer host brachiopod *Mucrospirifer* as resting on its hingeline and the strophodontid brachiopod host Strophodonta as resting with the convex valve oriented up.

25: 2:00 PM, Booth 10
Presenter: BOSE, RITUPARNA

SYNECOLOGICAL INTERACTIONS OF THE BRACHIOPOD *RHIPIDOMELLA* FROM THE MIDDLE DEVONIAN DUNDEE FORMATION OF OHIO, USA

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In three fossiliferous units of the Middle Devonian Dundee Fm. exposed at Whitehouse Quarry, Ohio, only the small orthide brachiopod *Rhipidomella* preserves evidence of interactions with predators and endobionts, whereas the larger atrypides, spiriferides, and stropheodonts in the fauna do not. The biotic interactions are unique in the absence of all traces by other organisms on these larger brachiopods, even though they are often encrusted in other Devonian localities. The punctate shells of *Rhipidomella* preserve interactions with both endobionts and predators, which is generally uncommon in punctate brachiopods. All endobionts on *Rhipidomella* were preserved as traces; if calcified encrusters were present, they likely were lost postmortem. Several *Rhipidomella* individuals bear partially repaired traces from parasitic interactions with sinuous, boring organisms, attributed to ctenostome bryozoans. These parasites bored into the shell along the commissure, likely benefiting from the inhalant and exhalant currents produced by the brachiopod, and in some cases, expanded away from the commissure following the host's death. Straight U-shaped borings in one *Rhipidomella* specimen with boreholes are similar in morphology to *Caulostrepsis* traces. Other endobiont traces were probably left on the shells post-mortem. Predation repair scars

are present on two specimens, indicating the presence of predators and the survival of some *Rhipidomella* individuals from durophagy. This study thus documents a relatively rare incidence of endobiosis from a carbonate sedimentological regime, which contributes to our understanding of endobiont occurrences in Paleozoic limestones. By demonstrating that evidence for endobiosis can be preserved on small, imperfectly preserved brachiopod specimens, this work may also assist future workers in addressing the question of why such interactions appear to be more common in siliciclastic versus carbonate environments.

25: 2:00 PM, Booth 11
Presenter: MYERS, ANDREW

AN ORDOVICIAN ORCHOCLAD DEMOSPONGE FAUNA FROM THE LENOIR LIMESTONE OF EAST TENNESSEE

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Orchoclad demosponges are common components of many Ordovician faunas often associated with mounds or buildups. Here we report on an unusual new locality bearing two species of orchoclad sponges in a, crinoidal limestone. Specimens were collected from the Upper Ordovician Lenoir Limestone exposed in a sinkhole near Lenoir City, Tennessee. The locality is dominated by orchoclad sponges, including an undescribed anthaspidellid with affinities to *Rugocoelia* and the streptosolenid *Allosaccus prolixus*. The limestone bed is nodular with a thickness of about 1 meter, and has an appreciable amount of shale partings. The bulk of small skeletal debris consists of isolated ossicles of crinoids, with minor amounts of bryozoans and brachiopods. The preserved sponges are slightly fragmented. The abundant crinoid holdfasts are in life-position, but the sponges are not. The arrangement of sponges and crinoids in the environment seems to suggest that the sponges were washed into the area prior to burial. The anthaspidellid appears to be a new species characterized by having a relatively large body with an average height of 15 cm. Specimens are vase-shaped with a large spongocoel and a thin lateral wall ~ 8 mm thick, and have large concentric rings on the exterior surface. Radial canals are straight and normal to the lateral wall, and vertically stacked into a checkerboard pattern. *Allosaccus prolixus* is smaller in size, and is vase-shaped with a height of up to 7 cm and a very thick lateral wall and a shallow central depression. The outer surface is covered by a thick dermal layer. The radial canals are somewhat sinuous branching and irregularly distributed on outer surface and the spiculation is relatively complex. Description of these sponges will allow better characterization of this unusual fauna.

25: 2:00 PM, Booth 12
Presenter: HARTWELL, CHRISTINA J.

PALEO-ECOLOGICAL COMPARISON BETWEEN THREE E.E. SUB UNITS IN THE MIDDLE DEVONIAN OF EASTERN NORTH AMERICA

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The hypothesis of Coordinated Stasis proposes that various intervals in the rock record contain long-lasting faunal associations with little to no change in their composition. To date, investigations of Coordinated Stasis have been conducted primarily on taxonomic composition. This study purposes examine the stability of ecological niche partitioning across three Ecological Evolutionary sub-Units in the Middle Devonian of eastern North America: the Onondaga, Stony Hollow, and Hamilton faunas.The fauna of the Stony Hollow interval, though fairly well understood, still remains some what of an enigma as it is preserved in a very thin interval in most areas. Taxa of the Stony Hollow Fauna are known to have immigrated into the area from what were at the time more equatorial areas in northern Canada, displacing the existing suite of taxa for nearly one million years. This fauna is thought to have followed a major sea level rise and influx of warmer water down into the basin that was extant across the state at this time. Although the basic nature of the Stony Hollow Fauna is known as described above, a precise description of the ecological nature of the fauna has yet to be completed. The proposed project will consists of collection of samples throughout the Stony Hollow interval across eastern North America and a thorough description of the paleoecology of all taxa present. To date only the brachiopod taxa of the Stony Hollow Fauna have been examined in any great detail while other abundant forms, such as bivalved mollusks and corals, remain almost completely unknown. With a more complete understanding of the unique fauna of this interval it will be possible to make broader comparisons of faunal change across wide areas of the globe and elucidate the precise mechanisms driving large-scale faunal change.

25: 2:00 PM, Booth 13
Presenter: HUBBARD, DENNIS K.

SEDIMENTATION AND REEF “HEALTH” IN HOLOCENE REEFS OF THE ENRIQUILLO VALLEY, WESTERN DOMINCAN REPUBLIC

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Holocene reefs in the western Dominican Republic are spectacularly exposed at their original elevation/depth owing to the rapid closure of the baymouth and subsequent evaporation of the sea starting ca. 4,000 CalBP. Over 7,000 years of continuous reef accretion have recorded changing paleo-community structure in response to local oceanographic conditions and rising sea level. All reef zones found in the present Caribbean (branching, mixed, massive, platy) can be identified in the outcrops. The dominance of fringing reefs along steep valley sides and the restricted nature of the embayment argue for high sedimentation within a low-energy regime. This is supported by reduced coral-growth rates (ca 20% of linear extension for similar species at the same depths on open-Caribbean reefs) and a dominance of conical and columnar colonies that reflects restriction of lateral extension by sediments. Exquisite preservation of epi- and endobionts, and the overwhelming dominance of large lithophagid molluscs likewise argue for high influx of both sediment and nutrients. Sediments incorporated within the reef contain up to 30% transported intraclasts from the adjacent Miocene hillsides, and show no significant onshore-offshore difference, inferring that the introduction of terrestrial sediment to the near-shore was sufficient to affect all parts of the forereef equally. Despite what seems like overwhelming evidence for both high sedimentation and low wave action, 26 species of corals have been identified and constitute nearly 75% of the volume of the preserved reefs. This value is based on numerous meter-wide vertical transects along which 100 points were counted in successive quadrats. Allowing for ~50% of the preserved corals along an imaginary timeline having been alive at any one time, coral abundance was probably between 30 and 40%. This pattern contrasts with our perceptions that high sedimentation results in low cover by a limited number of particularly sediment-tolerant species.

25: 2:00 PM, Booth 14
Presenter: WILSON, GREGORY P.

AMPHIBIAN PALEOCOMMUNITY DYNAMICS OF THE HELL CREEK FORMATION IN NORTHEASTERN MONTANA AND THE CRETACEOUS-TERTIARY EXTINCTION EVENT

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The Hell Creek Formation in northeastern Montana provides arguably the most complete view of a latest Cretaceous continental biota. Previous studies of paleocommunity dynamics leading up to and across the Cretaceous-Tertiary boundary in northeastern Montana and southwestern North Dakota have mainly focused on turtles, mammals, and plants. This study tracks patterns of amphibian paleocommunity structure through the Hell Creek Formation. Due to their biphasic lifecycle, amphibians are commonly considered ecological indicators that importantly reflect the overall health of an ecosystem. Thus, they represent excellent models

for examining paleoecological dynamics and testing Cretaceous-Tertiary extinction hypotheses. Using an amphibian fossil database of 500+ catalogued specimens identifiable to genus, we examined changes in taxonomic composition, richness, and relative abundances, during the last 2 million years of the Cretaceous in Garfield County, northeastern Montana. Amphibian specimens were recovered from over 53 vertebrate microfossil localities in exposures of the Hell Creek Formation that span much of its ~93-meter thickness. Localities are tied into a temporal framework based on stratigraphic positional data. Results suggest that taxonomic composition of amphibians changed little during the last 2 million years of the Cretaceous, with seven predominant Caudata genera persisting through the formation. Relative abundances of some taxa fluctuated during the last 500,000 years of the Cretaceous with high relative abundance of *Opisthotriton* and low relative abundances of *Scapherpeton* and *Habrosaurus*. These faunal fluctuations correlate with changes in relative abundances of mammal species and with a warming trend or related climatic factors suggested by proxies. Whereas the results record measurable responses to climate changes during the latest Cretaceous, the muted response at the Cretaceous-Tertiary boundary itself has implications for selectivity and causal hypotheses of the extinction event.

25: 2:00 PM, Booth 15
Presenter: MARTIN, JACLYN B.

BIOFACIES ANALYSIS ALONG A MIDDLE DEVONIAN PALEOGRADIENT: WATER DEPTH AS A PRIMARY CONTROL ON BIOFACIES FORMATION IN THE STAGHORN POINT CORAL BIOSTROME

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The issue of biofacies response to sea level fluctuations has been analyzed to a large extent in vertical stratigraphic successions; the matter is complicated by the interplay of controls such as sediment input and water depth on the formation of biofacies. In order to disentangle these two effects, it is necessary to examine biofacies changes along a single time-parallel gradient, where one of these factors can be assumed to be nearly constant. One such possibility would be a gradient that runs parallel to the direction of incoming sediment supply and perpendicular to depositional shoreline strike, where water depth is known to change. Just such a case exists in the Middle Devonian of the Appalachian Basin in the coral beds of the Otisco Member of the Ludlowville Formation of central New York State. Exposures of the Staghorn Point submember along the shores and tributaries of Skaneateles Lake run roughly perpendicular to the main gradient of sediment supply in the basin and display a deepening trend to the northwest. The Staghorn Point coral biostrome is a dense thicket of mainly solitary rugose corals that sits atop a siltstone platform at most localities. This coral biostrome comes to an abrupt edge at a buried submarine escarpment, but the horizon, marked by

phosphatic pebbles can be traced for nearly 10 km down ramp into distal facies. Biofacies found along the gradient preserved within the Staghorn Point submember range from shallow water associations dominated by abundant rugose and rare tabulate corals into deeper water associations dominated by athyrid and leiorhynchid brachiopods. The biofacies spectrum preserved within the single time-plane of the Staghorn Point submember is analogous to the suite of biofacies associated with a sea level oscillation cycle in areas where water depth change dominates over sediment input as a biofacies control.

25: 2:00 PM, Booth 16
Presenter: XIONG, XIN QI

PALAEOECOLOGICAL SIGNIFICANCE OF ANISIAN (MIDDLE TRIASSIC) COMMUNITIES FROM THE QINGYAN AREA, GUIZHOU, SOUTHWEST CHINA AND RECONSTRUCTION OF THE BRACHIOPOD RECOVERY PROCESS

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Five fossil communities dominated by brachiopods and bivalves are identified from the Anisian Qingyan Formation at Qingyan, Guizhou province, southwest China. These Anisian communities can be representive of the recovery benthic faunas after the end-Permian mass extinction. In ascending order, they are the *Mentzelia*, *Athyris-Leptochondria*, *Ornithopecten-Chlamys*, *Aulacothyris-Rhaetina* and *Diholkorhynchia-Mentzelia* communities. According to the features of these fossil communities and the characters of their hosting rocks, palaeoecological significance has been analyzed. Our study on the community compositions and structures are utilized to demonstrate the replacements of these communities that were likely affected by the variations of relative sea level. Besides the communities, our data also show clearly that there existed the replacements of the ecological positions between brachiopods and bivalves. In addition, taxonomic analysis of these brachiopods in different life habitats that had been identified by the community features enables a reconstruction of the Triassic brachiopod recovery process.

25: 2:00 PM, Booth 17
Presenter: HANSON, KATHLEEN M.

A MIDDLE DEVONIAN TERRESTRIAL ARTHROPOD TRACKWAY FROM THE CATSKILL DELTA

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The Middle-Upper Devonian Catskill Delta sediments of New York State preserve some of the earliest complex terrestrial ecosystems anywhere on the planet. Contained within the strata of the Catskill Delta are the remains of the world's oldest fossil forest, the Gilboa Forest, along with the first spiders, centipedes, and various other terrestrial arthropods. A recent discovery along the Catskill Front in Katterskill Clove has yielded a diplichnities-type trace fossil in a purely terrestrial environment. The stratigraphic position of this trace is slightly lower than the previously mentioned well-known fossil arthropods found in Schoharie County farther to the north and west. This trace is a slightly meandering track-way approximately 1.5-2cm wide and extends for over 30cm in total length, with the distance between the individual track-marks ranging from 1 to 3mm. This trace fossil is hypothesized to represent tracks made by a large terrestrial arthropod that lived on fluvial plane of the Catskill Delta. This project aims to better determine the nature of the trace maker along with elucidating the paleoecological interactions of early terrestrial arthropods.

25: 2:00 PM, Booth 18
Presenter: MARTINDALE, ROWAN C.

PALEOECOLOGY OF LATE TRIASSIC REEFS AND IMPLICATIONS FOR THE END-TRIASSIC MASS EXTINCTION

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The Norian-Rhaetian stages of the Triassic (217-200 mya) are known for prolific carbonate deposition and reef growth, but at the Triassic-Jurassic boundary, reefs and most marine life vanished in one of the largest extinctions and reef crises of the Phanerozoic. The term “reef” is a general expression, which often implies a certain degree of interpretation that may not be warranted - many “reefs” have unique paleoecologies and often grow in different environments. The majority of knowledge on Triassic reef paleoecology is decades old, and a rigorous understanding of “healthy” Late Triassic reefs is not known. Without this baseline, it is impossible to determine how reef ecosystems responded to the extinction. This study examines Norian-Rhaetian reefs with three main objectives; (1) establish what a healthy coral reef ecosystem is, (2) determine what ecological gradients existed with latitude, and (3) resolve what change can be observed in ecology as the end-Triassic extinction approached.In order to satisfy objectives one and two, four sites from the Norian of Panthalassa have been chosen: Lime Peak, Yukon; Summit Point, Oregon; Mina, Nevada; and Sierra del Álamo, Mexico. Several Austrian localities, Norian and Rhaetian in age, will be investigated in order to

find one or two where objective three can be assessed; these include, but are not limited to, the Steinplatte, Adnet, and Hoher Göll. These buildups will be studied utilizing mapping, microfacies analysis, polished hand samples, and acetate peels. Preliminary investigation in Nevada and Oregon suggests unique reef paleoecologies. Oregon buildups display little coral or sponge framework, however they do exhibit well-preserved coralline algae and binding microbial fabrics. These likely grew in a high-energy environment where only small, knobby algae and encrusters could survive. Conversely, framework-building corals dominate Nevadan reefs, which likely grew in moderate-energy shallow waters, analogous to modern coral patch reefs.

25: 2:00 PM, Booth 19
Presenter: SCHRAMM, THOMAS J.

PRELIMINARY REFINEMENT OF THE STRATIGRAPHY AND FAUNAL TURNOVER IN THE GREEN POND-SKUNNEMUNK OUTLIERS, MIDDLE DEVONIAN OF SOUTHEASTERN NEW YORK AND NORTHEASTERN NEW JERSEY

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The Green Pond and Skunnemunk outliers of southeastern New York and northeastern New Jersey contain Siluro-Devonian sediments separated by approximately 40 kilometers and more from the main New York-New Jersey outcrop belt. The Green Pond and Skunnemunk outliers have previously been determined to be thrust into place by the Allegheny Orogeny, having been transported from farther to the east. The sediments preserved in the outliers represent some of the earliest near shore Hamilton facies; the oldest sediments of the Catskill delta. Hamilton-age units in the Green Pond and Skunnemunk outliers consist of the Cornwall Shale, Bellvale Sandstone, and Skunnemunk Conglomerate. Further investigation of these units is being conducted to determine patterns of sedimentation, aimed at interpreting sea level cyclicity in hopes of refining the correlation of strata originally deposited further to the east to that of the rest of the Hamilton Group to the west. In addition, examination of the paleoecology of the strata will take place as these units provide a rare glimpse at some of the most proximal biofacies of the lower Hamilton interval preserved in the Appalachian basin. Once a detailed stratigraphic framework is in place, it will then be possible to compare biofacies through time; of especial interest will be the comparison of lower and upper Hamilton near-shore and paralic biofacies.The Cornwall Shale is a dark-gray, fissle shale, lying above the Kanouse Sandstone that contains elements of the Onondaga Fauna. Taxa of the Hamilton Fauna occur within the upper portions of the Cornwall Shale; the fauna of the lower portion of the Cornwall Shale is poorly understood at this time due to limited exposure.

Specific attention will be paid to examining as many outcrops of the lower Cornwall Shale as this interval may contain the Kacak Bio-event.

25: 2:00 PM, Booth 20
Presenter: MORAN, LISA M.

COPROLITES AS ECOLOGICAL INDICATORS AT THE ARLINGTON ARCHOSAUR SITE, WOODBINE FORMATION (CENOMANIAN), NORTH CENTRAL TEXAS

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The Arlington Archosaur Site (AAS) is a North Texas fossil locality that preserves fossil elements of a Mid -Cretaceous ecosystem from a low lying coastal plain. The site lies within the Cenomanian (~95 mya) rocks of the Woodbine Formation of North Texas; Arlington, Tarrant County. The depositional environment is a Gyttja style channel fill; fine grained sediments, rich with organic material; wood and coal. Typically the Woodbine is known for remains of vertebrates in variable states of preservation. The vertebrate fossils recovered from the AAS to date include: ornithopod (*Protohadros*), theropod, crocodile (*Woodbinesuchus*), turtle, shark (*Cretodus*), dipnoan, pycnodont and lungfish. Other faunal components include; plant leaf imprints, wood and numerous coprolites. This project reports the occurrence of an abundance of coprolites found in the Woodbine Formation and uses them as ecological indicators. A collection of ~90 coprolites has been recovered from the Arlington Archosaur Site. The coprolites demonstrate variable morphologies suggestive of multiple taxa. Dinosaur feces are interpreted as being the largest. The morphologies of the specimens are cylindrical, spiral and ovoid. Spiral coprolites exhibit the preserved mucro intact. The cylindrical coprolites are interpreted as cololites, crocodilian intestinal tract material, based on size, morphology and content. The spiral specimens have pronounced external spirals with isopolar and amphipolar types present. The spiral coprolites are indicative of marine taxa. Spiral coprolites are typically associated with the shark *Hybodus*. Hybodont spines and *Cretodus* teeth are present in the studied section and thus interpreted as the sources. The large, ovoid coprolites are indicative of dinosaur. The specimens recovered to date are preserved intact, not flattened, or deformed and retain the original shape.

25: 2:00 PM, Booth 21
Presenter: CLAYTON, ANGELA A.

ANALYSIS OF AN EOCENE BONEBED CONTAINED WITHIN THE TALLAHATTA FORMATION, OF COVINGTON COUNTY, ALABAMA

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The Point "A" Dam and adjacent spillway located near River Falls, Alabama allows an extraordinary look at an Early to Middle Eocene bonebed contained within the Tallahatta Formation. The exposed formation is comprised of unconsolidated glauconitic sand with a claystone layer immediately below. This bonebed features a diverse assemblage of marine fauna consisting of Chondrichthyan and Osteichthyan teeth and remains, reptile and mammal remains, and unidentified bone material. The Tallahatta Formation overlies the Hatchetigbee Formation and is overlain by the Lisbon Formation above. The Tallahatta Formation is a loosely to non-consolidated glauconitic, fossiliferous, non-calcareous, muddy sand ranging in thickness between 20 and 40 meters thick. During the Early to Middle Eocene (55.8-40.4 Ma) a sharp rise in temperatures occurred which caused a relative rise in sea level. The Tallahatta Formation is the product of a transgressive systems tract, at a passive-margin shelf setting, caused by a thermal maximum and subsequent melting of glaciers. The oceans, during the Eocene, were host to a wide array of sea life, including the first appearance of marine mammals, the introduction of the Carcharinid sharks, and a large increase in sea snakes and reptile. By definition, a bonebed is the preservation of any vertebrate hard parts from two or more individuals that reside in close ecological proximity. The single sedimentary strata must have a more dense concentration of bone material than the surrounding strata both vertically and horizontally.This bonebed appears to produce an extensive assemblage of marine vertebrates including mammals, reptiles, boney fish, and Chondrichthyans. The concentration of each is a major focus of this research project. Additionally, the project seeks to use the collected data and samples to aid in interpreting the paleoecology and depositional environment of this region.

25: 2:00 PM, Booth 22
Presenter: DYNOWSKI, JANINA F.

AN ECHINOID DOMINATED EARLY JURASSIC BLACK SHALE

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Within the generally marly to carbonaceous Sinemurian (early Jurassic) strata of South West Germany, a thin series of bituminous black shales developed on a small local scale is known as "alpha black shale" or "*Cidaris* black shale", the name being derived from the mass occurrence

of a small regular echinoid. These shales bear a striking similarity to the renowned slightly younger Posidonia black shales but interestingly the Sinemurian shales are not dominated by bivalves but by small echinoids (*Eodiadema* sp.). These remarkable beds have been left mostly unconsidered since the first more detailed mention of their faunal assemblage by Quenstedt in the late 19th century. In a recent temporary road cut, the "*Cidaris* black shale" is excellently exposed and accessible for detailed study, and interestingly overlies a crinoid dominated limestone. We here present first results of our recent field work aiming at a high-resolution palaeontological and sedimentological assessment of the black shales. The formation of these bituminous black shales, the rare macrofossils other than echinoids (mainly marine reptiles, actinopterygians, crustaceans), their palaeoecological background and especially the nature of the highly unusual mass occurrence of regular echinoids are the focus of this study.

25: 2:00 PM, Booth 23
Presenter: ZUSCHIN, MARTIN

HYPOXIA AND ANOXIA IN A MODERN "PALEOZOIC" BENTHIC COMMUNITY FROM THE NORTHERN ADRIATIC SEA

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The northern and central Adriatic shelf serves as a rare modern equivalent to typical Paleozoic and Mesozoic epeiric seas. This shelf extends over more than 300 km, with an average water depth of only few tens of meters. This shallow sea features seasonally high productivity and a stable thermocline, with destratification mostly due to storms. These characteristics, intensified by ongoing anthropogenic euthrophication, result in frequent bottom water oxygen deficiencies and mass mortalities of benthic organisms, which have also been suggested as typical features of ancient epeiric seas. The benthic fauna here is characterized by Paleozoic-style, high-biomass epifaunal sedentary suspension feeders (including sponges, ascidians and anemones). This peculiar epifauna is developed on densely burrowed muddy soft bottoms, where it colonizes shell grounds to form bioherms, which are a habitat to numerous other invertebrates (ophiurids, echinoids, crabs, molluscs). This unique setting is affected by oxygen-deficiencies, serving as a case study for behavioural modifications and mortalities of the benthic fauna during hypoxia and anoxia. We deployed a specially developed underwater chamber - equipped with time-lapse camera, flashes and a sensor array - to artificially induce and analyze such ecosystem collapses in situ. The underwater photo documentation, combined with oxygen- and hydrogen sulphide data, yields a catalogue of behavioural responses and mortality sequences of epifauna and infauna. For example,

many organisms try to reach higher levels in the water column as oxygen values drop. The various taxa show different susceptibilities to oxygen deficiency. Regular and irregular echinoids, ophiurids and small crustaceans are very sensitive, whereas gastropods and anemones are more tolerant. We determine the specific thresholds and conclude that the development of this peculiar epifauna is related to seasonal high productivity and that elevation above the sediment-water interface helps to survive the related risk of hypoxia.

25: 2:00 PM, Booth 24
Presenter: SHOUP, BEN

SEDIMENTOLOGY AND TAPHONOMY OF A SHELL BED ASSEMBLAGE FORM THE UPPER CRETACEOUS HELL CREEK FORMATION OF EASTERN MONTANA

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Aggregate shell bed accumulations within coastal marine sediments are numerous and have been thoroughly studied. In contrast, terrestrial shell bed assemblages have received less attention due to their paucity within the existing strata. Such terrestrial shell bed assemblages provide a wealth of data concerning paleoenvironments, paleobiologic populations, and diagenetic processes. A channelized shell bed discovered in the Upper Cretaceous Hell Creek Formation contains thousands of exceptionally well-preserved specimens representing eight genera with twenty recognized species. This shell bed provides valuable insight into paleoecologic and sedimentologic systems of the Hell Creek Formation. Field data was collected during the summers of 199 and 200. Geologic data was collected for regions laterally and vertically contiguous with the shell bed. Seventeen separate lithofacies were identified in the study area on the basis of grain size and sedimentary structures. Lithofacies associations were subsequently determined for the characterization of depositional environments. Architectural element analysis was employed to aid in the recognition of discrete depositional facies. Taphonomic data was collected within the shell bed with a primary focus on the molluskan fauna present. Data collection included taxonomic identification, shell articulation and modification, and shell orientation. Three distinct depositional systems were recognized within the study area including a fluvially dominated channel belt with tidal influence, a lacustrine system with subsequent clastic infilling, and an anoxic low-energy swamp environment with limited lcastic input. The shell bed assemblage is preserved in the lacustrine system and represents an event concentration with minimal time-averaging.

25: 2:00 PM, Booth 25
Presenter: DELINE, BRADLEY L.

MARINE BRINE SEEP YIELDS A NEW TYPE OF SOFT-TISSUE PRESERVATION

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A sea urchin placed on the sea floor near an active brine seep was recovered after 13 years with a heretofore undescribed type of preservation. Growth of an amorphous solid with small amounts of the mineral bassinite occurred on the spines and test. The solid also exhibits striations at both the macro- and microscopic scales that preserve the muscle texture of the sea urchin. Such soft-tissue replacement and mineralization could lead to exquisite fossilization. Soft tissue mineralization has been previously replicated in controlled laboratory conditions (Briggs D, Kear A (1993) Fossilization of soft tissue in the laboratory. Science 259: 1439-1442.), however, this is the first report of the fossilization of soft tissues in an open marine experiment. Soft tissue preservation is exceedingly rare in echinoderms and this instance represents the first report of soft tissue preservation within echinoids. Examples of extraordinary fossil preservation, or Lagersätten, give a distinct snapshot of the past and have led to a greater understanding of the history of life. Soft-tissue lithification and preservation of articulated skeletons are generally assumed to occur in special circumstances of low oxygen, cold water, and rapid burial of recently dead organisms. Our results indicate that soft tissue preservation may not necessitate immediate burial given that this urchin was at or very near the sediment-water interface for thirteen years.

25: 2:00 PM, Booth 26
Presenter: BRETT, CARLTON E.

TAPHONOMY OF RHYTHMIC TRILOBITE BEDS IN THE LOWER DEVONIAN OF MOROCCO: THE PARADOX OF “CYCLIC EVENT BEDS”

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The mid-Emsian Hollardops Member of the Khebchia Formation is a 5-15 meter thick interval of rhythmically bedded limestones and shales in the Dra Valley of southwestern Morocco. These beds contain a rich and well preserved trilobite fauna, including the nominal dalmanitid trilobite *Hollardops mesocristata*. This interval contains approximately 160 cycles; an idealized

cycle is 20 to 50 cm thick and comprised of: A) thin skeletal lags; B) medium dark gray to black shales; C) calcareous medium gray mudstone; D) lenticular to tabular concretionary argillaceous limestones and light gray calcareous, fossiliferous marls. Limestones yield articulated trilobites, including complete outstretched, gently reflexed, incompletely and completely enrolled specimens, as well as abundant molt ensembles, indicating a near absence of transport. Articulated trilobites commonly occur in attitudes perpendicular to bedding, and single blocks show varied orientations including bed-parallel, inverted, upright, and vertical. This suggests that the trilobites were physically reoriented within viscous uniform muds, perhaps as single-event mudflows that moved carcasses and other skeletal parts very slightly from their living sites, in some cases lifting the bodies or skeletal parts upward within the sediments. Enclosing sediments are strongly bioturbated indicating prolonged periods of non-deposition following rapid emplacement and prior to early diagenetic cementation. Concretionary limestones also transcend facies, occurring in both sparsely fossiliferous, dysoxic facies near the base of the Hollardops member and more abundantly fossiliferous sections near the top, and hence, record a regular, recurring cycle superimposed upon an overall shallowing trend. Time series analysis of magnetic susceptibility data suggests that these cycles record overall durations of 10s of Kyr (possibly precessional) with concretionary limestone bands probably forming by carbonate redistribution over several millennia. Non-random representation of obrutionary muds in the cemented beds apparently reflect the input of thick mudflows in the regressive portions of short-term cycles, followed by periods of sediment starvation.

25: 2:00 PM, Booth 27
Presenter: GAHN, CHRISTOPHER T.

EXPERIMENTAL TAPHONOMY OF COILED CEPHALOPODS

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Cephalopods represent a diverse and biostratigraphically important group in the fossil record and yet little is known about the taphonomy of this long-ranging class of mollusks. The shells of fossil and extant cephalopods are basically constructed of conical or coiled hollow tubes with a number of partitions called septae, each of which is pierced by a small hole. During the life of the animal, a fleshy tube called the siphuncle extends through the chambers via the small hole in each septum and controls fluid exchange between the chambers of the shell allowing the animal to control its buoyancy within the water column. Fossil cephalopods are often found with the chambers completely filled in with fine-grained sediment and this presents somewhat of an enigma. Somehow sediment must be transferred between the chambers through the siphuncular opening in each septum, but the question remains as to how to fill all the chambers quickly enough with such a small hole to transmit the sediment.

Previous workers have suggested that some shells are pierced near the end of the shell and any currents flowing over the shells as they lie on the sea floor would produce a negative pressure within the shell causing water and sediment to draft into the shell like smoke being pulled through a chimney. Few other hypotheses have yet been put forward to explain the taphonomy of these ubiquitous fossils. The purpose of this study is to better understand exactly how the cephalopods are preserved, specifically how did the chambers fill so completely with mud if they were not exposed for long periods of time on the sea floor. The project involved further examination of fossil specimens from the Devonian of Morocco, as well as various taphonomic experiments involving modern cephalopod shells as analogues for the fossils.

25: 2:00 PM, Booth 28
Presenter: HOUSE, AARON M.

TESTING THE EFFECTS OF REWORKING ON MOLLUSCAN PRESERVATION USING THE STORM BEDS OF THE KANOSH FORMATION (MIDDLE ORDOVICIAN, UTAH)

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The fossil record, even among skelotinized biotas, is biased toward those organisms whose remains are best preserved. Aragonitic shells are far less stable than calcitic ones, especially during intervals of “Calcite Oceans”. It is been postulated that aragonite may be preserved in storm beds where buffered from dissolution. However, prolonged storm reworking should act to destroy fragile shells and molds. In considering the preservation of mollusks in the Kanosh Shale of West-Central Utah (Middle Ordovician), for instance, we can determine the effect that storm reworking has on the preservation of its diverse fauna. Approximately 150 beds of this formation were examined in situ at Fossil Mountain, Utah during the summers of 2007 and 2008. Sedimentologic and taphonomic data collected in the field and from hand samples were retained for taphonomic analysis permit the determination of which beds have been heavily reworked as well as those beds that have undergone reworking through a single event. Molluscan preservational/distributional data have been roughly correlated to this information to determine what, if any, pattern is present. Preliminary data suggest that mollusks were better preserved in beds that have experienced a single storm event which would have buffered their aragonite shells by surrounding them with an abundance of carbonate and then restricting them from the overlying geochemistry of Ordovician calcite seas as the storm receded. Conversely, complex, amalgamated storm beds contain only the most resistant remains, such as cephalopod endocones. Further study is necessary and will be taken up in the Cincinnatian (Late Ordovician) during the summer of 2009. Current investigations will be extended to determine the extent of the observed relationship. Ultimately, this will provide a clearer understanding of the importance of storm processing on the preservation of aragonitic

shells, some of the most abundant skeletonized organisms, which might otherwise be taphonomically filtered.

25: 2:00 PM, Booth 29
Presenter: MILLER, DANIEL J.

EXPERIMENTAL MEASUREMENT OF PYRITE OXIDATION UNDER SIMULATED MUSEUM STORAGE: IMPLICATIONS FOR FOSSIL SPECIMEN CONSERVATION.

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Many natural history museums house fossils containing the mineral pyrite (FeS_2). Often the environmental conditions suitable for fossilization were also ideal for pyritization and/or the formation of sedimentary pyrite. However, pyrite is susceptible to oxidation in the presence of oxygen and water, and the reaction produces harmful acids, secondary minerals, and physical stresses that can permanently damage specimens, labels, and storage trays. Consequently, specimen conservation should be a primary focus of paleontology museums. In this study, we designed and fabricated a highly sensitive Barcroft differential manometer to measure pyrite oxidation rates under a variety of simulated museum storage environments. To ensure data reproducibility, sample preparation and experimental conditions were carefully controlled, including maintaining a constant temperature of 25°C± 1°C and crushing euhedral crystals of pyrite into a fine powder with an average feret diameter of 3.9 µm ± 0.4 µm (within the range reported for disseminated sedimentary pyrite). Replicate trials show high sensitivity and reproducibility and we can consistently measure oxygen consumption as little as 10-6 moles. Pyrite oxidation rates are highly dependent upon relative humidity (RH), with rates at RH 100% approximately one hundred times greater than at RH 10%. Current best practices for storing pyritic fossils include storage under relatively low RH (<40%) and the use of barrier-film microenvironments combined with desiccants and oxygen scavengers. Our experiments demonstrate that the addition of desiccants significantly decreases oxidation rates, supporting their use in specimen conservation. Indeed, oxidation rates were slowed sufficiently with desiccant alone that the use of costly and non-renewable oxygen scavenger in barrier-film microenvironments may be unwarranted in most cases. However, our results also indicate that fresh, fine-grained pyrite experiences significant oxidation at RH values that are widely considered to be safe for long-term storage (20-40%), suggesting that the use of barrier-film microenvironments in museums should be expanded.

25: 2:00 PM, Booth 30

Presenter: GARDNER, ELEANOR E.

LINKING MACRO- AND MICRO-LEVEL TAPHONOMIC ALTERATION IN AVIAN BONES AS A FUNCTION OF AGE, SEX, AND ENVIRONMENT

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Studies of modern bird bone taphonomy are crucial for developing precise interpretations of the bird fossil record. Relatively few such investigations have been conducted for the avian fossil record, compared to those for the mammal and reptile records. Past avian taphonomic studies focused on macro-level aspects, like decay, disarticulation, and weathering of carcasses and bones. For this study, classical external weathering (i.e., weight change) is considered a macro-level alteration; changes in bone density, porosity, and diagenesis are considered micro-level alterations. Linking micro- and macro-levels in avian taphonomy may be key to understanding how bones of particular microstructure degrade in certain environments. This project, a yearlong experiment investigating effects of age and sex on bird bone preservation in different environments, correlates diagenetic changes within bones with external weathering patterns. Eighty bones (femora and tibiotarsi) from chickens (*Gallus gallus*), grouped by age and sex, were deployed in two siliciclastic field locations in three habitats: terrestrial, freshwater pond, and saltwater marsh. Six-month data indicate that juvenile bones lost between 50 to 75% of initial deployment weight and density, whereas adult bones lost less than 50% of initial weight and density. Bones in saltwater marshes experienced greater taphonomic loss (between 40 to 80% weight and density loss) than those in freshwater ponds (losses between 30 to 65%). No discernible sex-linked taphonomic differences were found over this period.Within six months, rapid taphonomic loss of bone material occurred in younger compared to older birds, indicating a bias toward adult birds in the fossil record. Rapid loss also occurred in bones exposed to saltwater compared to freshwater habitats, illustrating that depositional environments directly affect the preservation potential of bird bones. There was no perceptible difference between male and female bone preservation, possibly suggesting no bias in avian sex type in the fossil record.

25: 2:00 PM, Booth 31
Presenter: TARHAN, LIDYA G.

TAPHONOMY AND CLASSIFICATION OF LATE CAMBRIAN MEDUSAE OF CENTRAL WISCONSIN AND NORTHEASTERN NEW YORK: PROBLEMS OF PRESERVATION

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In Wisconsin and New York tens of thousands of medusae occur in Late Cambrian (Paibian) medium-grained orthoquartzites of the Elk Mound and Potsdam Groups. Medusae occur in intertidal and sand flat facies containing abundant microbial sedimentary structures. Over 90% of medusa-bearing bed surfaces contain individuals closely associated with sedimentary structures indicating extremely shallow marine to emergent conditions. One medusa-bearing surface exhibits direct evidence of subaerial exposure and remaining medusa-bearing surfaces are intercalated between beds bearing polygonal mudcracks, raindrop imprints and adhesion structures. This suggests that stranding events may be responsible for medusa deposition. Concave bell pulsation rings are present in many individuals, suggesting that both living and dead individuals were transported or swam into shallower settings and were stranded onshore. A small proportion (<10%; N = 2436) of medusae occur as full-relief agglomeritic clusters within beds lacking surficially-produced sedimentary structures; this suggests possible entrainment and burial of medusae by sediment-laden fluids. Burial veneers commonly lack sedimentary structures, suggesting the presence of a binding agent preventing reworking of the underlying material. Pustular and stromatolitic textures are associated with at least seven out of 19 medusa horizons; microbial biofilms or mats may have mediated preservation of the medusae.Absence of a chitinous float suggests that medusae were not chondrophores; the presence of oral arms suggests scyphozoan, rather than hydrozoan morphology. At least two distinct species of scyphomedusae are recognized. One taxon, of probable semaeostomean affinity, is characterized by large diameter (commonly ~20-45 cm), high relief, tri- or quadriradial gastrovascular structures, trailing tentacular and strand-like oral arms interspersed with ovoid to spherical swellings, and escape rings (>35%; N = 2261). The second taxon, of probable rhizostomean affinity, is smaller (~7 cm diameter), has high relief, circular bell morphology, packeted or bead-like oral arms, and lower frequency of escape rings (~5-10%; N = 175).

25: 2:00 PM, Booth 32
Presenter: DAHL, ROBYN M.

TAPHONOMIC SIGNATURE OF MOLLUSK SHELLS FROM HYDROCARBON SEEP ASSEMBLAGES

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Hydrocarbon seeps occur commonly on modern marine offshore shelf environments and support high-density faunal assemblages when compared to the surrounding seafloor. These assemblages are typically dominated by lucinid clams, bathymodiolid mussels or

pogonophoran tubeworms with other clams, mussels and gastropods occurring with less frequency. Seeps as ancient as the Paleozoic have been recognized in the fossil record but such ecosystems may be more common than previously thought. The recognition of ancient seep assemblages is improving, but understanding the history of formation and duration of seepage requires a better understanding of seep death assemblages. This study compares the taphonomic signature of experimentally-deployed mollusk shells at hydrocarbon seeps and in non-seep environments to naturally-occurring seep mollusk shells. The study was conducted in the Gulf of Mexico and experimental shells were deployed for 12-15 years. Taphonomic criteria used in the comparison include dissolution, biont cover, pyrite staining/crusts, presence of grayed areas of the shell carbonate and presence of borings and etchings on the shells. Results show that the signature of seep mollusks is different from non-seep mollusks. The signature obtained by the naturally occurring shells was similar but more pronounced than that of the experimental shells deployed at seep sites, suggesting that the seep signature is slow to fully develop. Our results indicate that shells from hydrocarbon seep assemblages can be recognized based on the following criteria: moderate dissolution of shell carbonate, presence of pyrite crusts and stains, sparse accumulation of sclerobionts and gray shell staining.

25: 2:00 PMBooth 33
Presenter: STIDHAM, THOMAS

AVIAN TAPHONOMY AND ISOTAPHONOMY IN THE PLIO-PLEISTOCENE HOMININ-BEARING CAVE DEPOSITS OF THE BLOUBANK RIVER VALLEY, SOUTH AFRICA: IMPLICATIONS FOR PALEOENVIRONMENTAL RECONSTRUCTION

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Bird remains are relatively rare among the cave deposits in the Bloubank (Sterkfontein) Valley, but given the extensive sampling at those sites, large collections of avian bones exist. However, very little work has been done on the avifauna. I have examined a preliminary dataset of over 7,000 avian specimens from most of the cave deposits, including Kromdraai A and B, Plovers Lake, Sterkfontein, Swartkrans, Drimolen, Gladysvale, Coopers D, and others. Statistical analysis (in addition to qualitative similarities) of those specimens appears to support that most, if not all of the avian remains so far examined are isotaphonomic with respect to skeletal element representation and other factors. The hypothesis that owls were the major accumulator of avian bones is supported by the overall small size of the majority of avian remains (dominated by passerines) and the near absence of bone surface modifications (gastric etching and bite and cut marks). Other accumulation mechanisms appear to have aided to a lesser degree. The presence of isotaphonomic avian bone accumulations through the stratigraphy at sites and among sites within the valley is significant. Analysis of the changes in avifaunal taxonomic composition through time and among sites should be

reflective of past changes in the bird faunas (rather than a taphonomic overprint). Today, bird bone assemblages are good indicators of habitat, and fossil avian assemblages have been used elsewhere to reconstruct the paleoenvironment. Therefore, the presence of a large number of forest and woodland habitat avian taxa (lovebirds, parrots, and barbets) in some cave deposits in the valley has a great importance for the development of a landscape view of paleohabitats. The local extinction of those birds likely is indicative of a decrease in the amount of tree cover (and increase in grasslands) in the valley through the Pleistocene.

25: 2:00 PM, Booth 34
Presenter: WAHL, WILLIAM R.

NOVEL PRESERVATION OF SKIN IMPRESSIONS IN A STEGOSAUR FROM THE LOWER MORRISON FORMATION, CARBON COUNTY, WYOMING.

WAHL, WILLIAM R., Research, BigHorn Basin Foundation, 110 Carter Ranch Road, Thermopolis, WY, 82443, United States, wwahl2@aol.com

In the course of preparation of partially articulated stegosaur skeleton large sections of skin impression were revealed preserved in sandstone both near the skeleton and between bones. As the skin impression occurred between the scapula and the largest observed plate it may record the taphonomy of an osteoderm. The plate has appeared to have collapsed laterally against the body suggesting interesting implications for integument contact and plate support. There is a noticeable differentiation of skin structure and shape occurring very close together as well. The skin is flat in topology with little or no wrinkles, though contact with bone may have retained bulges associated with the partially articulated ribs.The preservation is clear enough that pitting is observed within the center of the skin “scale” retaining individual hexagonal shape. The orientation of the more acute angle on the skin over the ribs is parallel to those ribs in contact with the vertebrae which suggests in situe orientation may have occurred along with skeletal articulation. Arthropod damage in the form of bone boring is present on the ends of the ribs but appears not to have occurred on the skin.

25: 2:00 PM, Booth 35
Presenter: BALMAKI, BEHNAZ

PALAEOBATHYMETRY AT CENTRAL ALBORZ, IRAN USING FORAMINIFERA

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In this research the Late Cretaceous sediments at Ziarat-kola section, Central Alborz were studied in order to investigate palaeobathymetry and sea level change. These sediments with about 200m thickness consist of monotonous Marl and limy marl. Based on Planktonic foraminifera, Maastrichtian stage is indicated (*Abathomphalus mayaroensis*). There are three common methods that consist of analyzing the morphotypes of Planktonic foraminifera, Planktonic to benthic ratio, and determinging genus species of benthic foraminifera, in order to study the paleobathymetry and sea level change. With morphotype analysis it was indicated that a morphotype indicating a deeper index increases at the initial part and another morphotype indicating a shallow index increased at middle section. In this manner, depth change was examinated used to two genera, *Globotruncana* (deep dweller) and *Pseudoguembelina* (Mixed layer dweller). In orther to assign palaeodepth at this area, we compared the number of Planktonic foraminifera to total foraminifera minus infaunal Benthic foraminifera with the regression equation [Depth = e (3. 58718 + (0. 03534 x %*p)]. Examination of genera and the Benthic foraminifera species depth index were indicating that these sediments were in upper bathyal and middle bathyal. Thus, results indicate that beginning and end are deeper than the middle section.

25: 2:00 PM, Booth 36
Presenter: BALMAKI, BEHNAZ

STUDYING PALEOECOLOGY OF THE CALCAREOUS MEMBER OF SEIMARE IN ORDER TO RECOGNIZE ECHINOIDS OF WESTERN IRAN

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12 echinoids species, are described from the Maastrichtian Gorpi Formation exposed in the west of Iran. Studying the paleontology indicated Campanian-Maastrichtian age at this section that rests over Ilam Formation to disconformity. The calcareous member at Seimare consists of Brown limestone. This member includes bivalve fossils, as well as Brachiopoda and Echinoids. This part was found just in Lorestan and approximately is accounted as a special stratigraphy in that vicinity. Approximately equal numbers of regular and irregular echinoid species are known; about 80% of the total echinoids collection is surrounded by 12 species.The following new species are erected: *Iraniaster morgani*, *Globator bleicheri*, *Coniopygus superbus*, *Cidaris persica*, *Hemiaster noemae*, *Orthopsis miliaris*, *Salenia nutrix*,

Hemipneustes compressus, *Coptodiscus noemia*, *Pygurostoma morgani*, *Conulus douvillei*, *Coenholectypus infiatus*.

25: 2:00 PM, Booth 37
Presenter: ROSTAMI, MASOUD ASGHARIAN

USING BENTHIC FORAMINIFERA MORPHOTYPE AND *UVIGERINA* GENUS TO DETERMINE ORGANIC MATTER, ZIARAT-KOLA SECTION, CENTRAL ALBORZ,IRAN

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The section studied is located in south of Ziyarat-kola village, south of Behshahr, Central Alborz Mountains. The section consists of 9m. thickness of monotonous marl and thick limestone. Based on planktonic foraminifera, the age of the section is Early Paleocene (Danian age). At this section in order to determine the amount of organic matter, we used benthic foraminifera, in particular the ratio of epifauna to infauna morphotypes ; epifauna showing well oxygenated conditions and and decreased organic matter, while more infauna indicates low oxygen and high organic carbon condition. By these factors, we determined five zones: high organic carbon was shown at first and fourth zones with increased infauna morphotype and abundance of *Uvigerina* genus. At zone three epifauna and infauna percent and *Uvigerina* presence is approximately equal that to reflecting intermediate organic carbon condition. Increased epifauna and decreased *Uvigerina* demonstrate decrese organic matter condition at zone five.

Session No. 26, 8:00 AM; Friday 26 June 2009
Topical Session T7. Paleocommunities and regional dynamics

26: 8:00 AM-8:15 AM
Presenter: NG, TIN-WAI

BIOFACIES AND ALPHA DIVERSITY OF LATE MARJUMAN (UPPER CAMBRIAN) TRILOBITES FROM THE EASTERN GREAT BASIN

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In order to investigate the distribution of trilobites in both space and time within the eastern Great Basin area, biofacies patterns and alpha diversity through time were investigated. For biofacies patterns, the computer program PC-ORD 5.0 was used and Q- and R-mode two-way cluster analysis was performed. A total of 61 collections and 31 taxa were included in the analysis. Twenty collections were newly obtained in this study and the other data were compiled by Westrop and Cuggy (1999). Only collections with 50 or more individuals were included and taxic data are at genus level and above. The collections were assigned to five different depositional environments.Six clusters can be recognized and each of them can be interpreted as a biofacies. The six biofacies are: 1. *Blountia-Crepicephalus* biofacies; 2. *Glaphyraspis* biofacies; 3. *Kingstonia-Agnostoid* biofacies; 4. *Tricrepicephalus-Llanoaspis* biofacies; 5. *Uncaspis* biofacies; and 6. *Lonchocephalus* biofacies. Subgroups may also be recognized with some of the bigger clusters. To further investigate this pattern, both non-metric multi-dimensional scaling (NMS) and detrended correspondence analysis (DCA) were carried out. Axis 1 in each analysis can be interpreted as gradients of water depth and/or silicate content. Rarefaction was used to examine the data through time and three different sections from the eastern Great Basin were compared. Changes in alpha diversity conform to stratigraphic correlation and could be explained by local sea-level changes with several high siliciclastic influxes.

26: 8:15 AM-8:30 AM
Presenter: QVILLER, LARS

COMMUNITY RESPONSES TO SEA LEVEL FLUCTUATIONS IN AN ORDOVICIAN SEDIMENTARY FORMATION AT LANGESUND, NORWAY

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Sea level changes can drastically modify the compositions of local benthic communities. Temporal changes in sea levels in the geologic past have been investigated using both paleoecological data and lithological information. Typically, benthic paleoecological data have been used to infer discrete changes in Paleozoic sea level, rather than as a continuous process. Here, I use new paleoecological and paleocurrent data from an upper Ordovician (upper Sandbian) benthic Paleozoic macrofauna in the Oslo Graben area to investigate local changes in sea level. Previous lithologic studies suggested a simple transition from a drowning to a lowstand event. My analyses, using paleocommunity data, show continuous changes in species composition that reflect sea level changes transcending beyond a simple two-step event. In particular, primary producer species such as *Coelosphaeridium* sp and *Mastopora* sp clearly decreased in abundance along a species turnover gradient. Paleocurrent analyses based on both biological and lithological features confirm finer scale changes in sea level revealed by paleocommunity analyses. In summary, analyses of community structure can

provide valuable information regarding paleoenvironmental conditions, supplying inferences beyond a conventional lithological approach.

26: 8:30 AM-8:45 AM
Presenter: WITTMER, JACALYN M.

SPATIAL AND TEMPORAL PATCHINESS OF TENTACULITOID-RICH FOSSIL ASSEMBLAGES IN THE TYPE CINCINNATIAN

WITTMER, JACALYN M., Dept. of Geology, University of Cincinnati, 500 Geo/Phys Building, Cincinnati, OH, 45221, United States, wittmejn@email.uc.edu; MILLER, ARNOLD I., Dept. of Geology, University of Cincinnati, 500 Geo/Phys Building, Cincinnati, OH, USA, 4522

Tentaculitoids have long been regarded as problematic taxa, despite an extensive global reach during their early Paleozoic zenith. To complement an ongoing dissection of the global paleogeographic and paleoenvironmental distributions of tentaculitoids, we conducted a regional, quantitative analysis of tentaculitoid-rich fossil assemblages in the C5 sequence (Waynesville Formation) of the type Cincinnatian. Prior to this work, tentaculitoids had been viewed simply as uncommon, problematic components scattered throughout regional strata. Multivariate analyses of 166 bed-level samples, collected from a series of stratigraphic sections placed 10-40 m apart at three localities, reveal a set of temporal and spatial variations related to environmental and community transitions. Tentaculitoid-rich assemblages tended to favor carbonate-rich, deep subtidal environments and many tentaculitoids were observed to be vertically oriented in sampled beds. The stratigraphic distribution and abundance of tentaculitoids tended to co-vary with ramose and mound-forming bryozoans. Within-locality lateral variation between stratigraphic sections suggests that tentaculitoid richness was somewhat patchy, although beds that were particularly rich in tentaculitoids tended to maintain this richness across outcrop faces. There were notable stratigraphic transitions in tentaculitoid abundance at the outcrop scale, suggesting meaningful shifts in abundance through time and along a paleoenvironmental gradient. Results suggest that spatial variation of tentaculitoids between beds indicates a true biotic signal of a benthic mode of life because of a patchy distribution, vertical orientation in beds, and a strong association with particular bryozoan growth forms, suggesting a possible ecological relationship.

26: 8:45 AM-9:00 AM
Presenter: DUDEI, NICOLE

ASSESSING BIOGEOGRAPHIC RESPONSE OF BRACHIOPOD SPECIES DURING THE RICHMONDIAN (LATE ORDOVICIAN) INVASION IN THE CINCINNATI ARCH USING ECOLOGICAL NICHE MODELING

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Within the Cincinnati, Ohio region, the beginning stage of a large-scale biotic invasion is recorded in the C4 depositional sequence (Late Ordovician, Richmondian Stage), which includes the Arnheim Formation and its correlates. The fauna and strata of this region are well studied and the ecological changes present in these strata provide a unique opportunity to study biogeographic changes associated with the onset of a biotic invasion. GIS-based ecological niche modeling (ENM) was used to examine the biogeographic and paleoecological impact of both the regression and the biotic invasion. GARP (Genetic Algorithm for Rule Set Production), an ENM program, was used to model species' fundamental niches from environmental data as estimated from sedimentological variables associated with known species occurrence data. Once environmental parameters of the niche are modeled, the resulting rule set is used to project the geographic boundaries of potential habitat and estimate the spatial extent occupied by each species. Ranges of eight brachiopod species were modeled for three temporal intervals within the C4 sequence. Modeled ranges provide the basis for quantitatively assessing the shifting roles of native and invasive species throughout the C4 sequence. Several overarching trends occur within the fauna. (1) Generalists tend to track their habitats closely from the first into the second time interval and do maintain or expand the size of their geographic range during this transition. (2) Ecological specialists exhibit decreasing geographic range size through the sequence and are more likely to shift geographic areas inhabited within the study area. (3) A large range shift was observed by all species late in the sequence, representing the stabilization of community structure following the biotic invasion and concomitant community reorganization. Understanding and quantifying biogeographic patterns during ancient invasions, such as this one, may provide insight into long term impacts of a modern invasive species.

26: 9:00 AM-9:15 AM
Presenter: WALLS, BRADLEY J.

UTILIZATION OF ECOLOGICAL NICHE MODELING METHODS TO ASSESS QUANTITATIVE PALEOBIOGEOGRAPHIC PATTERNS OF MAYSVILLIAN (LATE ORDOVICIAN) BRACHIOPOD SPECIES OF THE CINCINNATI ARCH

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This project utilizes ecological niche modeling (ENM) a GIS-based method for range reconstruction, to predict the geographic distribution of eight articulate brachiopod species of the Corryville and Mt. Auburn Formations of the C3 (Late Ordovician, latest Maysvillian) depositional sequence near Cincinnati, Ohio. The intensive sampling, excellent preservation, and numerous prior paleoecological and sedimentological analyses within this region form an excellent framework for detailed paleobiogeographic study. Previous studies of Cincinnatian strata have addressed biodiversity patterns, paleoecology, and sequence stratigraphy; however, none have addressed the shifting paleobiogeographic patterns as a result of a regression within a depositional sequence. ENM predicts the geographic extent of a species range using environmental data inferred from sedimentological proxies coupled with known species occurrence data. The combined environmental and occurrence data are used to develop an idealized ecological niche for each species; the species is then predicted to occur wherever that set of environmental conditions occurs within the study region. Distributional patterns were reconstructed for three time slices during the C3 sequence. Recovered range predictions were quantitatively analyzed to identify temporal range changes. Results indicate that all brachiopod species analyzed were affected by the change in relative sea level; some track their habitat while others evolve into new niches through time. Average geographic range of species in early time slice is statistically larger than ranges of the middle and late time slices. Brachiopod species dramatically shifted their ranges in response to the rapid rise in relative sea level that occurs at the beginning of the C3 sequence. Once relative sea level stabilized in the later time slices, niches also stabilized. Understanding these patterns may be useful for predicting affects of climate change on modern species since the most dramatic shifts in the Late Ordovician species occurred in response to the rapid phase of sea level rise.

26: 9:15 AM-9:30 AM
Presenter: HOLLAND, STEVEN M.

TESTING THE IMPORTANCE OF INCUMBENCY: THE CONSERVATION OF ECOLOGICAL RESPONSE CURVES ALONG AN ONSHORE-OFFSHORE GRADIENT

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Two recent studies have challenged the concept of incumbency in the fossil record by showing that species rise slowly to peak occupancy or geographic extent and then slowly decline until their extinction (Foote et al., 2007 for Cenozoic mollusks; Liow and Stenseth, 2007 for Cenozoic planktonic microfossils). In terms of gradient ecology, this apparent pattern could reflect true changes in a species' peak probability of collection (PA), environmental tolerance (ET), or preferred environment (PE), any of which would indicate a weaker role for incumbency. This apparent pattern could also arise as a sampling artifact, in

which different positions along an environmental gradient are sampled through time, a situation likely to arise in regional studies as a result of basin evolution. These scenarios were tested with benthic macroinvertebrates from six depositional sequences in the Upper Ordovician of the Cincinnati Arch. Values of PA, ET, and PE along an onshore-offshore gradient were fit to each sampled genus in each sequence, with separate estimates obtained by weighted averaging and logistic regression. Both methods indicate that PA is generally conserved, being highly correlated among not just successive sequences, but throughout the study interval. PE shows weaker positive correlations, with weighted averaging indicating stronger correlations among abundant taxa. Logistic regression indicates weak correlation of ET, although weighted averaging shows no correlation, likely owing to greater uncertainties in its estimates. Our results show positive, yet generally weak correlations, indicating that species are neither locked into a rigid form of incumbency nor are they following a fixed pattern of rise and fall in their ecological attributes. These results might suggest an environmental sampling bias in Foote et al. (2007), but they may also indicate real differences in the role of incumbency through time or among higher-level taxa.

26: 9:30 AM-9:45 AM
Presenter: IVANY, LINDA C.

RELATIVE TAXONOMIC AND ECOLOGIC STABILITY IN DEVONIAN MARINE FAUNAS OF NEW YORK STATE: A TEST OF COORDINATED STASIS

IVANY, LINDA C., Dept. of Earth Sciences, Syracuse University, Syracuse, NY, 13244, United States, lcivany@syr.edu; BRETT, CARLTON E, Department of Geology, University of Cincinnati, Cincinnati OH 45221; WALL, HEATHER AND PATRICK, Earth Sciences, Syracuse University, Syracuse NY 13244; HANDLEY, JOHN C., Xerox Corporation, Webster NY 14580

The concept of coordinated stasis, manifest as a pattern of long intervals of concurrent taxonomic and ecologic persistence separated by comparatively abrupt periods of biotic change, has been challenged in several recent studies that claim a lack of prolonged persistence of taxa and associations. A key problem has been the difficulty of distinguishing faunal change owing to localized, short-term environmental fluctuation or patchiness from that indicating regionally pervasive, long-term evolutionary or ecological change. We use an extensive database from the Middle Devonian Hamilton Group of the Appalachian Basin to test for taxonomic and ecologic persistence within this succession of purported relative stability. Replicate samples collected from many localities and stratigraphic horizons over a wide geographic area allow us to address the effects of small-scale environmental variation and localized faunal patchiness while exploring basin-scale variation in faunal composition within and between the formations of the Hamilton Group. Observed stratigraphic distributions of fossils is consistent with all taxa persisting from bottom to top of the unit, with absences resulting only from sampling failure. While small-scale variation in faunal composition indeed does occur, there is no more variation among formations than occurs

within them. Assemblages from different formations, whether defined by taxonomic or ecologic composition, are statistically indistinguishable based on several independent metrics, including ANOSIM and a maximum likelihood estimation. Tests on simulated datasets indicate that results are most consistent with species-level extinction of 2.6% per my within the Hamilton Group, far lower than the global Givetian rate. Such faunal persistence over the ~5.5 million years encompassed by this unit is consistent with the pattern of coordinated stasis. Earlier studies showing greater amounts of temporal turnover in Hamilton Group faunas are likely influenced by their smaller geographic scale of analysis, suggesting that regional studies done elsewhere may yield similar results.

26: 9:45 AM-10:00 AM
Presenter: HANDLEY, JOHN C.

ASSESSING COORDINATED STASIS WITH INFORMATION THEORETIC MODEL RANKING: AN ILLUSTRATION FROM THE MIDDLE DEVONIAN HAMILTON GROUP OF NEW YORK

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The pattern of “coordinated stasis” suggests that faunas persist in their preferred environments for intervals of up to several million years with relatively little net change in assemblage composition or morphology of component taxa (taxonomic stasis), and that faunal associations tend to remain relatively consistent in terms of ecological properties. The concept has engendered controversy about the degree to which a pattern of relative stability might exist under different circumstances, whether it can be demonstrated at all, and how one might quantify it. Much of the debate revolves around whether a particular quantitative test can substantiate a pattern of relative stability or detect substantive change. Traditional methods of comparing assemblages (including MDS and ANOSIM) use pairwise similarity coefficients, the choice of which can be arbitrary and can result in significantly different outcomes. We propose an alternative method that departs from previous approaches in two ways. We formulate the problem as change-point detection, which recognizes that the samples are time-ordered and that stasis is characterized by lack of significant change between samples. Samples between changes points are clusters. Second, we employ information theoretic model ranking to select the model best supported by the data from a set of scientifically plausible models. We demonstrate this approach with an extensive data set from the Middle Devonian Hamilton Group of New York using two widely adopted procedures, Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC). BIC is generally preferred in clustering applications and the optimal model using BIC for these data supports the pattern of coordinated stasis. AIC favors complex models that often over-fit the

data and in this case finds more change points (clusters) than BIC. Nevertheless, the clusters found through AIC are interpretable and demonstrate that using AIC and BIC in combination can uncover structure in data at different resolutions.

26: 10:30 AM-10:45 AM
Presenter: SESSA, JOCELYN

THE LONG-TERM ECOLOGICAL EVOLUTION OF SHALLOW MARINE ASSEMBLAGES IN THE EARLY PALEOGENE OF THE GULF COASTAL PLAIN, USA

SESSA, JOCELYN, Dept. of Geosciences, Penn State, 541 Deike Bldg, University Park, PA, 16801, United States, jsessa@psu.edu; BRALOWER, TIMOTHY J., Geosciences, Penn State,541 Deike Bldg, University Park PA 16802; PATZKOWSKY, MARK, E., Geosciences, Penn State,541 Deike Bldg, University Park PA 16802; IVANY, LINDA, C., Department of Earth Sciences, Syracuse University, Heroy Geology Laboratory, Syracuse, NY 13244

Mass extinction and climate change are considered governing influences on shallow marine invertebrate assemblages. The aftermath of the Cretaceous-Paleogene (K-Pg) mass extinction and several climate shifts are preserved in the Gulf Coastal Plain of the United States (GCP), and this study documents how these external forces shaped the diversity, dominance structure, and ecological characteristics of molluscan paleocommunities.Although the diversification of GCP molluscan assemblages has been broadly described by Hansen and coworkers, previous studies were limited by the statistical techniques in use at the time and by the lumping together of unlithified and lithified collections. Here, we combine new, field-collected abundance data with collections from the published literature to document the ecological diversification of various feeding, mobility, and tiering “˜guilds' through the first fifteen million years of the Paleogene. Species diversity of local assemblages recovers to pre-K-Pg mass extinction levels within approximately two million years. After this initial recovery period, local diversity remains essentially unchanged for the next 13 million years. The number of ecological guilds follows a strikingly similar pattern. Assemblages in the initial recovery period are characterized by the dominance of only one or two guilds. The distribution of guilds becomes more equitable through time, so that younger assemblages are not as dominated by any one particular guild. Interestingly, the proportion of predators does not increase with time, which would be expected under the escalation hypothesis.Although climatic data from the GCP early Paleogene are scarce, there seems to be a poor correlation with either species diversity and temperature or guild diversity and temperature. It appears that species and guild diversity are controlled by processes such as species saturation or an invariant species pool, whereby both quickly return to pre-extinction levels and then plateau at the number of species and guilds that the environment can support.

26: 10:45 AM-11:00 AM
Presenter: HARNIK, PAUL G.

TESTING THE GENERALITY OF MACROECOLOGICAL THEORY IN THE EARLY CENOZOIC

HARNIK, PAUL G., Committee on Evolutionary Biology, University of Chicago, 5734 S. Ellis Avenue, Chicago, IL, 60637, United States, pharnik@uchicago.edu

Interspecific ecological variation contributes greatly to the structure of biodiversity at multiple scales. Differences in ecological characteristics such as abundance, body size, and geographic range may facilitate species coexistence in local and regional faunas and generate variation in evolutionary rates. Yet ecological characteristics routinely covary and multivariate approaches that account for these interdependencies are essential. A burgeoning literature in the field of macroecology provides numerous empirical assessments of the relationships between abundance, body size, and geographic range. However, the generality of these relationships remains unclear as most studies are conducted on terrestrial vertebrates and rely almost exclusively on present-day ecological data. Because human activities can substantially alter ecological distributions, a deeper-time perspective is necessary for evaluating the temporal and spatial generality of macroecological theory and neontological pattern. Using the early Cenozoic fossil record of the eastern U.S., I investigate several canonical macroecological relationships (abundance-body size, abundance-geographic range, and body size-geographic range) across three clades of marine bivalves and evaluate the volatility of these relationships over multiple scales (taxonomic, temporal, and spatial). Species-level data for these analyses were gathered through quantitative sampling in the Gulf Coastal Plain and use of existing museum collections and literature records. Several key results emerge: (1) bivalve species do not exhibit the negative scaling of abundance with body size observed in many other systems, regardless of the scale of analysis; (2) while certain macroecological distributions (e.g., body size) are largely invariant over the Paleogene, dynamic shifts in other ecological characteristics (e.g., geographic range) yield macroecological covariance structure that is not static over the evolutionary history of clades. Spatial and temporal variation in macroecological covariance structure may result from ecological and evolutionary change over the early Cenozoic as well as shifts in the sampled rock record. Sensitivity analyses distinguish the relative contributions of these factors.

26: 11:00 AM-11:15 AM
Presenter: DOMINICI, STEFANO

SHALLOW MARINE FAUNAL GRADIENTS IN THE EOCENE GREENHOUSE

DOMINICI, STEFANO, Geology and Paleontology, Museo di Storia Naturale, Università di Firenze, Via La Pira 4, Florence, 50121, Italy, stefano.dominici@unifi.it; ZUSCHIN, MARTIN,

Department of Palaeontology, University of Vienna Geocenter, Althanstrasse 14, A-1090 Vienna, Austria

A large quantitative data set of lower-middle Eocene (Ypresian-Bartonian) mollusk assemblages from the Pyrenees and the Paris basin has been analyzed to reconstruct faunal gradients in intertidal to inner shelf settings at middle latitudes. The time interval is characterized by the highest temperatures of the Cenozoic, a greenhouse climate much different from the icehouse temperatures of the last 3 million years. Eocene subtidal communities from sandy bottoms had a very high diversity and were dominated by the same families of modern seas, with similar abundance distributions. On the other hand, intertidal and very shallow subtidal settings hosted a fauna much more different from the modern. Intertidal settings in Western Europe were dominated by the potamidids, a group of gastropods today thriving in mangrove-fringed coasts, but with a much lower diversity than during the Eocene. At the same time, very shallow subtidal bottoms were characterized by ampullinid gastropods, a family containing only one extant species, an algal grazer. It is suggested that peculiarities of Eocene mollusks were connected to the ongoing diversification and increase in biomass of plants.

26: 11:15 AM-11:30 AM
Presenter: JARDINE, PHILLIP E.

SPATIAL HETEROGENEITY IN PALEOCENE PARATROPICAL FORESTS ON THE U.S. GULF COAST

JARDINE, PHILLIP E., University of Birmingham, School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, West Midlands, B15 2TT, United Kingdom, pej083@bham.ac.uk; HARRINGTON, GUY J., School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, West Midlands, United Kingdom, B15 2TT; STIDHAM, THOMAS A,. Department of Biology, Texas A&M University, 3258 TAMU, College Station, Texas, United States, 77843-3258

Studying spatial heterogeneity in assemblages of taxa is essential for properly understanding the patterns and processes of community change over time. It is expected that heterogeneity in composition and community structure should increase with distance due to differential speciation, extinction and immigration within any particular community. Using the pollen record as a plant proxy, we assess heterogeneity in Late Paleocene plant communities on the US Gulf Coast that are homologous to modern tropical to subtropical forests. Fifty samples were taken from outcrops of the Calvert Bluff Fm. in Robertson and Bastrop counties, east-central Texas, and from the Tuscahoma Fm. in the OSM No. 2 Wahalak core from Choctaw County, western Alabama. These study areas are approximately 900 km apart, and are taken as being representative of the western and eastern Gulf Coast, respectively. The two study areas are both marginal marine, muddy strand lines with brackish water deposits with occasional emergent swamps. There are no significant taphonomic biases between them. We

evaluate compositional dissimilarity and diversity dynamics within and between the study areas. Diversity is considered both as evenness and richness, and richness is additively partitioned into alpha (within-sample richness), beta (between-sample heterogeneity) and gamma (total assemblage richness) diversity. The two areas show highly similar levels of alpha (~40 species), beta (~120 species) and gamma (~160 species) diversity. A decline in within-sample evenness over time in Texas is not matched in Alabama. Compositional trends relating to subtle relative abundance changes can be identified within the two study areas, and compositional differences between Texas and Alabama do not simply imply sampling from one homogenous regional species pool. These results demonstrate that even subtle spatial structuring in fossil assemblages can be recognized and quantified, and show the importance of considering spatial as well as temporal variation in paleoecological studies.

26: 11:30 AM-11:45 AM
Presenter: ZUSCHIN, MARTIN

PALAEOCOMMUNITY DYNAMICS ACROSS THE LOWER TO MIDDLE MIOCENE BOUNDARY OF THE CENTRAL PARATETHYS

ZUSCHIN, MARTIN, Dept of Palaeontology, University of Vienna, Althanstrasse 14, Geocenter, Vienna, 1090, Austria, martin.zuschin@univie.ac.at; HARZHAUSER, MATHIAS, Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, Vienna, Austria, 1090; MANDIC, OLEG, Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, Vienna, Austria, 1090

The 3rd order sequence boundary from the Lower to the Middle Miocene of the Paratethys is characterized by a well-known major change of the molluscan fauna. This change was mainly studied based on regional species lists, which suggest a transition from low-diversity Burdigalian to highly diverse Langhian assemblages. Here, we present quantitative data from 3 Burdigalian and 6 Langhian localities to capture the anatomy of this faunal transition by comparing species-abundance patterns of local assemblages. 108 bulk samples, comprising more than 30,000 shells, were taken from shell beds; all molluscs > 1mm were studied quantitatively and sorted into 451 species. Independent sources (e.g., palaeogeographic position of localities and environmental data from foraminifera) suggest a water depth ranging from the intertidal to several tens of meters for the studied assemblages. Ordination methods indicate that benthic assemblages in the study area developed along the same depth-related environmental gradient across the 3rd order sequence boundary. Due to strong facies shifts at the boundary, the Burdigalian faunas are mostly preserved in nearshore settings, but the Langhian faunas range from intertidal to shelf depth. Statistical analyses indicate that differences between the total of Burdigalian and the total of Langhian assemblages are smaller than any differences among individual localities. The striking differences among the studied localities are most likely due to heterogeneous environments present on the Lower and Middle Miocene shelf of the Central Paratethys. Clearly,the immigration of several

thermophilic molluscan families and superfamilies (e.g., Strombidae, Tonnoidea, Isognomonidae, and Carditidae) reflects climatic changes at the onset of the Langhian transgression. Our quantitative approach, however, favours the strong facies shift at the Lower / Middle Miocene boundary as the main reason for the pretended faunal turnover observed from regional species lists, because species abundance patterns from local assemblages indicate largely persisting palaeocommunities.

Session No. 27, 8:00 AM (morning session) and 1:30 PM (afternoon session); Friday 26 June 2009
Symposium S15. Biotic Response to Environmental Change: Ecology, Evolution and the Future - A Symposium in Honor of Jeremy B.C. Jackson

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27: 8:15 AM-8:30 AM
Presenter: WULFF, JANIE L.

IS PERSISTENCE OF THE PORIFERA PROMOTED BY STRUCTURAL SIMPLICITY?

WULFF, JANIE L., Department of Biological Science, Florida State University, Tallahassee, FL, 332306, United States, wulff@bio.fsu.edu

Sponges, extreme in their structural simplicity and homogeneity, continue to be among the most diverse and abundant groups of animals in hard-bottom marine systems. Persistence of the sponges may be promoted by characteristics, such as morphological versatility, facile regeneration, and diverse collaborations, that derive directly from their uniquely simple construction. Morphological versatility, and ability to regenerate and propagate asexually, allow sponges to explore a wide range of life history and morphological strategies for coping with space limitation, physical disturbance, and partial mortality due to predators and pathogens. Extreme propensity for striking up intimate associations with organisms of other species allows sponges to acquire useful characteristics such as mobility, photosynthesis, predator deterrence, and resistance to breakage, by collaboration. In order to understand the contribution to sponge success of these characteristics that derive from simple construction, relative to other sponge traits such as efficient water filtering and exceptional biochemical diversity, I have been challenging sponges of 30 species, of assorted growth forms, demosponge orders, shallow tropical habitats, and degrees of participation in intimate associations, by transplanting them into situations differing in abiotic factors, food, predators, and competitors. Their sometimes surprising responses, measured by differences in growth rates, shapes, collaborations, mortality, and recovery after partial mortality, provide a base for making predictions about continued sponge persistence, as water column productivity, storm frequency and fury, pathogens, sedimentation, and predator abundance change. Gathering

data that will help to predict the future of sponges is impelled by the many key ecosystem services provided by sponges, and increasing reports of dramatic sponge increases as well as abrupt losses. These data also address a fundamental question in the evolution of multicellular animals: what is gained by eschewing the many benefits of internal division of labor and integration, and sticking with simplicity?

27: 8:30 AM-8:45 AM
Presenter: BUSS, LEO W.

WHY DO THEY HAVE SO MANY POLYPS?

BUSS, LEO W., Department of Ecology & Evolutionary Biology, Yale University, New Haven, CT, 6520, United States, leo.buss@yale.edu

Jeremy Jackson was amongst the pioneers in thinking about colonies as colonies. While respectful of their phylogenetic peculiarities, he opened our eyes to their ecological commonalities. If one accepts that physiology plays the role of keeping ecological realities from becoming genetic liabilities, then physiological effector systems may well bear their own commonalities. I here build the case that integration in colonial metazoans is constrained by limits upon pressure driven pumping and upon mixing in fluid conducting systems. I will seek to make this point in a fashion similar to that employed so successfully by Jeremy Jackson in the past. I first introduce a series of uncontroversial claims, in this case regarding laminar flow at microfluidic length scales, and then interpret what would otherwise seem arbitrarily idiosyncratic natural history detail as a consequence of these claims.

27: 8:45 AM-9:00 AM
Presenter: LIDGARD, SCOTT

ZOOIDS AND MODULARITY IN BRYOZOANS

LIDGARD, SCOTT, Dept. of Geology, Field Museum of Natural History, 1400 S. Lake Shore Dr., Chicago, IL, 60605, United States, slidgard@fieldmuseum.org

There are remarkably few groups of bilaterian animals in which coloniality is characteristic. In bryozoans, individual zooids as developmental modules have been fundamental in the advent of new body plans that appear to have evolved to satisfy different functions or goals. These modules originate from budding loci and differentiate as populations of cells and thus can be individuated using key evo-devo criteria. However, they are also inclusive of another level of modularity absent in non-colonial bilaterians, in that organs differentiate as entities or parts of the zooids. This additional level is an entrenched developmental pattern instrumental both in

evolvability of new structures (fusion and integration of spines to form a costal shield or ovicell) and atavism and loss at a lower level of modularity (vestigial polypides in avicularia). These examples show that, to some extent, modules at these levels are disassociated. Ecological factors such as epibiont predation may be related to repeated instances of modular integration. One way of looking at this is that entrenchment of overtly modular design proposes a limited range of conceivable evolutionary directions, and selection culls from these ones that more consistently contribute to fitness.

27: 9:00 AM-9:15 AM
Presenter: ERWIN, DOUGLAS H.

WAS THE METAZOAN RADIATION BIOLOGICALLY DRIVEN?

ERWIN, DOUGLAS H., National Museum of Natural History, Dept. Paleobiology, MRC-121, Smithsonian Institution, Washington, DC, 20013-7012, United States, erwind@si.edu

The origin and early diversification of animals occurred during an interval of profound environmental change, including intervals of extensive continental glaciation, peculiar post-glacial ocean chemistry, wide swings in carbon isotopes and a progressive oxidation of the deep oceans, replacing formerly sulfur-rich (euxinic), and perhaps iron-rich, seas. By the Early Cambrian an environmental revolution had taken place: the oceans had become oxygenated to a depth of at least several hundred meters, euxinic conditions had retreated to local settings, oxygen levels increased in the atmosphere, the carbon cycle settled down to a pattern more similar to today, and microbially bound sediments were replaced by more bioturbated sediments. Various advocates have proposed environmental, developmental and ecological drivers for these events; the latter includeing predation and the environmental transformation driven by sponges. These two hypotheses differ considerably in the network effects that they produce, however: Sperling and Peterson's suggestion that sponges progressively oxygenated deep oceans is a positive spillover effect of the sort that often drives innovation through environmental modification. Similarly, the advent of penetrating vertical burrows transformed sedimentary redox gradients, and can greatly increase microbial primary productivity: similar positive spillover effects. Thrombolitic reefs may have had similar effects in the latest Ediacaran. Proposed ecological drivers for the Ediacaran-Cambrian diversification can be characterized by the extent of their positive feedback effects on the environment, suggesting that a specific class of adaptations that provide positive environmental effects (diversity-independent) had the most transformative impact in increasing biological diversity. Thus certain critical intervals within appear to encompass biologically mediated environmental change.

27: 9:15 AM-9:30 AM

Presenter: GINGERICH, PHILIP D.

EVOLUTIONARY RATES AND LRI LOG-RATE-INTERVAL SCALING

GINGERICH, PHILIP D., Geological Sciences, University of Michigan, Museum of Paleontology, Ann Arbor, MI, 48109-1079, United States, gingeric@umich.edu

In 1967 Benoit Mandelbrot described what he called fractals: patterns with fractional dimensions and properties that change with scale. He used logarithms and it wasn't controversial. We have always calculated rates to remove the effect of time, but this doesn't always remove the effect of scale. Time and time scale can be conflated, but they are different. The twentieth century started before we could study rates in paleontology, and ended with surprising resistance to quantification of rates and scaling. Moving forward, we have to understand both if we are to understand evolution. Objections to LRI scaling include misunderstanding of logarithms; resistance to testing correlations that might prove spurious; suspicion that morphology and time are incomparable, or should not be compared; commitment to stasis; and belief that microevolution and macroevolution, once named, must differ in more than scale. In the empirical world: (1) morphology is geometric-normal, logarithms are required to make measurements comparable, and natural log (ln) transformation is standard; (2) dependence and independence are tested by quantifying relationships, plotting variables against each other; (3) morphology and time can be plotted and analyzed to see if they are related; (4) stasis is a question of interest; and (5) microevolution and macroevolution can be compared to test whether they differ in relation to scale. LRI order-of-magnitude (log) scaling is just like fractal scaling: the simplest, most efficient, and most powerful approach to comparison of rates, testing how rates scale, and interpreting patterns of scaling. LRI scaling is illustrated by application to the textbook study of Neogene Caribbean *Metrarabdotos*. Within-species rates comprise those on all time scales, not just the longest scale, which reduces the contrast of within-species (stasis) and between-species (punctuation) rates considerably. What are the rates? What are the time scales? Can one explain the other?

27: 9:30 AM-9:45 AM
Presenter: BUDD, ANN F.

HYBRIDIZATION, SPECIATION, AND EXTINCTION AT THE GEOGRAPHIC MARGIN OF A REEF CORAL SPECIES COMPLEX

BUDD, ANN F., University of Iowa, Department of Geoscience, 121TH, Iowa City, IA, 52242, United States, ann-budd@uiowa.edu; PANDOLFI, JOHN M., Centre for Marine Studies and School of Earth Sciences, University of Queensland, Brisbane, Queensland, 4072, Australia

Recent molecular analyses have shown that many reef corals form hybridizing species complexes composed of numerous genetically distinct species or lineages, which periodically fuse and/or split as they extend through time. Hybridization within complexes has been found to be rare on ecological time scales, but is hypothesized as playing an important role in range expansion and adaptation to changing environments on geological time scales. Here we test this hypothesis by comparing patterns of lineage fusion and splitting at scattered Caribbean locations during the late Pleistocene using geometric morphometrics. We focus on the *Montastraea "annularis"* complex because previous work has shown that morphologic and genetic data in the complex concur. Our samples consist of colonies collected in five Pleistocene units (>500Ka, 300Ka, 125Ka of Barbados; 125 Ka of the Bahamas; 125Ka of the Dominican Republic), as well as genetically characterized colonies from Panama. We distinguish species by comparing colony growth forms using canonical variates analyses, and test for differences among species using Mahalanobis distances. Our results reveal 3-4 species within each sample unit. Distances among species are significantly lower in the Bahamas than in the other four Pleistocene units or the Recent, indicating lineage fusion and hybridization. Most species within the Dominican Republic and Bahamas are the same as the Recent species in Panama. However, two or more species in each of the two older Barbados units are not found at other geographic locations; they arise and become extinct within Barbados, indicating high rates of lineage splitting and extinction. One of two new species in the youngest Barbados unit is more widely distributed, but it too is now extinct. These results confirm that lineage fusion and splitting are concentrated at peripheral geographic locations, but that different evolutionary responses may occur in different regions of the periphery.

27: 9:45 AM-10:00 AM
Presenter: VERMEIJ, GEERAT

THE NEOGENE MARINE TROPICS: A STUDY IN CONTRASTS

VERMEIJ, GEERAT, Department of Geology, University of California, Davis, 1 Shields Ave., Davis, CA, 95616, United States, vermeij@geology.ucdavis.edu

Today's shallow-water marine tropics are divided into two great realms, the Indo-West Pacific (IWP), encompassing the Indian Ocean and the western and central Pacific east to Polynesia; and the Atlantic-East Pacific realm (AEP), encompassing the coasts of West Africa and both sides of tropical America. Phylogenetic studies and the fossil record of molluscs indicate that these realms have gone their separate evolutionary ways since at least early Miocene time. An analysis of ecological and morphological innovations arising since the separation of these realms indicates that novel ways of life have been heavily concentrated in the IWP, and that even highly diverse EAP clades have remained relatively conservative. Pliocene extinctions, especially in the western Atlantic part of the EAP, have amplified the adaptive contrasts between the two tropical realms.

27: 10:30 AM-10:45 AM
Presenter: KARLSON, RONALD H.

SPATIAL COMPETITION ON SUBTIDAL MARINE HARD SUBSTRATA:

KARLSON, RONALD H., Biological Sciences, University of Delaware, 266 Carters Mill Rd, Elkton, MD, 21921, United States, rkarlson@udel.edu

Solitary and colonial animals differ substantially in how they compete for space on marine, hard substrata. Jackson (1977) presented a multi-faceted synthesis of empirical results, the invertebrate zoology/ecology literature, and ecological theory to highlight these differences, promote colonial animals as generally superior spatial competitors, and explain exceptions to the rule. Based on theory, colonial and solitary animals were predicted to differ in recruitment rates, geographic distributions, and palatability to predators. The ISI Web of Science database indicates that 7% of all 1968-2008 JBCJ citations (6658) refer to Jackson (1977), his second most highly cited journal article. In terms of number of citations per year, it is the sixth most highly cited article among 98 journal contributions. As a consequence of all this attention, I revisited Jackson (1977) and 120 recent articles citing it. I recorded the journal, organisms, habitats, and reasons for the Jackson (1977) citation. Half of the journals were marine publications; approximately 10% were from the paleontological literature. The most common organisms considered were cnidarians or a diverse range of epifaunal phyla; 3% of the articles dealt only with algae. The most common habitats included coral reefs, fouling communities, and rocky benthos. The main reasons for citing Jackson (1977) included support for the importance of spatial competition, dominance of colonial animals over solitary forms, or one of several specific attributes of life on marine hard-substrata. Few citations addressed the explicit predictions in Jackson (1977). A follow-on database search yielded more papers yielding mixed results. The major influence of Jackson (1977) has been to provide a strong conceptual framework to ecological and paleontological studies on marine hard-substrata. The predictions from Jackson (1977) would appear to be less important being strongly linked to a body of theory which has changed substantially over the years.

27: 10:45 AM-11:00 AM
Presenter: STENECK, ROBERT

CAUGHT IN THE MIDDLE: POSSIBLE LIMITATIONS FOR DECAPOD MORPHOLOGICAL GRADES INTERMEDIATE BETWEEN LOBSTER AND CRAB BODY PLANS IN A WORLD OF ESCALATING PREDATION

STENECK, ROBERT, School of Marine Sciences, University of Maine, Darling Marine Center, Walpole, ME, 04573, United States, steneck@maine.edu; PALMA, ALVARO T. C. , Center for

Advanced Studies in Ecology and Biodiversity, Departamento de Ecologia , Casilla 114D, Pontifica Universidad Catolica de Chile, Santiago, Chile

Morphological evolution in decapod crustaceans trend from shrimp and lobster-like (macruran) ancestors in the Paleozoic era and Triassic period to crabs (brachyuran) in the Cretaceous. Today, both groups attain large size and high abundance in shallow marine habitats. The same is not true for the intermediate morphological grade characterized by galatheid decapods. This group was broadly distributed and abundant in shallow marine habitats during the Mesozoic Era but never attained large size. It now thrives primarily at great ocean depths (ca 2,000 m) or in freshwater rivers in southern South America. We compared rates of predation and size-specific mobility of the abundant freshwater galatheid, *Aegla papudo* with its marine counterparts in central Chile and with lobsters and crabs of the western North Atlantic. This galatheid is small (ca 15 mm carapace length) conspicuous and diurnally active. It lives in relatively predator-free aquatic environments, walks slowly compared to crabs, and has limited swimming ability compared to lobsters. Size-specific tail-flip swimming was only possible for the smallest galatheid individuals. Their short abdomen uses only half of its six segments for movement. We suggest this intermediate morphological grade functionally compromises the rapid walking and rotation of brachyurans and the swimming capacity of macrurans necessary to avoid predators at vulnerable sizes. Southern South America has a uniquely depauperate fish fauna with relatively few, small, native predatory fishes. We speculate that the Tertiary radiation of advanced percoid fishes with their unique buccal architecture and ability to attack benthic invertebrates created a hostile environment for small, slow moving galatheides. The depauperate fish fauna may have resulted from the Andean orogeny during the Tertiary. Today this grade of intermediate decapod morphology persists primarily in habitats having low predation potential however this anachronistic decapod is now threatened by introduced predatory fishes in South America.

27: 11:00 AM-11:15 AM
Presenter: VAN VALKENBURGH, BLAIRE

PLEISTOCENE PANDEMONIUM: DENTAL FRACTURE RATES SUGGEST GREATER COMPETITION IN PAST THAN PRESENT PREDATOR GUILDS

VAN VALKENBURGH, BLAIRE, Ecology And Evolutionary Biology, UCLA, 965 Stunt Rd, Calabasas, CA, 91302, United States, BVANVAL@UCLA.EDU

Large predatory mammals, such as lions and hyenas, are common in African game parks, and recently released gray wolves have multiplied rapidly in Yellowstone National Park. This suggests that these species are doing well and may be close to carrying capacity. However, we have few data on their abundance prior to the 20th century, and it is even more difficult to assess prehistoric population levels. Nevertheless, such data could inform the development of

conservation strategies for these species. A recent study of tooth fracture frequencies in carnivores offers a novel window into the behavior of extinct species and past ecosystems. Among living species, fracture frequencies are highest among species or populations that regularly consume bone. Heavier carcass utilization results in bone consumption and is associated with increased levels of food competition. Interestingly, multiple populations of Pleistocene carnivores, including, lions, sabertooth cats, gray wolves, dire wolves, and coyotes display greater numbers of broken teeth and heavier wear than their modern counterparts. This suggests increased food competition in the Pleistocene that might reflect greater abundances of large carnivores than are observed anywhere at present. Alternatively, it might indicate low ungulate densities, but this appears unlikely based on other evidence. If more intense intra- and interspecific competition among large, mammalian predators was the norm in the Pleistocene, it suggests that the dynamics of present-day ecosystems and species interactions have undergone significant changes in the recent past. Moreover, it indicates species are not pushing the limits of their tooth strength (and probably other anatomical structures) as often as they did in the Pleistocene and thus aspects of their anatomy (e.g., tooth dimensions) and behavior (e.g. sociality) might reflect to some degree the ghosts of competition past rather than present conditions.

27: 11:15 AM-11:30 AM
Presenter: WING, SCOTT L.

HOW UNSTABLE WAS THE QUATERNARY?

WING, SCOTT L., Dept. of Paleobiology, Smithsonian Institution, NHB121, , PO Box 37012, Washington, DC, 20013-7012, United States, wings@si.edu; HUNT, GENE, Dept. of Paleobiology, Smithsonian Institution, PO Box 37012, Washington, DC, USA, 20013-7012; LIANG, MING-MEI, Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK; JACKSON, STEPHEN T., Dept. of Botany, University of Wyoming, 3165, 1000 E. University Ave., Laramie, WY, USA, 82071

The Quaternary was a time of large, geologically rapid fluctuations in climate and vegetation, but Quaternary fossil records are also studied at finer temporal resolution than most deep-time records. Was community change in the Quaternary more rapid, or is that an artifact of fine temporal resolution? Rates of change calculated from palynological records using standard methods show that rate is strongly dependent on the duration over which it is measured. Short time intervals between samples yield fast rates, long intervals yield slow rates. Thus fine temporal resolution favors the perception of rapid change.To further comparisons of Quaternary with deep-time records we gathered new data and developed improved analytical methods. We sampled pollen in varved lake deposits from Shanwang, China (36.5 Â°N). The small maar lake (500x700 m) existed in the globally warm early Miocene (~16 Ma), surrounded by temperate and subtropical forests growing in a warm, wet climate with mild winters. Analytical time-averaging within samples is ~100 years, intersample

durations average 600 years, and the total record is >20 ky, similar to the geographic and temporal dimensions of many Quaternary pollen records. Instead of assuming linear change between samples we quantified rates using an ecological drift model of change in community composition. Rates calculated in this way are far less dependent on the duration over which they are measured.Rates of floral change measured at Shanwang are an order of magnitude slower than those measured from 21 Quaternary pollen sequences spanning a wide range of latitudes and vegetational types More stable forest composition in the Miocene mid-latitudes than in any Quaternary record may reflect dampened orbital and shorter-term climate variation during the Miocene Climatic Optimum. Our results suggest that greater community stability in deep time is a real phenomenon, one with important ecological and evolutionary implications.

27: 1:30 PM-1:45 PM
Presenter: COATES, TONY

THE PANAMA PALEONTOLOGY PROJECT (PPP), A JACKSONIAN LEGACY

COATES, TONY, Smithsonian Tropical Research Institute, Panama, 34002, Panama, coatesj@hardynet.com; COLLINS, LAURIE, Department of Earth Sciences, Florida International University, Miami, FL 33199; O'DEA, AARON, Smithsonian Tropical Research Institute, Panama, 34002, Panama

The PPP takes advantage of the "natural experiment" provided by the Miocene to Pliocene emergence of the Central American Isthmus to assess its evolutionary and ecological impacts of environmental change and geographic isolation on marine invertebrate faunas of the neotropics. Initiated by Jeremy Jackson and Anthony Coates in 1986, the PPP has involved 57 scientists from 20 institutions in seven countries, and to date has organized almost 40 expeditions to 8 different countries and published 200 articles. The Jacksonian legacy was 1) to install a massive bulk sampling and processing system that allowed macropaleontological data to be analyzed within modern ecological approaches; 2) to create a separate team to measure and date sections with microfossils, thus allowing correlation of environmental and evolutionary events at very fine scales; 3) to provide participating scientists large numbers of processed, curated and dated specimens from their respective specialist clade for study; 4) to collect and describe the Recent faunas on each side of the Isthmus at an unprecedented level and use them as time zero; 5) to identify environmental changes in the fossil record through analysis of sediments, paleobathymetry, and mean annual ranges of temperature, independent from biological changes; and 6) to use all of the above to explore a range of fundamental evolutionary processes from extinction to community evolution. The rigorous paleontological framework of the PPP presents evolutionary biologists with a unique view of 15 million years of life and environments in a tropical region.

27: 1:45 PM-2:00 PM
Presenter: O'DEA, AARON

LIFE HISTORY EVOLUTION AND ENVIRONMENTAL CHANGE IN TROPICAL AMERICA

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The closure of the Isthmus of Panama profoundly altered the Caribbean environment and the response in shallow marine communities was complex and non-linear. The cupuladriid bryozoans reveal a sequence of turnover typical for many benthic groups, with origination initially stimulated by habitat diversification, but followed by extinctions delayed by 1-2 million years. Explaining these patterns is only possible with 1) rigorous ecological and independent environmental data, 2) understanding of the life histories of the organisms concerned and 3) the massive sampling effort of the Panama Paleontology Project. Both origination and extinction of cupuladriid species was found to be highly selective based upon the ability to clone, as predicted from modern day studies on cupuladriid reproduction. New species that originated as the Isthmus began to close were aclonal. Those that survived did so by decreasing levels of clonal reproduction, while those that went extinct failed to alter their reproductive life history. Abundances of doomed species reveal that even though their extinction was postponed, their ecological importance was dramatically reduced as soon as environments altered. These data therefore strongly support an environmental cause to a multi-faceted evolutionary effect.

27: 2:00 PM-2:15 PM
Presenter: JOHNSON, KENNETH

ASYNCHRONOUS RESPONSE OF CARIBBEAN AND SOUTHEAST ASIAN CORAL REEF ECOSYSTEMS TO LATE CENOZOIC GLOBAL CHANGE.

JOHNSON, KENNETH, Natural History Museum, Cromwell Road, London, N/A, SW7 5BD, United Kingdom, K.Johnson@nhm.ac.uk

Analysis of specimen-based compilations of reef-coral species occurrences indicate widely differing Late Oligocene to Recent trajectories for coral reef ecosystems in Southeast Asia and the Caribbean. Both regions were influenced by global climate change superimposed on regional environmental changes associated with constriction of tropical ocean gateways (the Central American Seaway and the Indonesian Throughflow). Caribbean reef ecosystems were altered by regional extinction during the Oligocene/Miocene and the Pliocene/Pleistocene. The Oligocene/Miocene extinction was associated with the collapse of reef building in the region, but contrary to expectations, the Pliocene/Pleistocene extinction is associated with

regional reef recovery. The depauperate extant Caribbean biota includes survivors of this extinction, and very few new species have appeared since. In Southeast Asia, there was an expansion in reef carbonate development during the Oligocene/Miocene that coincides with diversification of reef biota. No intervals of accelerated extinction have been discovered yet in the Southeast Asian Neogene, suggesting that the high diversity of the regional reef biota is a function of continuous diversification and that reefs in the region were not substantially affected by Neogene climate change. These results suggest that the regional response of coral reef ecosystems to global environmental change is strongly modulated by regional historical factors. Therefore, attempts to understand long-term global patterns of diversity and ecosystem function as responses to large-scale environmental change are enhanced by analysis of variation at non-global scales.

27: 2:15 PM-2:30 PM
Presenter: COLLINS, LAUREL S.

PALEOBIOGEOGRAPHIC COMPARISONS OF BENTHIC FORAMINIFERA FROM THE PANAMA PALEONTOLOGY PROJECT

COLLINS, LAUREL S., Dept. Earth and Environment, Florida International University, Miami, FL, 33199, United States, collinsl@fiu.edu

Paleontologists previously studying Miocene sedimentary deposits of Venezuela and Ecuador have noted the strong similarity of Caribbean and tropical Eastern Pacific faunas of foraminifera and mollusks. In Pliocene time, about 4 million years ago, as a result of the long-term rise of southern Central America, the seaway that had connected tropical Atlantic and Pacific waters closed completely. Today, Caribbean and tropical Eastern Pacific faunas are considerably different in composition. This project is tracing the paleobiogeographic divergence of shallow-water, tropical Eastern Pacific and Caribbean benthic foraminiferal faunas from Miocene to Pleistocene time, and relating it to the geologic events that caused the rise of the Central American isthmus, paleoceanographic changes and geographic separation. Assemblages of benthic foraminifera from Panama, Costa Rica, Ecuador and Venezuela have an excellent Neogene fossil record. Because of the logistical difficulty of collecting and identifying a sufficient number of fossil taxa to characterize the total diversity of shallow to deeper waters for successive intervals of time, comparisons of coeval, isobathymetric assemblages from either side of the Central American isthmus are being used to assess their degree of similarity. The collections have been placed within the global biochronology of planktic foraminiferal and calcareous nannofossil zonation. The paleoecology of those species still living (> 50%) indicates the paleoenvironment, including paleobathymetry, of the fossil assemblages. The prediction is that with increasing constriction of the Central American seaway, there was increased divergence of faunas between the two sides of the isthmus and increased similarity among regions of the Caribbean. Preliminary

results of differences in similarity indices through the interval of seaway closure support these predictions.

27: 2:30 PM-2:45 PM
Presenter: TODD, JONATHAN A.

MAKING THE RIGHT CHOICE: ECOLOGY AFFECTS INTERPRETATION OF CLADE DYNAMICS IN POLYSTIRA (GASTROPODA: TURRIDAE) THROUGH THE NEOGENE OF THE AMERICAS.

TODD, JONATHAN A., Dept of Palaeontology, Natural History Museum, Cromwell Road, London, England, SW7 5BD, United Kingdom, J.Todd@nhm.ac.uk

Biologists seeking to use the fossil record to date the origins of their study taxon typically disregard its ecology. Absolute dates are put into increasingly sophisticated programs to calibrate molecular trees and thence to derive evolutionary scenarios. I will examine how different patterns of life history and its ecological correlates affect this enterprise within one hyperdiverse marine snail clade. The carnivorous snail genus *Polystira* contains hundreds of largely undescribed species living in shelf depths throughout the subtropical and tropical Americas and ranging from the Miocene through to the Recent. I have re-systematized living and fossil *Polystira* species using morphological characters in concert with molecular data from three genes for the Recent species. Fossil species have been mapped onto the molecular trees. Distinct modes of larval development are present. Specimen-level occurrence data for the past 12 My has been compiled from Panama Paleontology Project collections and museums world-wide. These data have been examined to test whether larval developmental mode in Recent species correlates with; geographic range size, abundance and body size. All three attributes are expected to affect the potential of specimen recovery from the fossil record. Using selected clades of *Polystira*, I will examine how mode of larval development and its ecological correlates affect the sampling of fossil species and clades and their inferred evolutionary response to environmental change. Clades with non-planktotrophic larvae are likely to be poorly sampled from the fossil record and, if possible, should be avoided for molecular calibration and subsequent analysis of diversification patterns.

27: 2:45 PM-3:00 PM
Presenter: SANDIN, STUART A.

RECONSTRUCTING REEF ECOLOGY WITH INSIGHTS FROM REMOTE ISLAND AREAS

SANDIN, STUART A., Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA, 92093-0202, United States, ssandin@ucsd.edu

Most modern-day ecosystems have been altered dramatically by the activities of humans, complicating our ability to differentiate 'natural' from 'impacted' ecosystem properties. The description of ecosystems outside the influence of human activities provides essential insights to contextualize the relative condition of modern ecosystems. Complementing historical and paleoecological efforts, recent field studies to remote and uninhabited atolls of the central Pacific have provided novel ecological insights into the structure of coral reef ecosystems largely outside the influence of human activities. Remote island areas confirm that overfishing is perhaps the most striking impact of human activities on coral reefs, with disproportionate effects suffered by top predators. Studies from remote, 'baseline' reefs have revealed that a host of consistent changes in ecosystem structure and functioning appear to be coupled with the removal of predators. I will discuss our investigations into the generalized changes associated with predator removal from coral reef ecosystems. These changes range from structural (e.g., shifts in species composition and size structure of prey) to dynamical (e.g., reductions in fisheries productivity and loss of ecosystem resilience). I will present results from a series of studies tailored to address these predictions, with work principally conducted in the tropical central Pacific. In the few remaining 'baseline' coral reefs of the world, we have unique opportunities to understand what ecological dynamics have shifted and the likely implications of these changes. Given the wholesale degradation of reef areas globally, ecological studies in these remote regions are analogous to historical or paleoecological reconstructions of the past of reef ecology. However, with effective research programs and applications of ecological findings to management, we may be able to rebuild a modicum of the historical bounty to the reefs of tomorrow.

27: 3:00 PM-3:15 PM
Presenter: SALA, ENRIC

HUMAN-INDUCED REVERSAL OF ECOLOGICAL SUCCESSION IN MARINE ECOSYSTEMS

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There are regularities commonly found in ecological successions. Some general changes occurring from early to mature successional stages are increases in species richness, number of trophic levels, biomass of higher trophic levels, total biomass and three-dimensional biogenic structure; and a decline in turnover rate. Human impacts (as well as other kinds of catastrophic disturbance) nearly always reverse successional trends. To add structure and information to urban ecosystems (cities) beyond what local resources allow, we accelerate the turnover rate of other ecosystems from which we extract resources, subsidized by energy resources from the past (fossil fuels). Understanding the general principles of ecological succession and measuring emergent properties of ecosystems is the single best way to understand our impact at the ecosystem level (and the biosphere in general), to identify management goals, and to measure success of conservation actions.

27: 3:15 PM-3:30 PM
Presenter: KIDWELL, SUSAN

NOBODY'S PERFECT: ASSESSING MODERN DEATH ASSEMBLAGES AS HISTORICAL RECORDERS USING “LIVE-LIVE” COMPARISONS

KIDWELL, SUSAN, University of Chicago, Dept. of Geophysical Sciences, 5734 S. Ellis Avenue, Chicago, IL, 60637, United States, skidwell@uchicago.edu; TOMAŠOVÝCH, ADAM , Dept of Geophysical Sciences, University of Chicago5734 S. Ellis Avenue, Chicago, IL 60637

Comparisons of the composition of molluscan death assemblages (DA) with local living assemblages (LA) in modern marine sediments shows that live-dead (LD) agreement is imperfect. However, before attributing LD discordance to taphonomic bias and time-averaging, the appropriate null-model is “live-live” (LL) discordance among LA samples that arises from natural and sampling variability. Does LD agreement differ from the magnitude of LL agreement, or from patterns of variation in LL agreement? Here, we use temporally replicate samples of LAs from 48 time-series (sampled =7x within 13 months) to define LL variability in habitats analogous to, but geographically distinct from, those where LD datasets are available (118 total). Because samples within LL time-series are likely autocorrelated, these are maximum estimates of LL agreement, and thus a high benchmark for judging the adequacy of LD agreement for (paleo)ecological inference. So far, focusing on species rank-abundance, LD agreement is indistinguishable from LL agreement (median Spearman rho's = 0.38 and 0.42, respectively), and LD and LL agreement both increase significantly with mesh size. Multiple regression finds that, in terms of explanatory power, the first-order factor in both LD and LL agreement is anthropogenic influence: mean LD agreement declines from pristine to degraded habitats (from rho 0.46 to 0.17), consistent with taphonomic inertia of the DA to a shifting ecological baseline, whereas LL agreement improves (from 0.19 to 0.66) as natural variability is suppressed and dominance by single species increases. Considering only pristine habitats, LD agreement exceeds LL agreement and both vary significantly only with environment: mean LD rho is 0.58 in coastal embayments but only 0.31 on open shelves; mean LL rho drops from 0.33 to 0.10. Thus LD agreement is comparable to LL agreement and varies in parallel, and thus will be a valuable tool for tracking and predicting biotic response to anthropogenic change.

27: 4:00 PM-4:15 PM
Presenter: BAUM, JULIA K.

ECOLOGICAL AND CONSERVATION IMPLICATIONS OF REMOVING TOP PREDATORS FROM THE WORLD S OCEANS

BAUM, JULIA K. , Scripps Institute of Oceanography, University of California, San Diego, 9500 Gilman Dr. (0202), La Jolla, CA, 92093-0202, United States, juliakbaum@gmail.com

Oceanic ecosystems are increasingly impacted by multiple stressors, from exploitation and habitat degradation to pollution and climate change. Among these impacts, the depletion of oceanic predators has elicited considerable concern about the conservation of these species and the fisheries they support. A rich history of evidence from freshwater and nearshore coastal ecosystems, showing that top-down control by predators of their prey populations can be an important determinant of ecosystem structure and function, suggests that predator depletions also may trigger cascading indirect effects through oceanic food webs. Yet until recently there was little evidence for these effects, because of the constraints on studying ecological processes at large spatial and temporal scales in the ocean. Mounting evidence from “pseudo-experimental” ecosystem-scale studies of continental shelves, seas, and the open ocean suggests that predator depletions can indeed significantly alter the abundance of other species, the viability of other commercial fisheries, and the resilience of ecosystems. On the U.S. east coast, for example, depletion over the past 35 years of 11 great shark species that consume other elasmobranchs (sharks, skates, rays) was followed by substantial increases in 12 of 14 of their prey species. Effects of this community restructuring appear to have cascaded downward from one elasmobranch mesopredator, the cownose ray, whose enhanced predation on its bay scallop prey was sufficient to terminate North Carolina s century-long scallop fishery. The likelihood of cascading effects depends both on ecosystem properties, including predator diversity, and the nature of exploitation, which can for example reduce whole predator functional groups. Disentangling cascading effects of predator depletions from other oceanic ecosystem stressors, identifying key stressors, and understanding interactions among stressors is an ongoing challenge, but one that is essential for the successful long-term ocean management and conservation.

27: 4:15 PM-4:30 PM
Presenter: PANDOLFI, JOHN M.

REEFS SINCE CAPTAIN COOK: AN ANTIPODEAN PERSPECTIVE

PANDOLFI, JOHN M., Centre for Marine Studies, University of Queensland, Centre for Marine Studies, University of Queensland, St Lucia, QLD, 4072, Australia, j.pandolfi@uq.edu.au; LYBOLT, MATT; ROFF, GEORGE; NARAYAN, ROSHNI; REYMOND, CLAIRE; CLARK, TARA, Centre for Marine Studies and ARC Centre of Excellence for Coral Reef Studies, University of Queensland, St Lucia, Queensland, Australia, 4072;

In his pioneering study of the past history of Caribbean reefs, Jackson (1997) exposed the fallacy of “pristine” coral reef ecosystems. Since then, trajectories of decline of coastal marine ecosystems, resulting in long term losses of abundance, diversity and habitat structure, have been documented throughout the world. However, little is known about the historical ecology of the Queensland coastline before the first European encounter of Captain James Cook in 1770. We examined historical change in coral reef habitats from the tropical Great Barrier Reef (GBR) and subtropical Moreton Bay (Queensland, Australia) using coral and foraminiferal community structure, in order to quantify the magnitude and rate of ecosystem response to anthropogenic interaction through time. In the inshore regions of the GBR, significant temporal shifts in coral community structure are associated with European settlement of the adjacent Queensland coast around 1864. Historical mortality events resulted in the loss of branching 'acroporid' communities, resulting in shifts in community composition and loss of diversity. This mortality occurred prior to the mass bleaching episodes in 1998 and 2002 and prior to the advent of long-term monitoring. Marginal reefs from Moreton Bay are developed in episodes since 5.5 ka and show high sensitivity to Holocene changes in sea level and ENSO intensity. Despite this, coral and foraminifera community structure was constant and stable among episodes of reef-building. But within decades of European settlement, reef community composition shifted well outside of the historical range of natural variability characteristic of the preceding Holocene. These recent and dramatic ecological changes in community structure are associated with decreased water quality and huge increases in resource exploitation, urbanization, pollution and coastal development. Taken together, these examples provide evidence of widespread habitat degradation since Captain Cook's initial austral encounter, and illustrate Jackson's plea for silencing the notion of 'pristine' ecosystems.

27: 4:30 PM-4:45 PM
Presenter: KAUFMAN, LES

MULTIPLE ALTERNATIVE STATES IN ANTHROPOCENE CORAL REEF SYSTEMS: SLIME IS NOT THE WORST OF IT.

KAUFMAN, LES, Biology, Boston University and Conservation International, Boston University Marine Program, 5 Cummington Street, Boston, MA, 02215, United States, lesk@bu.edu; SHANK, BURTON, Biology, Boston University, 5 Cummington Street, Boston, MA 02215

The notion that recent tropical littoral bioherms exhibit phase shift between hermatypic coral and fleshy algal or cyanobacterial dominance (Jacksonian “slime”) has served as a consensus paradigm for understanding rapid changes in reef structure and function under chronic anthropogenic stress. The key question concerns the reverse transition probability: i.e., can tropical coral reefs regenerate during our lifetimes, or is the Holocene epoch of coral reef growth coming to a close before our eyes? We review the nature and mechanics of the shift in both directions, as informed by a comparative cross-sectional and longitudinal study of four

coral reef systems located in Brazil, Belize, Panama, and Fiji. Loss of coral cover to epizootics and thermal anomalies are pandemic, but circumstantial evidence strongly suggests that eutrophication and overfishing aggravate their impacts. A key process, largely overlooked, is the irreversible degradation and destabilization of reef framework due to a failed regeneration choreography: knock-on mortality of massive corals, recruitment failure by rapid framework-builders, and accelerated carbonate excavation due to endolith release and recovered hard grazer populations. The resulting erosional phase forestalls reestablishment of scleractinian dominance, It is unknown whether local interventions can trigger reverse transition in a new ocean of high temperature and low pH. The way to find out is to experiment.

27: 4:45 PM-5:00 PM
Presenter: HUGHES, TERRY P.

ECOSYSTEMS, PEOPLE AND SCALE: THE “WICKED PROBLEMS™ OF THE GALAPAGOS ISLANDS

HUGHES, TERRY P., ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD, 4810, Australia, Terry.hughes@jcu.edu.au

The geographic isolation that has shaped the unique evolutionary history of the Galapagos has progressively broken down with increased globalization, exposing the islands to global drivers of change – introduced pests, rapid growth in tourism, and inclusion in world markets. In the marine realm, international market drivers have led to illegal fishing by roving bandits and to the sequential collapse of whale, seal, grouper, lobster and sea-cucumber stocks. Recurrent El Niño events are increasing in frequency and intensity, causing unprecedented and increasingly unpredictable ecological impacts, including loss of major habitats and species extinctions. Access to resources has resulted in recurrent conflict between major players – primarily conservationists, fishers, and tour operators - which has been partially resolved by local and national governance. However, the strengthening links between the unique archipelago and globalized society has weakened local institutions that are poorly equipped for coping with large-scale drivers (such as climate change, turbulent global financial markets and external pressures from population and economic growth elsewhere). The Galapagos’ social and ecological system provides a unique window to the future as similar scenarios unfold globally, and demonstrates a universal imperative for coping with change and ecological uncertainty in an increasingly inter-connected world.

27: 5:00 PM-5:15 PM
Presenter: KELLER, BRIAN

SLIPPERY SLOPES AND MANAGEMENT OF MARINE PROTECTED AREAS

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Pandolfi et al. (2005) used the Florida Keys National Marine Sanctuary (FKNMS), a marine protected area managed by the National Oceanic and Atmospheric Administration, as an example of what the U.S. is doing to enhance its coral reef assets. They noted that “the economic future of the Keys is gloomy owing to accelerating ecological degradation” because, “without a clear goal for recovery, development and ratification of the [Sanctuary's} management plan became a goal in itself.” This Policy Forum in the journal *Science* caused a bit of a furor in the Keys, and several letters of clarification or disagreement were published. The authors' response noted that “we need to wake up fast to the true challenges we are facing to save our reefs by quickly following the Australian example of vastly increased protection and by implementing more comprehensive management.” This wake-up call amounts to simultaneously addressing overfishing, pollution, coastal development, and global change (Pandolfi et al. 2005; Jackson 2008). I will discuss findings about marine reserves that have been published since this discussion, particularly with regard to efficacy of marine protected areas in addressing effects of overfishing and ameliorating coral bleaching. Progress on improving wastewater treatment in the Florida Keys has been slow, but has been mandated by the State of Florida with criteria to be met by 2010. Populations of heavily exploited reef fishes increased dramatically within highly protected zones in the FKNMS between 1997 and 2003, only to decline even more dramatically after the active hurricane seasons of 2004 and 2005. A public review of the zoning plan of the Sanctuary has started, which provides an opportunity to increase the proportion of no-take protection from 6%, as was done recently in the Great Barrier Reef Marine Park. Some goals for re-zoning the FKNMS will be discussed.

27: 5:15 PM-5:30 PM
Presenter: KNOWLTON, NANCY

THE FUTURE OF CORAL REEFS

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Coral cover has declined by 80% in the Caribbean and is on the same trajectory in the Pacific. The principle culprits are overfishing, poor water quality, and greenhouse gas emissions. We can in principle do something quickly about the first two of these, and we know that local protection can make a difference to the health of reefs - this is not rocket science. Warming and especially acidification pose more serious threats, in part because reducing greenhouse gases is harder and we are running out of time, and in part because adaptation potential may be limited. Here, rocket science may be needed to figure out how to remove already released carbon dioxide, and how to preserve biodiversity before it is lost forever. Reefs shelter at

least 25% of all marine species, and we know almost nothing about how reef degradation will impact them. The future of reefs will ultimately depend on the degree to which the public and policy makers take the threats to reefs seriously, and that will depend, at least in part, on the willingness of scientists to speak out.

Session No. 28, 8:00 AM (morning session) and 1:30 PM (afternoon session); Friday 26 June 2009
Symposium S16. IGCP 572: Recovery of Ecosystems After the Permo-Triassic Extinction

28: 8:00 AM-8:15 AM
Presenter: ISOZAKI, YUKIO

ILLAWARRA REVERSAL: THE FINGERPRINT OF A SUPERPLUME THAT TRIGGERED PANGEAN BREAKUP AND THE END-GUADALUPIAN (PERMIAN) MASS EXTINCTION

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The Permian magnetostratigraphic record demonstrates that a remarkable change in geomagnetism occurred in the Late Guadalupian (Permian; ca. 265 Ma) from the long-term stable Kiaman Reverse Superchron to the Permian-Triassic Mixed Superchron with frequent polarity changes. This unique episode called the Illawarra Reversal probably reflects a significant change in the geodynamo in the outer core of the planet after 50 million years of stable geomagnetism. The Illawarra Reversal was likely led by the appearance of a thermal instability at the 2,900 km-deep core-mantle boundary in connection with mantle superplume activity. The Illawarra Reversal and the Guadalupian-Lopingian boundary event record the significant transition from the Paleozoic to Mesozoic-Modern world. Major global environmental changes in the Phanerozoic occurred almost simultaneously in the latest Guadalupian; e.g. 1) mass extinction, 2) ocean redox change, 3) sharp isotopic excursions (C and Sr), 4) sea-level drop, and 5) plume-related volcanism. In addition, a change in the core's geodynamo needs more attention as it may have determined the course of the Earth's surface climate and biotic extinction/evolution. When a superplume is launched from the core-mantle boundary, the resultant thermal instability makes the geodynamo's dipole of the outer core unstable, and lowers the geomagnetic intensity. Being modulated by the geo- and heliomagnetism, the galactic cosmic ray flux into the Earth's atmosphere changes with time. The more cosmic rays penetrate through the atmosphere, the more clouds develop to increase the albedo, thus enhancing cooling of the Earth's surface. The Illawarra Reversal, the Kamura cooling event, and other unique geologic phenomena in the Late Guadalupian are all convincingly explained as consequences of the superplume activity that initially triggered the

breakup of Pangea. The secular change in cosmic radiation may also explain the long-term global warming/cooling trend in Earth's history in terms of cloud coverage over the planet.

28: 8:15 AM-8:30 AM
Presenter: ALGEO, THOMAS

A MARINE PRIMARY PRODUCTIVITY CRASH IN THE EASTERN TETHYAN REGION AT THE PERMIAN/TRIASSIC BOUNDARY?

ALGEO, THOMAS, University of Cincinnati, Dept. of Geology, 500 Geology/Physics Bldg, Cincinnati, OH, 45221-0013, United States, Thomas.Algeo@uc.edu; TONG, JINNAN, State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China; FENG, QINGLAI, State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China; HENDERSON, CHARLES, Geology and Geophysics, University of Calgary, Calgary, AB T2N 1N4 Canada

Permian/Triassic (P/Tr) boundary sections across the South China craton exhibit declines in total organic carbon (TOC) of 64 to 97% and in organic carbon accumulation rates (OCAR) of 32 to 76% from the latest Permian to the earliest Triassic. This pattern is in marked contrast to other P/Tr sections globally, most of which exhibit little change or pronounced increases in TOC and OCAR across the boundary. Although many factors influence the production and preservation of organic matter, lithologic and environmental factors are unlikely to account for the observed pattern in the South China region because bulk-sediment lithology changes little at most sites and watermass redox conditions became more reducing in the Early Triassic, which would normally serve to enhance preservation of organic matter. Rather, the near-disappearance of organic matter in basal Triassic units over an area of >1 x 10^6 km^2 may be evidence of a crash in marine primary productivity. The crash coincided with deposition of the most widespread of several rhyodacitic ash layers (the “boundary clay” of Bed 25 at Meishan) that are known to have an origin in the South China region. This association suggests that the productivity crash and attendant decimation of marine fauna on the South China craton was caused by an explosive volcanic event of regional origin, or its aftermath effects, the lethality of which was enhanced by pre-existing climatic and environmental stresses induced by Siberian flood basalt volcanism. Elsewhere globally, increases in TOC and OCAR values across the P/Tr boundary may reflect a fertilization effect associated with the distal fallout of nutrient-rich ash, or with the influx of soil-derived nutrients liberated as a consequence of terrestrial ecosystem destruction.

28: 8:30 AM-8:45 AM
Presenter: STANLEY, STEVEN M.

THREE MASS EXTINCTIONS SUPPRESSED GLOBAL DIVERSITY DURING THE EARLY TRIASSIC: EVIDENCE FROM AMMONOIDS AND CONODONTS.

STANLEY, STEVEN M., Geology & Geophysics, University of Hawaii, POST Bldg. 701, 1680 East-West Road, Honolulu, HI, 96822, United States, stevenst@hawaii.edu

Ammonoids and conodonts underwent severe mass extinctions during the Early Triassuc at the times of three negative global carbon isotopic excursions similar to those associated with the two preceding Permian mass extinctions. Both taxa were characterized by extraordinarily high rates of evolutionary radiation and extinction. They rediversified dramatically between the Early Triassic crises. Estimated mean durations are ~0.7 m.y. for ammonoid genera, which contained and average of 1.4 species, and ~0.9 m.y. for conodont species. The Smithian and Spathian mass extinctions of conodonts both elevated rates of extinction and reduced rates of speciation. Most other marine taxa were held at such low levels of diversity by low intrinsic rates of origination and extinction that their fossil records have failed to reveal their patterns of expansion and contraction during these crises. Furthermore the stratigraphic ranges of these species are not well constrained.Most species arise at small population size. Incipient species of suspension and deposit feeders are likely to suffer rapid extinction because they have the same generalized feeding habits as their congeners and therefore have little chance of expanding their populations markedly relative to other members of their guild. In contrast, species of ammonoids and conodonts, as mobile predators, were probably trophic specialists, so that many incipient species, by exploiting unique food resources (prey species), should have experienced population explosions that led to survival and high rates of speciation. The extant gastropod species *Conus*, which has diversified explosively during the late Neogene, exemplifies this phenomenon.The evidence of multiple mass extinctions for ammonoids and conodonts during the Early Triassic supports the hypothesis previously expressed by other workers that global diversity did not remain low during this ~ 6 m.y. interval because environmental conditions were persistently hostile but because a succession of mass extinctions prevented substantial evolutionary recovery by most taxa.

28: 8:45 AM-9:15 AM
Presenter: RETALLACK, GREGORY J

MULTIPLE GREENHOUSE CRISES OF THE EARLY TRIASSIC (KEYNOTE)

RETALLACK, GREGORY J, Department of Geological Sciences, University of Oregon, Eugene, OR, 97403, United States, gregr@uoregon.edu

The Sydney Basin in southeastern Australia is unique among terrestrial sequences across the Permian-Triassic boundary in the following combination of records: (1) U-Pb SHRIMP and K/Ar dated tuffs; (2) partial paleomagnetic record; (3) organic carbon isotopic records; (4) fossil plants with cuticular preservation, and (5) well developed paleosols. New SHRIMP dates from

the Sydney Basin confirm the new timescale of Ovtcharova et al (2006): a Permian-Triassic boundary at 252.6 Ma, top Spathian at about 248.7 Ma, and thus a short (4 Myr) Early Triassic. Stomatal index of fossil Lepidopteris leaves indicate 5 successive spikes of atmospheric CO_2 coincident with negative spikes of $\delta^{13}C_{org}$ and deep weathering of paleosols: basal Griesbachian (7832 ppmv followed by 836 ppmv), mid-Griesbachian (2845 ppmv followed by 744 ppmv), Smithian (3860 ppmv followed by 305 ppmv), end Spathian (3510 ppmv followed by 1583 ppmv), and early Anisian (3756 ppmv). Successive spikes of atmospheric CO2 of isotopically light composition coincide with unusually warm and wet (Ultisol) paleoclimates for this high paleolatitude sequence (ca. 61°S using Paleomap Platetracker ©). These greenhouse spikes were individually short-lived and more numerous than during the Late Permian and Middle Triassic, and successive crises may account for low diversity, small size, and simple morphology of Early Triassic floras and faunas. Successive greenhouse spikes also coincide with horizons of exceptional fossil preservation, including such famous fossil fish and insect localities of the Sydney Basin as Gosford, Brookvale and St Peters. Successive spikes of isotopically light CO_2 may be due to thermogenic methane formation by intrusion of feeder dikes to Siberian Trap lavas.

28: 9:15 AM-9:30 AM
Presenter: KOZUR, HEINZ W.

DETAILED CORRELATION OF MARINE AND CONTINENTAL BEDS AROUND THE PERMIAN TRIASSIC BOUNDARY (PTB): IMPLICATIONS FOR THE IMPORTANCE OF THE SIBERIAN TRAP FOR THE PERMIAN-TRIASSIC BIOTIC CRISIS

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Conchostracan-rich beds between flood basalts and the underlying thick tuffs of the Tunguska Basin can be correlated with conchostracan faunas of the Germanic Basin (that are correlated with the marine scale) and of Dalongkou. Between the Putorana flood basalts, beds with *Falsisca podrabineki* (restricted to this horizon) and *F. turaica* occur. F. *podrabineki* occurs in the *F. postera* Zone of Germany. The overlying Marininskij flood basalts contain sedimentary intercalations with Falsisca cf. verchojanica, the guide form of the basal Triassic (Kozur, 1998). The PTB therefore occurs within the flood basalts between the postera and verchojanica zones. This conchostracan boundary can also be recognised in Dalongkou, close to the LAD of the Permian vertebrate genus *Dicynodon*, whereas *Lystrosaurus* begins 49 m earlier (Kozur, 1998). In Germany it was confirmed by a minimum in $\delta^{13}C_{carb}$ (Korte & Kozur, 2005). The base of the *F. postera* Zone coincides with the base of the Germanic Buntsandstein and can be correlated with the event boundary (Kozur, 1998, 2007), the main extinction horizon in marine beds, which therefore coincides with the beginning of the Siberian Trap flood basalts. Step by step changes in continental faunas begin much earlier, contemporaneous with the beginning of thick tuffs below the flood basalts and correlative with the *Clarkina bachmanni* conodont

zone, where the gradual decline of $\delta^{13}C_{carb}$ begins. The main conchostracan extinction is marked by the disappearance of the Permian genera *Bipemphigus*, *Megasitum* and *Tripemphigus* in the middle Khungtukun tuffs of the Tunguska Basin and at 107 m above the base of the Guodikeng Fm at Dalongkou. “Triassic type” sporomorphs begin above this level.

28: 9:30 AM-9:45 AM
Presenter: JI, WENTING

LOWER-MIDDLE TRIASSIC CONODONT BIOSTRATIGRAPHICAL SEQUENCE AT QINGYAN SECTION, GUIZHOU PROVINCE, CHINA

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According to the research of Lower-Middle Triassic conodonts from Qingyan Section of Guiyang, Guizhou Province, 28 species in 4 genera that are stratigraphically significant have been recognized and 6 Conodont Zones are identified, in ascending order, they are *Neospathodus dieneri*, *Neospathodus waageni* , *Neospathodus pingdingshanensis*, *Neospathodus homeri* zone, *Chiosella timorensis* and *Neogondolella constricta* Zones. These Conodont Zones in the study area can have significance of correlation with that in other regions. Two important stratigraphical boundaries, the boundary of Induan-Olenekian and the boundary of Olenekian-Anisian, have been identified based on the occurrence of some typical conodont elements. The first appearance of *Neospathodus waageni* which is regarded as the indicator of the Induan-Olenekian boundary, is obtained from the lower-middle part of Luolou Formation and 74.9m above the PTB. Moreover, the boundary of Lower-Middle Triassic (Olenekian-Anisian) is recognized by the first occurrence of *Chiosella timorensis*, occupying in the base of Qingyan Formation.

28: 9:45 AM-10:00 AM
Presenter: VUKS, VALERY JA

EARLY TRIASSIC BIOTA OF THE GORNY MANGYSHLAK AND CAUCASUS

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The Early Triassic biota of the Gorny Mangyshlak and Eastern Precaucasus is mainly represented by bivalves, ammonoids, foraminifers and conodonts. In the first area the bivalve assemblages occur in the upper Induan and Olenekian deposits, but ammonoid, foraminifer and conodont assemblages are distributed in the upper Olenekian. Besides mentioned fauna, the upper Olenekian (the *Columbites* beds) contains abundant recrystallized microgastropods and ostracods. In the second area the mentioned faunal groups are in Olenekian. The richest and various faunal assemblages occur in the *Columbites* beds of the upper Olenekian. The maximal diverse and rich faunal groups correspond to the Late Olenekian time and they indicate more favorable paleoenvironmental conditions in this time.There are bivalves, ammonoids and foraminifers in the Lower Triassic of the Western Caucasus. Bivalve and foraminifer assemblages correlate to the upper Induan and lower Olenekian, and ammonoid assemblage - the lower Olenekian. The maximal variety of the faunal assemblages corresponds to the Early Olenekian time. It marks those more favorable conditions for marine fauna at this time. The foraminifer assemblage was found in the borehole material of the Western Precaucasus and it corresponded to the Olenekian - Anisian. Widely distributed species of foraminifers, conodonts, and ammonoids occur in the Lower Triassic of the mentioned regions. Therefore, it is possible to correlate the Lower Triassic (especially Olenekian) of the Gorny Mangyshlak to coeval deposits of the Eastern Precaucasus, and Western Caucasus, and to the global stratigraphic scale. The Olenekian transgression makes the conditions for existence of the different groups of fauna on the studied territories. This research was supported, at different times, by the Peri-Tethys Program, the Cariplo Foundation and Landau Network - Centro Volta. This work is a contribution to the IGCP 572.

28: 10:45 AM-11:00 AM
Presenter: BUCHER, HUGO F.R.

HIGH-RESOLUTION BIOCHRONOLOGY AND TAXONOMIC RICHNESS OF EARLY TRIASSIC AMMONOIDS AND CONODONTS: WHY METHODOLOGY MATTERS

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Owing to their unrivalled evolutionary rates during the Early Triassic, ammonoids and conodonts are ideal organisms for biochronology studies of that period. Since the foundation[1] of the modern Early Triassic ammonoid zonation, maximal assemblage or association zones (MAZ), which closely compare with Oppel zones and Unitary Associations, have been used.

Such MAZs take into account the discontinuous nature of the fossil record, which consists of a blend of the primary chronological signal of species turnover together with: ecological control over the distribution of taxa, sedimentary gaps, selective preservation, and sampling biases. Recently, inverse Monte Carlo-based simulations have also shown that the difference of taxonomic richness between two consecutive MAZs is independent from their respective duration[2]. Hence, MAZs yield robust and reliable diversity counts. Early Triassic conodont biostratigraphy has followed a different route, relying essentially upon interval zones. The basic assumption behind the use of this kind of zones (based on "bio-events") is that the FAD of an index species must be synchronous. Yet, whatever the dispersal rate of a new species, speciation is intrinsically a geographically restricted process, thus theoretically limiting the validity of this assumption to an unknown area. A single contradiction in the superpositional order of two FADs, or a single contradiction in the relative position of a FAD with a global, chemical or physical marker invalidates the zonation. We show that none of the conodont FADs proposed so far for Early Triassic stage boundaries (Changsingian-Induan, Induan-Olenekian, Olenekian-Anisian) escapes such contradictions, which has also significant consequences for the computing of diversity curves. Only the use of conodont MAZs will improve the robustness of our biochronological zonations and provide reliable diversity counts.1 Silberling NJ & Tozer ET 1968 Geol. Soc. Amer. Spec. Pap. 110.2 Escarguel G & Bucher H 2004 Pal. Pal. Pal. 202: 181-208.

28: 11:00 AM-11:15 AM
Presenter: KAIM, ANDRZEJ

BELEROPHONTID DOMINATED ASSOCIATIONS OF LOWER TRIASSIC GASTROPODS FROM SOUTH PRIMORYE, RUSSIA

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A 165-m-thick section of Lower Triassic strata in Abrek (South Primorye, Russia) yields abundant and well preserved fossils. A multidisciplinary study carried out due to Japanese-Russian Research Program resulted in a monograph describing the paleontological content of the locality, establishing detailed stratigraphical layout and discussing paleogeographical implications of the fauna. Ammonoids, nautiloids, gastropods, bivalves, brachiopods, conodonts, and shark fossils are abundant throughout the sequence, while crinoids and scaphopods are present only in the upper part. Based on these ammonoids and conodonts, the sequence ranges in age from Early Induan (Griesbachian) to middle Early Olenekian (middle Smithian). The gastropods occur in rich accumulations at several layers throughout the section. Of special interest are accumulations of bellerophontid shells belonging to two new species of *Warthia* and *Bellerophon* respectively. *Warthia* sp. nov. occurs in four layers (2 Griesbachian, 1 Dienerian and 1 Smithian) while *Bellerophon* sp. nov. occurs in three layers (1 Griesbachian and 2 Dienerian. Both species have never been found in the same layers though in places they form a bellerophontid-dominated coquina. The associations of remaining

gastropods are similar in several aspects to the Lower Triassic gastropods from Sinbad Formation in Utah. The shells have been classified to the following genera: *Worthenia*, *Chartronella*, *Strobeus*, *Coelostylina*, *Omphaloptycha* and a new genus based on *Naticopsis depressispirus* Batten and Stokes, 1983. Numerous are also protoconchs of unidentified genus and species of Trachyspiridae. The shells are usually well preserved including also fine details of their protoconchs. Both species of bellerophonts attain the size of nearly 18 mm in length. The largest specimen of canogastropod has been found in the uppermost Griesbachian and identified as *Omphaloptycha hormolira*. The specimen is 15 mm in height. The other gastropods range from nearly 2 mm high *Strobeus* sp. nov to nearly 9 mm wide *Naticopsis depressispirus*.

28: 11:15 AM-11:30 AM
Presenter: NÜTZEL, ALEXANDER

THE ROLE OF GASTROPODS IN THE EARLY TRIASSIC RECOVERY PROCESS

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Gastropods are present in many marine biota of the Early Triassic and commonly they form an important part of faunas. It has previously been emphasized that the end-Permian mass extinction event did affect gastropods (and bivalves) not as seriously as other invertebrate clades. Moreover, gastropods recovered quickly and consequently they became one of the most diverse invertebrate clades of the modern fauna. However, the study of well-preserved Late Paleozoic faunas shows that gastropods were obviously more important prior to the extinction than previously assumed. Gastropod body size as reflected by shell size is increasingly discussed as a proxy for environmental conditions in the aftermath of the end-Permian mass extinction event. However, there is no consensus about what a microgastropod is and any definition of this term is inevitably arbitrary. Moreover, most modern gastropod species and probably most fossil gastropod species are small animals. Size distribution diagrams of several Triassic gastropod faunas are compared. Gastropods from some collections of the Early Triassic Werfen Formation (Italy) are as large as gastropods from some collections from the Late Triassic Cassian Formation. Preservation and sampling (lithification, size selective collecting) may bias analyses of size distributions of fossil gastropods. However, it seems to be a correct observation that very large gastropods (c. 10 cm) are absent in the Early Triassic. The poor preservation of most known earliest Triassic gastropod faunas represents a handicap for taxonomy and diversity analyses. In general, gastropod alpha diversity seems to have increased considerably from the Induan to the Olenekian. Probably contemporaneously with the Anisian/Ladinian re-establishment of a tropical metazoan reef belt in the Tethys including a large number of ecological niches, gastropods had fully recovered.

28: 11:30 AM-11:45 AM
Presenter: ZAKHAROV, YURI D.

RECOVERY OF THE BRACHIOPOD AND AMMONOID FAUNAS FROM THE PERMIAN-TRIASSIC ECOLOGICAL CRISIS: NEW EVIDENCE FROM THE LOWER TRIASSIC OF THE FORMER USSR

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The Induan of South Primorye (SP) is characterized by seven articulate brachiopod species: early Induan *Lissorhynchia* sp. and six late Induan species, including *Abrekia sulcata* and new ones. Early Olenekian brachiopods from SP show a slight reduction in species number, largely due to a variety of facial conditions. Middle Olenekian brachiopods from SP (about eight species, including new ones) are diverser than those from Mangyshlak. In addition, information on late Olenekian brachiopods from SP (about five species, including new ones) and Mangyshlak (12 species), as well as the published data on Olenekian species from Eurasia and North America, illustrates a general trend in marked rising of taxonomic diversity of Mesozoic-type brachiopods from the lower Induan through the upper Olenekian. Basal beds of the Induan in Transcaucasia and Verkhoyansk are characterized by monospecific ammonoid assemblages. The Induan, lower, middle and upper Olenekian in SP are characterized by 20, 71, 11 and 30 species, respectively. Similar changes in ammonoid succession, with highest diversification for the early Olenekian, occur in some other Tethyan regions. Abundant Induan and Olenekian ammonoid assemblages are common also for the Boreal realm. However, no articulate brachiopods have been discovered in the Lower Triassic of Siberia. New results support the view (Zakharov, 1977) that achievement of biological progress by some groups of organisms, went through the end-Permian crisis, was realized by different ways: e.g. ammonoids have restored and exceeded their former taxonomic diversity and abundance in the early Olenekian. In sharp contrast, brachiopods have not reached a similar rate in recovery during early Triassic (even Mesozoic-Cenozoic) time. Migration of Induan brachiopods (*Obnixia* and *Hustedtiella*?) to the high latitudes was restricted. However, ammonoids occupied many regions of the Boreal realm immediately after the end-Permian extinction event. This research was carried out with the financial support of RFBR grant 09-05-98524-R_vostok_a, Russia.

28: 11:45 AM-12:00 PM
Presenter: SHISHKIN, MIKHAIL A.

PATTERNS OF AMPHIBIAN DIVERSIFICATION DURING TRIASSIC BIOTIC RECOVERY

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Decline of temnospondyl amphibians toward the end of the Permian led to restriction of their dispersal to Euramerican and Southern Gondwanan domains, with their inhabitants being dominated in each area by just a single family (Dvinosauridae and Rhinesuchidae, respectively). This picture underwent total re-modelling due to Permian-Triassic faunal turnover. Permian extinction that affected all the basic components of the tetrapod fauna resulted in different starting conditions for their subsequent recovery. In contrast to reptiles, the diversity of temnospondyl amphibians in the earliest Scythian increased in comparison with the pre-extinction biota, as documented by expansion of 4-5 new widespread aquatic families. The key event behind this change was an overall uplifting of Pangea, which led to increase in aridity on land and to dismembering of former lowland biotopes. All this forced the tetrapod life to concentrate close to local water basins, which gave an advantage to aquatic and amphibiotic forms. The process of recovery of temnospondyls in the Triassic shows two principal patterns. The earlier of them (mostly corresponding to Induan -Early Olenekian) can be outlined as explosive radiation and resulted in quick worldwide expansion of a few ephemeral lineages. The rest of the Triassic was characterized by a more gradual and conservative evolution, as is documented by the history of advanced capitosauroids, metoposaurs and plagiosaurs. This run of events reflects general trend toward stabilization of newly formed Early Mesozoic biota. In this light, the earlier (explosive) evolutionary pattern indicates the condition of devastated biotic environment with weakened ecosystemic control, which much extended the possible scope of viable modifications of the body plan within particular lineages. This phenomenon, known as an archaic diversity, is best demonstrated by the families Tupilakosauridae and Rhytidosteidae, whose morphotypes display unique combinations of advanced and ancestral characters known nowhere else among the early tetrapods.

28: 1:30 PM-1:45 PM
Presenter: CHEN, ZHONG QIANG

MARINE ECOSYSTEM EVOLUTION FOLLOWING THE PERMIAN-TRIASSIC MASS EXTINCTION IN THE GONDWANAN INTERIOR SEA

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The Permian-Triassic (P-Tr) mass extinction redirected dramatically the course of biotic evolution during the Mesozoic and Cenozoic. This event and its consequence have been

globally studied. However, few data about this ecologic crisis and subsequent recovery are known from Gondwana. Here, we report the evolution of marine ecosystems in the aftermath of the P-Tr mass extinction recorded in the Perth Basin, which was part of the interior sea of the Gondwana during the P-Tr transition. The P-Tr boundary and Early Triassic successions are seen in borehole cores as well as outcrop sections in the northern Perth Basin (NPB). A complete P-Tr boundary sequence is revealed in the Well Hovea-3 of the basin. The latest Permian succession records a diverse faunal assemblage. The early Induan succession seen in the drill cores indicates a harsh (probably poorly oxygenated) environment. The Early Triassic (mainly Dinerian-Smithian) successions are also exposed in the north Geraldton areas, where the stromatolites, resting on either pebbles or sandstone of the Silurian age, characterize the base of the section. Both pustular and smooth stromatolites and their growth patterns, including laminated mats and columns, as well as the associated microbial assemblages are well analogous to modern stromatolites in the Shark Bay. Following the stromatolites sequence, the reddish muddy limestone contains conspicuous wrinkle structures, shell beds and trace fossils. Abundant and diverse trace fossils are present in both exposures and drill cores. Briefly, the ecosystem in Gondwana has been destroyed by the P-Tr extinction and became unfavorable to most biota expect few disaster taxa within >one modillion years after the event. The restoration of marine ecosystems started in late Induan when stromatolites grew widely in the NPB. Ecosystem's amelioration is indicated by increase in diversity and complexity of trace-fossil assemblages recorded in the Kockatea Shale in the basin.

28: 1:45 PM-2:00 PM
Presenter: TONG, JINNAN

EARLY TRIASSIC FACIES AND MARINE ECOSYSTEM RESTORATION IN SOUTH CHINA

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Adverse environments and misshapen ecosystems occupied the Early Triassic. Through the Early Triassic the Paleozoic ecosystems lasting over 200 Ma and dominated by sessile, filter-feeding, epibenthic animals were replaced by the Mesozoic ecosystems of mobile epibenthic and endobenthic, and carnivorous animals with high metastasis. The late Permian facies differentiation supporting flourishing Paleozoic ecosystems in South China collapsed with the main end-Permian mass extinction. Then a uniform P/T “Transitional Bed” (TB) covered various facies throughout South China, indicating a homogeneous paleogeographic and sedimentary facies inhabited by the “mixed faunas” composed of many Paleozoic survivors and few Mesozoic newcomers. An “argillaceous rock member” (ARM) overlying the TB

widespread in earliest Triassic indicates a further deterioration of the ecological environment with the subsequent extinction of survivors. The ARM ecosystem is characteristic of prolific disasters with r-strategists but lack of K-strategists. The TB ecosystems after the mass extinction show quite "unusual ecological structures" composed mostly of cyanobacterian producers or only disaster taxa such as *Claraia*. But the ARM might represent the deepest crisis of ecosystem. Then the facies differentiation occurred with the restoration of ecosystem though it was bounded by some intermittent events. Early Triassic paleogeography and sediments of South China can be divided into 7 facies. Each facies had maintained different faunas and constructed different ecosystem successions. *Claraia*-type disaster taxa inhabited a wide range of facies, whereas shallow facies were predominated by the bivalves such as *Myophoria*, *Unionites*, and *Eumorphotis*, and deep facies had supported more nektonic animals such as ammonoids and fishes. But micro-organisms such as cyanobacterian contributed lot to the carbonate buildups. A well-structured ecosystem representing the full recovery and radiation of the Mesozoic communities occurred in the platform margin carbonate rocks facies at Qingyan, Guizhou Province. The Qingyan Fauna contains about 300 species of 17 groups and it is dated in the late Anisian.

28: 2:00 PM-2:15 PM
Presenter: SONG, HAIJUN

THE TIME AND PROCESSES OF BIOTIC RECOVERY FROM THE END-PERMIAN MASS EXTINCTION: EVIDENCE FROM MICROFOSSILS IN SOUTH CHINA

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More than 7563 individuals belonging to 131 species in 83 genera (including foraminifers, algae, and *Tubiphytes*) were obtained by a high resolution sampling from four sections (Qingyan section, Bianyang section, Guandao section, and Dajiang section) in Guizhou Province, South China. Most of these individuals are from Lower and Middle Triassic, adding to detailed conodont work in these sections, which may be the best data for researching the time and processes of the biotic recovery from the end-Permian mass extinction. Our data show that biotic recovery begins at early Smithian, and about 11 Triassic foraminiferal species and one common Middle Triassic reef-building taxon *Tubiphytes* occurred in the Smithian. The beginning of biotic recovery goes with the dramatic environmental changes, such as rapid increase of $\delta^{87}Sr$, the most prominent positive $\delta^{13}C$ shift, and the first extensive increase of ocean oxygen. The abundance and diversity of foraminifera, algae and Tubiphytes grow up

to a higher level in the Early Anisian and keep stable in the Middle and Late Anisian. The appearance of most common taxa in Early Anisian means that the main recovery stage has completed, which goes with the beginning of stable environment, such as the decrease of $\delta^{87}Sr$ and subsequent stability, the beginning of stable $\delta^{13}C$ in the Triassic, high level of ocean oxygen. The Shannon index and Dominance of foraminifera in South China indicate that the biotic recovery is a gradual process. The Shannon index of foraminifera in Late Permian is approximately 3.0, and decreases to nearly 0 in the aftermath of end-Permian extinction. After the survival stage (Griesbachian and Dienerian), the Shannon index grows gradually from about 0.6 in Early Smithian to almost 2.0 in Early Anisian, and keep the same level in Middle and Late Anisian. The evolution trend of Dominance is similar with Shannon index.

28: 2:15 PM-2:30 AM
Presenter: METCALFE, BRETT

CHANGES IN THE RATE OF GROWTH OF 'LILLIPUT' ANIMALS IN THE EARLIEST TRIASSIC

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Simultaneous marine and terrestrial ecosystem collapse at the end of the Permian led to the largest mass extinction of the Phanerozoic era. Associated with this extinction event are widespread deposits of black shales with faunal, geochemical and molecular evidence of euxinic and anoxic conditions. Previous studies have also reported primary productivity collapse within these marine environments. Species that survive the end-Permian extinction are all much smaller than their predecessors; a phenomenon termed the Lilliput effect, which is probably caused by the prevailing environmental conditions. Taxa that first appear in the immediate extinction aftermath are also small. The Lilliput effect is a temporary phenomenon, with most taxa (e.g. *Lingula*) returning to pre-extinction size in the first two conodont zones of the Triassic. In this study the rates of growth of some of these Lilliput animals were compared from different stratigraphic levels to determine how growth rate varied as body size recovered after the event. Measurements of the bivalves *Unionites* and *Claraia* and the brachiopod *Lingula* were made in the field, with subsequent growth line analysis conducted on well preserved specimens of *Claraia* and *Lingula*. Specimens were collected from the post-extinction Mazzin and Siusi Members (*Hindeodus parvus* - *Isarcicella isarcica* zones) of the Werfen Formation in northern Italy, from facies deposited in lower to mid carbonate ramp settings. Specimens collected from the Mazzin Member were smaller than the stratigraphically higher Siusi Member samples. Results of growth line analysis indicate that smaller (older) specimens had a greater quantity of more closely spaced growth lines than larger (younger) specimens. This indicates that the individual Lilliput animals in the immediate aftermath of the end-Permian event suffered more interruptions to growth and had overall a slower growth

rate. Presumably this reflects the frequency or severity of low oxygen episodes, temperature extremes or disruptions to primary productivity.

28: 2:30 PM-2:45 PM
Presenter: HUANG, YUNFEI

ECOLOGICAL SIGNIFICANCE OF THE EARLIEST TRIASSIC BIVALVE COMMUNITIES IN WEST GUIZHOU AND EAST YUNNAN

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The Zhongzhai and Tucheng sections in west Guizhou and east Yunnan, located at the east margin of the Chuandian paleocontinent, deposited a suite of clastic rocks with abundant benthic faunas dominated by bivalves, brachiopods and gastropods. Based on the data of conodonts and bivalves from the study area, the Permian-Triassic boundary has been fixed and the ecological evolution of the bivalves has been discussed in the paper. The earliest Triassic marine community in Zhongzhai section is named *Claraia* community, and in Tucheng section *Promyalina-Pteria-Towapteria* community. The *Promyalina-Pteria-Towapteria* community appeared after first appearance of *Hindeodus parvus* and prior to that of *Claraia wangi*. *Promyalina* and *Pteria* are dominant and characteristic genera in surviving interval following the end-Permian mass extinction in Tucheng section while *Claraia* is the main genus in Zhongzhai section, Then their ecological respondings are analysed from life styles, food resources and ecological strategies. Through our finding, all these genera are epi-bysaate and suspension-feeding styles. The diversity of either *Pteria-Promyalina* community or *Claraia* community is very low. It can be concluded that the environment was likely unstable with high energy, hypoxia and lack of organic matters in the sediments, which may restrain survival of other species. Moreover, shell sizes were measured to distinguish mature individuals from juvenile individuals. We got the same result in two communities that the juveniles are dominant, reflecting the ecologic strategy of r-selection for the *Pteria*, *Promyalina*, and *Claraia* to adapt to the unfavoured environment.

28: 2:45 PM-3:00 PM
Presenter: FRAISER, MARGARET

PALEOECOLOGY OF EARLY TRIASSIC SKELETOBIONTS

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The end-Permian mass extinction was the most severe mass extinction of the Phanerozoic, and lasting, widespread ecologic changes in the terrestrial and marine realms resulted from this event and associated environmental conditions. The focus of biodiversity and paleoecology studies of the Paleozoic/Mesozoic transition has been primarily skeletonized benthic or nektonic marine organisms. The ecology of secondary tierers or skeletobionts, the organisms that use the shells of other organisms to maintain a life position above the substrate, has been largely ignored. Skeletobionts encrust and bore into live or dead organisms and can comprise a significant proportion of benthic communities. They provide ecological and evolutionary information about paleocommunity dynamics, environmental conditions, and the life habits of host organisms (Lescinsky, 1996). The record of skeletobionts during the Paleozoic-Mesozoic transition has not been documented, so it is unknown how this aspect of paleocommunities was affected during this crucial interval in Earth history. Field work in the western U.S. and China combined with a literature search revealed that skeletobionts encrusted skeletonized marine organisms through the Early Triassic. The most common skeletobionts were microconchid tube-worms; some disarticulated bivalve shells are nearly completely covered by the skeletons of these encrusting organisms. The diversity of skeletobionts was very low (typically 1 taxon per valve or collection), but preliminary evidence indicates that diversity may increase through the Early Triassic. Skeletobionts are most abundant on bivalves. Collected data will reveal any skeletobiont macroevolutionary trends that were affected during the Paleozoic-Mesozoic transition, and will be used to test hypotheses for the cause of delayed biotic recovery following the end-Permian mass extinction.

28: 3:00 PM-3:15 PM
Presenter: KERSHAW, STEPHEN

WHAT EXACTLY IS A MICROBIALITE? LESSONS FROM THE PERMIAN-TRIASSIC BOUNDARY

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Microbialites take a wide variety of forms, commonly considered as falling generally into four principal varieties: stromatolite, thrombolite, leiolite, dendrolite. In some settings more than one of these may be found together in the same rock sequence, and suggest that variations in environmental forcing (such as depth and energy in open marine settings) controlled their

form. In the Permian-Triassic boundary interval, microbialites are often found in association with oolites; some authors have proposed that there is a causal relationship such that the removal of skeletal macrofossils led to excess carbonate available, and hence oolites formed. However, there are two different views on the status of oolites in the PTB interval: 1. some have further argued that oolites themselves may be considered as a form of microbialite, and have included oolites as part of a microbialite sequence; this is based on continuing discussion about the exact controlling processes which lead to ooid formation. 2. Nevertheless, there are numerous occurrences of oolites in the geological record that are unrelated to mass extinctions, and so an alternative view is that oolites should be considered separate from microbialites in mass extinction studies; that would lead to revision of the thicknesses of PTB microbialites in some cases. In this viewpoint, oolites play an important role in determining the depositional environments of microbialites, and emphasizes the contrast between formation processes of oolites and the four major microbialite groups. The preference of the present authors is for viewpoint 2.

28: 3:15 PM-3:30 PM
Presenter: CHEN, LIN

MOLECULAR RECORDS OF MICROBIALITES ACROSS THE PERMIAN-TRIASSIC BOUNDARY IN SOUTH CHINA

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Calci-microbialites were formed by various microbial mats that trapped and bound sediments. These rocks were widely distributed in the Precambrian but decreased sharply in the abundance in the Phanerozoic due to the radiation of faunas. Significantly, these calci-microbialites resurged during the biotic crises in Earth history, such as Early Triassic, Late Devonian, Late Ordovician, etc. On the basis of the analysis of gas chromatography (GC) and GC-mass spectrometry, a variety of significant biomarkers, including C15-C35 n-alkanes, pristane, phytane, C29-C34 triterpanes, C27-C29 regular steranes, phenanthrene, dibenzofuran, dibenzothiophene, and polycyclic aromatic hydrocarbons, were identified in Late Permian and Early Triassic carbonate rocks and in particular microbialites from the Huayingshan section, Sichuan Province, South China. All the samples collected from the carbonate rocks, including the calci-microbialite, show an invariant, monomodal distribution in the n-alkane carbon number, with the dominant homologues being C17 or C18. The dominance of lower-molecular-weight n-alkanes suggests the main organic input from algae and bacteria for the section investigated herein. Dibenzofuran (DBF) and its derivatives are believed to be common components in the aromatic fration of the extracts from terrestrial sediments. It has been demonstrated that enhanced terrestrial input, due to the enhanced erosion resulting from the collapse of rooted plants, caused an elevated abundance in DBF in marine sediments across the Permian-Triassic boundary. The relative higher values in the ratio

of DBF/(DBF+DBT+fluorene) are indicative of the enhanced abundance of DBF in calci-microbialite. In particular, an abrupt increase in the DBF/(DBF+DBT+fluorene) ratio was observed at the base of microbialite, consistent with the DBF records of the GSSP section at Meishan, Changxing, China. These integrated data are suggestive of the enhanced weathering immediately after the onset of end-Permian faunal mass extinction.

28: 4:00 PM-4:15 PM
Presenter: TWITCHETT, RICHARD J.

PALEOENVIRONMENTS AND ICHNOLOGY OF THE LOWER-MIDDLE TRIASSIC INAI GROUP OF MIYAGI PREFECTURE, NORTHEAST JAPAN: BIOTIC RECOVERY ON THE MARGINS OF PANTHALASSA

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The recovery of the benthic marine ecosystem can be studied in several ways. Incorporating evidence from ichnology is especially useful as trace fossils are the only records of the biotic responses of the soft-bodied organisms, which comprise the majority of the benthic community. Recently, a model was published [Twitchett, 2006, Palaeogeography, Palaeoclimatology, Palaeoecology, 232, pp. 190-213] that divided post-Permian biotic recovery into four discrete stages partly defined on the changing characteristics of the trace fossil community. This model has been used to demonstrate that recovery rates were variable in the Early Triassic, with highest rates in low-latitude seamounts and higher paleolatitude shallow shelf seas. These patterns have been confirmed in other studies. Here, data is presented on the ichnology of a mid-paleolatitude, siliciclastic shelf from the western Panthalassan margin, exposed today in Miyagi Prefecture, northeastern Japan. The early Olenekian Hiraiso Formation contains abundant higher tier crinoids and a trace fossil assemblage dominated by *Rhizocorallium*. This fauna is typical of Recovery Stage 3, which is not normally encountered in lower palaeolatitude shelf seas until the late Olenekian, but which may occur in higher paleolatitudes in the early Induan. This is further evidence of a latitudinal control on the rates of post-Permian recovery. Increases in burrow depth and size also reflect the recovery process and changing environments. A final (Stage 4) recovery fauna comprising large-sized *Thalassinoides* in a diverse ichnoassemblage is not encountered until the well-bioturbated shelf sediments of the latest Olenekian/early Anisian.

28: 4:15 PM-4:30 PM
Presenter: ZONNEVELD, JOHN-PAUL

ROLE OF ARTHROPODS IN TRIASSIC MARINE FAUNAS IN THE POST END-PERMIAN EXTINCTION RECOVERY INTERVAL

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The fossil record of Mesozoic marine arthropods is patchy. Thus their role in survival faunas after the end-Permian extinction is poorly known. However, trace fossils attributable to arthropod activity are comparably abundant and provide an excellent proxy for assessing the abundance and significance of these taxa in the absence of adequate body fossil data. Lower and Middle Triassic marine successions of western and northern Canada are characterized by locally diverse and abundant, primarily diminutive trace fossil assemblages. Trace fossils inferred to have been constructed by arthropods (eg. *Cruziana*, *Diplichnites*, *Kouphichnium*, *Monomorphichnus*, *Rhizocorallium*, *Thalassinoides*, *Trichophycus* and *Spongeliomorpha*) dominate Induan offshore transition to lower shoreface successions deposited on the northwestern coast of Pangaea. Although trace fossils attributed to other invertebrates also occur, arthropod constructed traces comprise disproportionately dominant components of the shallow marine infauna and epifaunal in these successions. In addition, many of these trace fossil taxa are typical Paleozoic forms (eg. *Cruziana*, *Monomorphichnus*, *Rusophycus*, and *Trichophycus*). Their presence in Lower Induan strata indicates either the presence of Paleozoic holdovers in northwestern Pangea or alternatively evolutionary convergence in the functional morphology of marine arthropods. Olenekian successions in the same geographic region contain modestly healthy and robust ichnofacies. Arthropod-constructed traces (including some exceptionally large forms) are dominant components of many shallow marine successions. However the arthropod bias is not as pronounced as that observed in Induan successions. By the Middle Triassic the arthropod bias disappeared and shallow marine trace fossil successions possess ichnofaunas that exhibit a similar balance of forms. Induan arthropod-dominated trace assemblages record an ecologically unbalanced post-apocalyptic, dystopian world dominated by carnivorous and detritus-feeding arthropods. Olenekian shallow marine faunas exhibit a segue into stronger ecological balance with Middle Triassic faunas exhibiting similar proportions to later Mesozoic and Cenozoic successions.

28: 4:30 PM-4:45 PM
Presenter: MATA, SCOTT A.

BIOGENIC STRUCTURES FROM THE LOWER TRIASSIC OF THE SOUTHWESTERN UNITED STATES: AN EXAMPLE OF THE IMPORTANCE OF DEPOSITIONAL ENVIRONMENT IN EXAMINING THE RECOVERY FROM THE END-PERMIAN MASS EXTINCTION

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The largest mass extinction of the Phanerozoic occurred during the Permian-Triassic transition and has been associated with a prolonged bout of anoxia and euxinia that spread across many marine basins during the Late Permian and Early Triassic (Isozaki, 1997). This environmental stress appears to have originated in the deep ocean and periodically impinged upon the continental shelves, resulting in a suppression of infaunal activity (e.g., Twitchett and Wignall, 1996).The use of biogenic structures as a proxy for the recovery from the end-Permian mass extinction has great utility because, unlike body fossils, biogenic structures such as trace fossils are not susceptible to transport, and can be readily and accurately ascribed to specific depositional environments. This study focuses on the environmental distribution of biogenic structures - including trace fossils and microbial structures - from the Lower Triassic Virgin Limestone Member of the Moenkopi Formation of the southwestern United States. Trace fossils reveal strong onshore-offshore gradients in diversity and extent of bioturbation. Nearshore assemblages are typically characterized by higher trace fossil diversities than contemporaneous offshore assemblages, and overall levels of bioturbation are much higher as well. Wrinkle structures - a microbially induced sedimentary structure - appear to mark the divide between nearshore and offshore trace fossil assemblages. These microbial features are believed to form under low levels of bioturbation and thus indicate ambient environmental stress (Pruss et al., 2004). Wrinkle structures formed primarily on proximal sandy storm layers deposited just below the shoreface, as well as across marine flooding surfaces in which the shoreface was submerged below fair-weather wave base.This study reinforces previous work that has shown that environmental stress (i.e., low oxygen conditions) may have crept into very shallow marine environments, and that wave-swept shoreface environments may have served as a refuge from these prevailing conditions (Beatty et al., 2008).

28: 4:45 PM-5:00 PM
Presenter: CHEN, JING

PALAEOECOLOGY AND TAPHONOMY OF TWO BRACHIOPOD SHELL BEDS FROM THE ANISIAN (MIDDLE TRIASSIC) OF GUIZHOU, SOUTHWEST CHINA: RECOVERY OF BENTHIC COMMUNITIES FROM THE END-PERMIAN MASS EXTINCTION

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Two brachiopod shell beds are documented from the Anisian Qingyan Formation at Qingyan, Guizhou province, southwest China. Taphonomic evidence indicates that the shell bed from the Yingshangpo Member of the Qingyan Formation, namely the *Madoia* sp. (M) assemblage, represents an autochthonous assemblage. This assemblage may have inhabited a low-energy, calm environment and the shells have been transported very little but undergone a long-term off burial after death. Another shell bed preserved in the Leidapo Member of the Qingyan Formation is termed the *Rhaetina angustaeformis* (R) assemblage, which represents either a paratochthonous assemblage or a residual and sorted but in situ assemblage living in a high-energy habitat. The M assemblage might be one of the recovery benthic communities following the end-Permian mass extinction because it not only has a much greater diversity, lower dominance, and higher evenness than the Early Triassic brachiopod assemblages, but it also shares similarities with the Changhsingian communities in terms of diversity indices. The Anisian brachiopod assemblage is also similar to the early Wuchiapingian recovery fauna in all diversity indices, but lacks distinctive Lazarus, surviving and generalist taxa, which are characteristic of the recovery shelly faunas following the end-Guadalupian mass extinction. This is probably responsible for the different faunal radiations after the biotic recovery following the end-Permian and end-Guadalupian mass extinctions, respectively. Brachiopod faunas rapidly diversified and proliferated in the middle-late Wuchiapingian, but patchily diversified in the Anisian in South China. In addition, a model of ecological strategy has been established to reveal the evolutional process of ecosystem through the end-Permian to middle Triassic.

28: 5:00 PM-5:15 PM
Presenter: GREENE, SARAH E.

THE MESOZOIC RETURN OF PALEOZOIC FAUNAL CONSTITUENTS: A DECOUPLING OF TAXONOMIC AND ECOLOGICAL DOMINANCE DURING THE RECOVERY FROM THE END-PERMIAN MASS EXTINCTION

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The Sepkoski diversity curve illustrates that the transition from taxonomic dominance of the Paleozoic Fauna to taxonomic dominance of the Modern Fauna is coincident with the Permo-Triassic boundary. Although a corresponding transition in ecological dominance must have occurred, its timing is unknown. One way to assess ecological dominance during the Early-Middle Triassic recovery interval is through the study of bioclastic accumulations. Early

Triassic bioclastic accumulations are largely dominated by constituents of the Modern Fauna. In this study, we examined bioclastic accumulations from the Middle Triassic, the interval after the environmental stress associated with the end-Permian extinction abated. Bioclastic accumulations from Panthalassan deposits (Ladinian Liard Formation at Williston Lake, British Columbia) and Tethyan deposits (Anisian-early Ladinian Muschelkalk Group, Germany) were examined. From the Liard Formation a total of 58 bioclastic accumulations were surveyed, of which 33 were dominated by terebratulid brachiopods, 23 were encrinites, and 2 were brachiopod-encrinite composites. From the Muschelkalk Group, 32 bioclastic accumulations were tabulated, of which 24 were bivalve-dominated and 8 were encrinites. Although the most common shell bed-producer differed between the two sites (bivalves, constituents of the Modern Fauna, in Germany and brachiopods, constituents of the Paleozoic Fauna, in Canada), both sites, though geographically disparate, contained significant encrinites.Crinoids, like many constituents of the Paleozoic Fauna, suffered drastic diversity losses at the end-Permian mass extinction and maintained relatively low diversity through the Middle Triassic. Despite reduced diversity, bioclastic accumulations show that crinoids regained some measure of ecologic dominance in the Middle Triassic. In addition, brachiopods, another constituent of the Paleozoic Fauna that suffered severe diversity losses at the end-Permian extinction, regained at minimum local ecological dominance in the Middle Triassic of Panthalassa. These data demonstrate that the transition to Modern faunal taxonomic dominance was decoupled from the transition to Modern faunal ecological dominance.

28: Poster
Presenter: CHONGLAKMANI, CHONGPAN

THAILAND PERMIAN-TRIASSIC BOUNDARY SEQUENCES. For full abstract, see *17: 2:00 PM, Booth 15*

28: Poster
Presenter: JACOBSEN, NIKITA D

PALAEOECOLOGICAL CHANGE THROUGH THE PERMIAN-TRIASSIC MASS EXTINCTION EVENT: COMPARISON OF METHODS. For full abstract, see *8: 2:00 PM, Booth 40*

Session No. 29, 8:00 AM; Friday 26 June 2009
Symposium S17. Progress and Perspectives on Paleontology in China

29: 8:00 AM-8:15 AM
Presenter: XIAO, SHUHAI

SIMS SULFUR ISOTOPE ANALYSIS OF PYRITE RIMS IN CHERT NODULES FROM THE EDIACARAN DOUSHANTUO FORMATION: IMPLICATIONS FOR THE ROLE OF SULFATE REDUCTION BACTERIA IN CHERT NODULE FORMATION

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The lower Ediacaran Doushantuo Formation in the Yangtze Gorges area contains abundant cm-sized chert nodules with exceptionally preserved microfossils, including cyanobacteria, multicellular algae, spiny acritarchs, and animal eggs and embryos. Microbial laminae in the surrounding argillaceous dolomicrites tend to warp around the chert nodules, suggesting that the nodules formed during early burial prior to compaction. Although the nodules are pervasively silicified, they typically have a microbial mat fragment in the center, a pyrite rim, and a blocky calcite rim. This study aims at reconstructing the authigenic sequence of silica, pyrite, and blocky calcite precipitation, with a goal to understand the role of bacterial sulfate reduction in authigenic mineralization and fossil preservation.Petrographic analysis indicates that the blocky calcite rim is of late diagenetic origin, formed after the pyrite rim and the silica core. The pyrite rim appears to have grown centripetally, representing a reaction front that was determined by the relative diffusion rates of H_2S (from degradation of mat fragments in the center of nodules by sulfate reduction bacteria) and Fe_2+ (from surrounding argillaceous dolomicrite matrix). SIMS analysis of individual pyrite crystals in the pyrite rim shows no significant difference in sulfur isotope compositions (+25-28 per mil CDT) between small crystals (~10 um in size, in outer rim) and large crystals (~500 um in size, in inner rim). The isotopically heavy and homogenous pyrites are evidence for rapid bacterial sulfate reduction in a diagenetic environment with limited sulfate availability. We hypothesize that the Doushantuo chert nodules nucleated on microbial mat fragments, which were degraded by rapid bacterial sulfate reduction, generating outward-diffusing H_2S that met inward diffusing Fe_2+ to precipitate the pyrite rims. Pyrite precipitation may have also altered the pH surrounding the mat fragment, driving dissolution of primary dolomicrite and simultaneous precipitation of amorphous silica responsible for fossil preservation.

29: 8:15 AM-8:30 AM
Presenter: ZHOU, CHUANMING

CARBON ISOTOPE CHEMOSTRATIGRAPHY AND BIOSTRATIGRAPHY OF THE EDIACARAN SYSTEM IN SOUTH CHINA

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The Ediacaran System in South China overlies ~635 Ma glacial deposits of the Nantuo Formation and underlies basal Cambrian cherts and phosphorites, and consists of the Doushantuo and Dengying formations. The composite $\delta^{13}C$ profile of the Ediacaran successions in shallow-water platform facies in South China shows, in chronostratigraphic order, 1) a negative $\delta^{13}C$ excursion (EN1) in the Doushantuo cap carbonate; 2) a broad and pronounced positive $\delta^{13}C$ excursion (EP1) in the lower Doushantuo Formation; 3) a short-lived, but strong negative $\delta^{13}C$ excursion (EN2) in the middle Doushantuo Formation; 4) a positive $\delta^{13}C$ excursion (EP2) in the upper Doushantuo Formation; 5) a sharp negative $\delta^{13}C$ excursion (EN3) to a nadir of <-8 ‰ in the uppermost Doushantuo Formation; 6) a positive $\delta^{13}C$excursion (EP3) in the lower Dengying Formation; 7) a stable $\delta^{13}C$ plateau (ca. +2.5 ‰ PDB; EI) in the middle and upper Dengying Formation; and 8) a -10‰ negative $\delta^{13}C$ excursion (EN4) immediately below the Ediacaran-Cambrian boundary. This composite $\delta^{13}C$ curve provides a first-order chemostratigraphic framework for the subdivision and correlation of the Ediacaran System in South China. Detailed palaeontological investigations in the past 30 years have clearly demonstrated that distinct fossil assemblages occur in the lower (characterized by Doushantuo-Pertatataka-type acritarchs, DPA) and upper (characterized by macro-metazoans and biomineralizing animals, such as Cloudina and Sinotubulites) Ediacaran in South China. Biostiatigraphic studies indicate that DPA make their first appearances during the interval with a broad and pronounced positive $\delta^{13}C$ excursion (EP1), shortly after the termination of Nantuo glaciation, and disappear before the rise of large Ediacara organisms, at a horizon with a pronounced negative $\delta^{13}C$ excursion (EN3) in the uppermost Doushantuo Formation. Biostratigraphic data from South China and elsewhere indicate that DPA and Cloudina are characteristic of the lower and uppermost Ediacaran System, respectively, and have greatest biostratigraphic potential.

29: 8:30 AM-8:45 AM
Presenter: ZHAN, RENBIN

THE GREAT ORDOVICIAN BIODIVERSIFICATION OF SOUTH CHINA: A SYNOPSIS

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There are several advantages of conducting intensive case studies on the great Ordovician biodiversification in South China. For the first time, the Ordovician radiation could be discussed against biozones, much more refined than ever before. Taxonomically, the brachiopod radiation commenced at the beginning of Ordovician, started to accelerate in the earliest Floian (*Tetragraptus approximates* Biozone), and got its first acme in the mid Floian (*Didymograptellus eobifidus* Biozone) which was 4-5 graptolitic biozones earlier than the global trend. The taxonomic diversity of trilobites keeps growing since the beginning of Ordovician and got its first acme in the *Nemagraptus gracilis* Biozone (early Sandbian) in South China. The diversity change of graptolites shows different patterns on the Yangtze Platform and the Jiangnan Slope. Paleoecologically, the Ordovician brachiopod radiation of South China first occurred in the shallow marine environments corresponding to lower BA 2 to BA 3, and then gradually expanded their ecospace both to more offshore and nearshore benthic regimes. Trilobite biofacies macroevolutionary trends of South China have been discussed in detail by Zhou Zhiyi and his colleagues in several papers. Cladistic analysis on the Ordovician graptolites of South China shows that the lower part of the Jiangnan Slope was the center of the graptolite evolutionary novelties, and then they expanded to the upper part of the slope and the vast area of the Yangtze Platform. Faunal analysis indicates that the great Ordovician biodiversification of South China was also manifested by faunal turnover in all major groups. The potential mechanisms and/or the environmental background of all these macroevolutionary processes are still controversial. More and more researchers now accept that there were multiple causative factors combining to induce the Ordovician biodiversification, e.g., intrinsic biological factors, global and/or regional extrinsic physical/chemical factors, as well as feedback of the biodiversification event on the physical environments.

29: 8:45 AM-9:00 AM
Presenter: FAN, JUNXUAN

GEOBIODIVERSITY DATABASE

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The Geobiodiversity Database (GBDB) Project (http://www.geobiodiversity.com) is facilitating regional and global collaboration based on large-scale fossil and sedimentary rock database, enabling a greater understanding of the life, sediment and geography of our planet during the earth history. The key elements of GBDB are data, analyzing tools and web services. The database of GBDB is structured around several independent subsets or tables, such as

reference, geography (locality or section), taxonomy (fossil classification), stratigraphy, and fossil collection. Each record of these subsets can be linked to a record or records in other subsets. For example, one reference may contain several sections and each section has a lithostratigraphic description and contains hundreds of fossil collections. The reference subset is compatible with Endnote and the function of uploading standardized reference list (text format, such MS word or rtf) to GBDB is also available. In the taxonomy subset, user can input general taxonomy information from phylum to species or subspecies. In the collection subset, user can relate geographic, chronostratigraphic, lithostratigraphic, taxonomic information as well as the isotopic age and paleogeographic information of any fossil collection by simply searching in different subsets. The GBDB provides a powerful text-searching engine. For example, user can search collection subset by using any combination of 22 fields, such as fossil name, locality and biozone. Results are viewable on present-day geographic and satellite maps at present. The statistical tools and related functions, such as data visualization (e.g., rangechart, data visualization on reconstruction maps), diversity statistics (e.g., diversity curve, origination and extinction rates), will be available sooner. The server of GBDB, which is hosted in the State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, is supported by the institute and the laboratory, and will provide stable, long-term, free service.

29: 9:00 AM-9:15 AM
Presenter: SHI, GUANG RONG

LATE PALEOZOIC GONDWANA IN CHINA: WHERE, WHY AND HOW SIGNIFICANT?

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Permo-Carboniferous depositional sequences and biotas of Gondwanan affinity are scattered in parts of China. Historically they are well known and well studied from southern Tibet. Since the 1980s, sedimentary deposits, some bearing undoubted Gondwana-type marine fossils, have also been recognized from western Yunnan in SW China. In comparison, ongoing great uncertainty still prevails concerning the presence of Carboniferous-Permian plants and marine invertebrates of possible Gondwanan affinities in East Asia, the most notable of which are in northeast China and neighbouring parts of Korea, Russian Far East and Japan. Here, the Permian biotic succession is distinctively tripartite in that the lower part is characterized by a warm-water biotic assemblage of Tethyan affinity; the middle part by a biogeographically mixed biota of both Tethyan and Boreal affinities; and the upper part by either a mixed Cathaysian-Angaran Late Permian flora or a continuously mixed cool- and warm-water marine biota. Despite the relatively well-established knowledge about the presence and distribution of Late Palaeozoic Gondwana in China, their potential significance for palaeogeographical,

palaeoclimatic and plate tectonic reconstructions of Eastern Pangea remains under-exploited. For example, it is possible to link the biogeographical evolution of the Permian marine biotas of Gondwanic Tibet-West Yunnan to the tempo and mode of the rift-drift history of Cimmeria to which both southern Tibet and western Yunnan belong. Evidence in support of this will be presented especially in terms of the co-evolution of regional palaeogeography, palaeoclimate and biogeography in eastern Cimmeria. In contrast, the story underlining the Permian biogeographical change in the so-called 'Gondwanan facies' of East Asia appears to be much more complex in character. Here, regional tectonism, unique palaeogeographical position and palaeoceanographical conditions are believed to have inter-played in concert to influence the biotic composition and dynamic evolution of marine biogeography of this vast region through the Permian.

29: 9:15 AM-9:30 AM
Presenter: SHEN, SHUZHONG

PROGRESS OF THE END-PERMIAN MASS EXTINCTION IN CHINA

SHEN, SHUZHONG, State Key Laboratory of Geology and Palaeontology, Nanjing Institute of Geology and Palaeontology, 39 East Beijing Road, Nanjing, Jiangsu, 210008, China, szshen@nigpas.ac.cn

The end-Permian mass extinction has been documented as the biggest extinction during the Phanerozoic. Rapid progress has been made in the understanding of duration, extent, causes, and consequences of the end-Permian mass extinction recently based on studies of sections in China. Latest high-resolution of biostratigraphic, chemostratigraphic and geochronological frameworks and marine biodiversity patterns in different environmental and paleogeographic settings in South China and Tibet suggest that the extinction happened very rapidly at the very end of Changhsingian and were associated with large negative carbon isotope excursions. This extinction is synchronous with the die-off of the tropical Gigantopteris rainforest in South China in terms of biostratigraphical data, geochronological ages of volcanic ash beds and geochemical signals. It was associated with catastrophic soil erosion, frequent wildfires, higher contents of pyrite in marine sequences and malachite in terrestrial sequences across the Permian-Triassic boundary. Based on these data, the end-Permian crisis is regarded to be triggered by the effects of severe changes in atmospheric chemistry including greenhouse conditions derived from excessive CO_2 increase and substantial atmospheric S-containing acid input to ecosystems both in the sea and on the land, which were likely caused by widespread volcanism.

29: 9:30 AM-9:45 AM
Presenter: WANG, YUE

QUANTIFYING THE ABRUPTNESS OF THE END-PERMIAN MASS EXTINCTION

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The detailed pattern of biotic change during the end-Permian mass extinction has been limited to single localities that record taxon richness in a particular community (alpha diversity), but regional and global patterns are still far from understood. Here we expand upon a previous species-level analysis based on the single locality at Meishan (Jin et al., 2000), and present a pattern of inter-regional, species-level diversity for over 2,500 serial estimates in a span of less than 16 million years with no temporal binning of taxon durations. First appearance datums (FADs) and last appearance datums (LADs) were sequenced for the observed ranges of 1450 species from 16 fossil clades in 18 sections from Late Guadalupian to Early Triassic in South China and the peri-Gondwanan region. This data set, based on new data collections and high-resolution conodont zones, includes a high-resolution geochronologic framework for the Lopingian and Permian-Triassic transition (Crowley et al., personal information). The composite species richness pattern across the Permian-Triassic boundary was produced using a simulated annealing heuristic as implemented by CONOP9 (Sadler, 2004) to find an optimal sequence for all of the species FADs and LADs. The integration of statistical analysis of paleontological data from a range of paleogeographic and depositional settings reveals a single catastrophic extinction event that occurred over a maximum of approximately 300,000 years. The sudden extinction onset at 252.43 Ma and its short duration point to a major deterioration in ecosystem structure to a point where there was no immediate biotic recovery. References:Jin Yugan, Wang Yue, Wang Wei et al., 2000. Pattern of Marine Mass Extinction Near the Permian-Triassic Boundary in South China. Science, 289:432-436. P. M. Sadler, 2004. Quantitative biostratigraphy - achieving finer resolution in global correlation. Annual Review of Earth and Planetary Sciences, 32: 187-213.

29: 9:45 AM-10:00 AM
Presenter: LUO, HUI

EARLY CRETACEOUS RADIOLARIAN FROM YONGLA SECTION, GYANGZE, SOUTHERN TIBET

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Upper Cretaceous oceanic redbeds are well developed in the Yongla Section, Gyangze, Southern Tibet. Well-preserved radiolarians were extracted from the chert samples collected in the lower parts of this section. More than 15 genera and 17 species are recognized from this radiolarian fauna, such as *Pantanellium squinaboli* (Tan), *Archaeospongoprunum patricki* Jud, *Archaeodictyomitra lacrimula* (Foreman), *Pseudodictyomitra leptoconica* (Foreman), *Thanarla gutta* Jud, *Xitus sandovali* Jud, *Dicerosaturnalis dicranacanthos* (Squinabol), emend. Foreman, *Cryptamphorella gilkeyi* (Dumitrica), *Cryptamphorella clivosa* (Aliev), *Hiscocapsa asseni* (Tan), *Hiscocapsa grutterinki* (Tan), *Sethocapsa* sp. aff. S*. kaminogoensis* Aita, *Jacus* (?) *italicus* Jud, *Stylospongia* (?) *titirez* Jud, *Paronaella* (?) *annemariae* Jud, *Stichomitra communis* Squinabol and *Angulobracchia portmanni* Baumgartner etc. According to these genus and species range chart established in western Tethys by O'Dogherty (1994) and Baumgartner et al. (1995), this radiolarian assemblage is comparable to the *Asseni* Zone - *Turbocapsula* Zone (O'Dogherty, 1994) or zones 20-22 of UAZones95 (Baumgartner et al. ,1995), which indicates the Barremian-Aptian in age. This age determined by radiolarians suggests that the black chert rocks bearing radiolarians in the lower parts of the Yongla Section should not be the coeval sediments with the Upper Cretaceous oceanic redbeds and should be an exotic block of the mélange in this area.References: Baumgartner et al., 1995: Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology. Mémories de Géologie (Lausanne). No.23. 1172pp.O'Dogherty, L., 1994: Biochronology and paleontology of Mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mémories de Géologie (Lausanne). No. 21, 1-415.Supported by NSFC (No. 40572007; 40772004) and National Basic Research Program of China (No. 2006CB701400).

29: 10:30 AM-10:45 AM
Presenter: ZHOU, ZHONGHE

EARLY CRETACEOUS JEHOL BIOTA AND ITS GEOLOGICAL BACKGROUND

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The Early Cretaceous Jehol Biota from northeastern China has produced hundreds of exceptionally preserved fossils such as feathered dinosaurs, birds, mammals, pterosaurs, amphibians, fishes, insects and flowering plants that have substantially changed our views about the global diversity and patterns of evolution through the Early Cretaceous and revolutionized our understanding of the Cretaceous terrestrial ecosystem. The Jehol Biota had lasted for at least 11Ma (131~120Ma) thanks to recent geochronological studies of the fossil-bearing deposits, with the most significant radiation occurring between Barremian and Aptian (approximately 125Ma). The Jehol Biota is also characteristic of the presence of a remarkably high percentage of arboreal and herbivorous vertebrates, i.e., pterosaurs, dinosaurs, lizards, birds and mammals, suggesting the presence of flourishing forests associated with the extensively distributed lake ecosystem. The Jehol Biota also demonstrates a trend of a general

body size increase of birds, pterosaurs, dinosaurs and mammals in the Early Cretaceous that extends to the Late Cretaceous.The success of the Jehol Biota coincides with several major global and local geological events, such as strong tectonic activities, frequent volcanic eruptions, increase of atmospheric CO_2 and temperature towards the greenhouse climate in middle Cretaceous, and the Cretaceous Normal Superchron (CNS). Local geology in northeast China also reflects the impact of the increasingly active West Pacific tectonics on this region, which had most likely resulted in the Mesozoic lithospheric thinning beneath the North China Craton that mainly occurred in the Early Cretaceous (120-130Ma). Although frequent tectonic and volcanic activities must have had a major effect on the evolution of the Jehol Biota, the exact relationship between the biological evolution and the paleoenvironmental changes remains largely unknown.

29: 10:45 AM-11:00 AM
Presenter: SATO, TAMAKI

A NEW SKELETON OF MIODENTOSAURUS BREVIS (DIAPSIDA: THALATTOSAURIA)

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The recently described thalattosaurian *Miodentosaurus brevis* was represented by only one specimen. The holotype is well-preserved material but some postcranial elements (e.g. posterior portion of the tail, parts of the girdles, manus and pes) are not available for study due to the postmortem damage and/or disarticulation. We report on a new specimen referred to *M. brevis* that provides a full knowledge of the osteology of this taxon.The referred specimen is slightly smaller than the holotype individual, and it came from the Triassic Falang Formation in Guizhou, China, i.e., same as the latter. The ventral side of the skull is exposed and differs little from the holotype, confirming the peculiar characteristics of this taxon such as the reduced dentition and extremely shortened snout. Vertebral counts in each presacral region (cervical, dorsal, and sacral) are same as the holotype. The long, complete caudal series consists of 65 vertebrae, and each vertebra is equipped with neural spine and chevron until the very end of the tail. Pectoral and pelvic girdle elements are disarticulated but nearly complete with limited overlaps; the anterior flange of the scapula is a previously unknown feature for this taxon, and there are minor differences in the morphology of other elements between the two specimens. Except for the disarticulated left forelimb, the limb elements are mostly in articulation and well preserved. There are seven ossified carpals and six tarsals, and the phalangeal formula is 2-3-4-4-4 in the manus and 2-3-4-5-5 in the pes. The latter is unique within the Thalattosauria.

29: 11:00 AM-11:15 AM
Presenter: DENG, TAO

SEQUENCE OF THE LATE CENOZOIC MAMMALIAN FAUNAS IN THE LINXIA BASIN IN NORTHWESTERN CHINA AND THE UPLIFT OF THE TIBETAN PLATEAU

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In recent years, our fieldwork in the Linxia Basin of Gansu Province resulted in an explosive growth of new knowledge of the Chinese mammalian faunas of the Late Cenozoic. A successive sedimentary sequence from the Oligocene to the Pleistocene is developed and exposed in the Linxia Basin, containing a large number of mammal fossils. The Hezheng area is the most fossiliferous area of the Linxia Basin, covering about 1,300 km^2. The area has become well known for its rich Late Cenozoic mammal fossils, such as the late Oligocene giant rhino (*Dzungariotherium*) fauna, the middle Miocene shovel-tusked elephant (*Platybelodon*) fauna, the late Miocene three-toed horse (*Hipparion*) fauna, and the early Pleistocene true horse (*Equus*) fauna. The Linxia Basin produces the most abundant mammal fossils in China as well as the whole Eurasia. Besides mammal fossils, the Linxia Basin also produces other Cenozoic fossils of different animals. The reptile fossils from the Linxia Basin are represented mainly by *Testudo* from the late Miocene red clay deposits with a great number of specimens, which is an important member of the *Hipparion* fauna. Some bird fossils also found from the late Miocene red clays in the Linxia Basin, such as the earliest fossil ostrich in China. Mammals are very sensitive to environmental changes. The strong uplift of the Tibetan Plateau during the Late Cenozoic might dramatically affect environments, which must be reflected in the evolution of mammalian faunas. The Linxia Basin is located in a transitional zone between the Tibetan and Loess plateaus. This area not only has the mammalian assemblages to accurately determine their ages, but also has well-exposed deposits to reflect environmental changes. As a result, the Linxia Basin provides a very good site for studying the uplift history of the Tibetan Plateau and its influence to environments.

29: 11:15 AM-11:30 AM
Presenter: LAI, XULONG

ANCIENT DNA EXTRACTED FROM GIANT PANDA

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The giant panda (*Ailuropoda melanoluca*), as the one of the famous endangered species, has attracted attention of scientists and public. However, the panda's position in the phylogenetic tree has been debated for more than 100 years. In family level, it was assigned to families of bear, raccoon and panda. In view of evolution, ancient DNA data of giant panda will help us for better understanding of classification of panda, and increasing the resolution of the phylogentic tree. Ancient DNA approach has been conducted into the study of two individuals of giant panda skeleton from Jiangdongshan sinkhole of Tengchong, Yunnan Province, China. AMS dating results of the two giant panda individuals are 5025 ±35 yr BP and 8470 ±45 yr BP. The genome of cytochrome b gene (1140 bp) and about 845 bp of 12S rRNA gene have been successfully retrieved from bones of two panda individuals. Both homologous cytochrome b gene sequences and 12s rRNA gene sequence were aligned and used as datasets for phylogenetic analyses. All the neighbor-joining (NJ), maximum parsimony (MP) as well as Bayesian trees show that giant panda has the closer phylogenetic relationship with the members of the bear family. It support that the giant panda belongs to the bear family.

29: Poster
Presenter: ZHANG, KEXIN

EARLY TRIASSIC SEDIMENTARY SEQUENCES AND CONODONT ZONES OF THE MEISHAN SECTION IN CHANGXING, ZHEJIANG PROVINCE, SOUTH CHINA. For full abstract see *17: 2:00 PM, Booth 11*

29: Poster
Presenter: XU, YADONG

PALAEOENVIRONMENTAL CHANGES REVEALED BY ANALYSIS OF MIO-PLIOCENE POLLEN IN THE GYIRONG BASIN, TIBET, CHINA. For full abstract see *17: 2:00 PM, Booth 12*

Session No. 30, 8:00 AM; Friday 26 June 2009
Symposium S18. Paleozoic Brachiopods: Morphology, Evolution, and Stratigraphy

30: 8:00 AM-8:30 AM
Presenter: BOUCOT, ARTHUR J.

ORDOVICIAN THROUGH MISSISSIPPIAN BIOGEOGRAPHY (KEYNOTE)

BOUCOT, ARTHUR J. , Zoology, Oregon State University, 2850 SW Fairmont Drive, Corvallis, OR, 97331, United States, boucota@science.oregonstate.edu

With emphasis on articulate brachiopods a description of Ordovician through Mississippian global biogeography is available. This is superimposed on a current synthesis of climatic belts and paleogeography for the time intervals. Attention is also given, where appropriate to rugose coral distributions (Mississippian) and to trilobite distributuions (Ordovician). An attempt is made to suggest surface current circulation patterns consistent with the biogeography, paleogeography and climatic belts.

30: 8:30 AM-8:45 AM
Presenter: SWISHER, ROBERT E.

COORDINATED BRACHIOPOD SPECIES TRENDS IN THE CINCINNATI ARCH FOLLOWING THE LATE ORDOVICIAN RICHMONDIAN INVASION, DEMONSTRATED THROUGH QUANTITATIVE PALEOBIOGEOGRAPHIC METHODS

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The C5 depositional sequence (Late Ordovician) in the Cincinnati region (Indiana, Kentucky, Ohio) records basin wide ecologic changes following the introduction of invader taxa at the onset of the Richmondian stage. Recent developments in environmental niche modeling (ENM) methods allow analysis of the paleobiographic pattern of brachiopods for this sequence with resolution comparable to neontologic studies. Two sets of data are used in ENM: species occurrences and environmental parameters. Estimates of the fundamental niche for individual brachiopod species were modeled using the ENM program GARP. GARP identifies non-random associations between species occurrence and environmental variables, creates a rule set for an environmental parameter, and then tests each rule through iterative processes to determine the statistically best niche model. Estimated niches are then projected into geographic space using ArcGIS, and ranges are quantified with Spatial Analyst. Individual case studies and regional trends demonstrate that brachiopod species responded individualistically, rather than as a tightly coordinated community, to dynamic environmental conditions across three time slices during the C5 sequence. Case study examples illustrate three trends: 1) habitat tracking of preferred environmental variables, 2) initial expansion followed by subsequent isolation of populations, or 3) reduction in range size. Regional species trends

indicate the establishment of a stabilized community structure. No statistical differences occur in geographic range size or trends between native vs. invasive or generalist vs. specialist species across time slices. Between the first and second time slices, niche evolution of species is evident from the expansion of species' ranges into areas of intermediate environmental conditions additional to those occupied in first time slice. This is followed by a decrease in predicted range values in the third time slice as the environment becomes patchy due to fractionation of the environmental conditions, indicating niche conservatism led to the development of the restricted range sizes.

30: 8:45 AM-9:00 AM
Presenter: BOSE, RITUPARNA

GEOGRAPHIC VARIATION AND EVOLUTIONARY CHANGE IN SILURIAN-DEVONIAN *ATRYPA RETICULARIS*: A GEOMETRIC MORPHOMETRIC APPROACH

BOSE, RITUPARNA, Geological Sciences, Indiana University, 1001 East 10th Street, Dept. of Geological Sciences, Bloomington, IN, 47405, United States, ribose@umail.iu.edu; POLLY, P. DAVID, Geological Sciences, Indiana University, 1001 East 10th Street, Bloomington, Indiana 47405

Species in the fossil record are often expected to be geographically homogenous entities that persist roughly unchanged through their history, with most morphological change occurring at speciation events. Here, we investigated shape variation in Paleozoic brachiopod morphology at the species level using geometric morphometrics. We measured valve shape in 330 *Atrypa reticularis* individuals from 5 time intervals from several EE subunits (Clinton, Lockport, Keyser, Helderberg, Schoharie, Onondaga and Hamilton), 112 of which were used to assess geographic variation within a single time unit (Michigan, New York, Indiana, and Germany). Using these data, 3 hypotheses were tested: (1) If this species evolved according to the punctuated equilibrium model, in which morphological change occurs predominantly at speciation, then we would expect no significant differences between samples of the species from different times. MANOVA showed significant shape differences between different time horizons ($p=0.01$), suggesting at least some anagenetic evolution within *Atrypa reticularis*; (2) If the species evolved in a gradual, directional manner, then we would expect samples close together in time to be more similar to one another than those more separated in time. Euclidean based cluster analysis shows samples widely separated in time are more similar; (3) If this species is homogeneous, then its morphological shape across different geographic provinces is likely to show no significant difference. MANOVA showed no significant morphological difference observed among the localities ($p=0.01$). Thus it appears that there may be significant change within species through time, though there is little evidence for variation in space within this species.

30: 9:00 AM-9:15 AM
Presenter: SCHEMM-GREGORY, MENA

THE PHYLOGENY OF DELTHYRIDOID SPIRIFERIDS - HOW IT BEGAN (BRACHIOPODA, SILURIAN TO DEVONIAN)

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The cosmopolitan genus *Howellella* is regarded as the root of delthyridoid spiriferids, a group of coarsely plicated and mostly alate brachiopods. During the Silurian and Early Devonian taxa of *Howellella* were globally distributed and closely related to each other. Within the Early Devonian, faunal isolation began resulting in endemic brachiopod provinces and realms each with its own phylogenetic developments in brachiopods. Extinction events followed by the re-settlements of brachiopod communities characterizing each region.The type species of *Howellella*, *H. elegans*, occurs in Wenlock strata of Gotland, Sweden, and is characterized by very small specimens with two to three ribs on each flank and a fimbriate micro-ornamentation consisting of single rows of micro-spines at the edge of each growth lamella. Geologically younger species show an increase in size and amount of ribs and development of other types of micro-ornamentation, e.g., capillate with and without micro-spines or fimbriate with more than one row of micro-spines. Several phylogenetic lineages are recognizable coming out of *Howellella*, e.g., the *vanuxemi-cycloptera-murchisoni* lineage in eastern North America or the *cortazari-salicamensis-arduennensis-mosellanus* lineage in Western and Central Europe. All taxa of *Howellella* seem very similar at first sight but can be subdivided into subspecies in Europe. Further lineages of brachiopod evolution based on the ancestral howellellid forms are introduced. All lineages under consideration are characterized by an increase in shell size of specimens, one of the most spectacular example is the ratio of size in *Howellella* and *Euryspirifer.* It is remarkable that in Quiringites, we see a small *Howellella*-like morphotype occurring for a short time again in the Eifelian.

30: 9:15 AM-9:30 AM
Presenter: JANSEN, ULRICH

BIOHISTORY OF LOWER DEVONIAN ORTHOTETID AND ORTHID BRACHIOPODS FROM THE RHENISH MASSIF (GERMANY)

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In the course of a comprehensive revision of “Rhenish” Lower Devonian brachiopods, several taxa of the orders Orthotetida and Orthida are studied which are common, but still poorly known constituents of the faunas. The “Rhenish” orthotetoids have mostly been misidentified as species of *Schuchertella*, *Orthotetes*, *Areostrophia*, or *Hipparionyx*. Two new chilidiopsoid genera have been recognized, one of these representing a phylogenetic descendant of *Iridistrophia*, the other one being closely related to *Eoschuchertella*. Close relatives of the first genus occur in SW Europe and NW Africa, the second genus is related to forms in SW Europe, Turkey and southern Siberia. Each of the orthid genera studied, among others abundant taxa of *Platyorthis*, *Proschizophoria*, *Rhenoschizophoria*, and *Pachyschizophoria*, are not morphologically as stable as often assumed, but show a step-wise, minor evolutionary development. Accordingly, new species and subspecies could be separated. The patterns of extinction and resettlement correspond to regional bioevents, e.g., the “Seifen” or the “Stadtfeld” events, but also to possibly global bioevents, such as the basal Emsian, Dalejian, and Chotec events. Finally, known and new species-group taxa of the Orthotetida and Orthida are used in a refined biostratigraphy and can be calibrated with the Rhenish high-resolution spiriferid zonation. The taxa can often be used for biostratigraphic assignments in formations lacking classic zonal fossils, for example of land-sea transitional facies, where other brachiopods do not occur. Former, poorly constrained assignments based on lithostratigraphical grounds could be refined or corrected. Representatives of *Iridistrophia* even help in the correlation of Ardenno-Rhenish and Bohemian stratigraphies or, respectively, in the neritic-pelagic correlation.

30: 9:30 AM-9:45 AM
Presenter: DAY, JED

FRASNIAN (UPPER DEVONIAN) HISTORY OF NORTH AMERICAN CYRTOSPIRIFEROID BRACHIOPODS

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The cyrtospiriferids *Cyrtospirifer* and *Tenticospirifer* initially migrated into North America during the Middle Frasnian. At that time *Cyrtospirifer* is known from western Canada and eastern North America, but expanded its range into all North American shelves during the semichatovae transgression in the Late Frasnian. *Tenticospirifer* was widespread in western and central carbonate platforms during the Middle Frasnian, although it was restricted to the southwestern US and was extinct in North America prior to the Lower Kellwasser Extinction (LKE). *Regelia* may have evolved from *Cyrtospirifer* during the Middle Frasnian and remained a North American endemic until its extinction in the Late Frasnian. The conispiriferid *Conispirifer* migrated into western Canada during the Middle Frasnian where it is now known in reef platform faunas in Alberta. It expanded its range during the Late Frasnian into most carbonate platforms of central and western North America. It was extinct in the subtropical

platforms after the LKE, but persisted into the very Late Frasnian in the equatorial carbonate platforms in western Canada prior the Upper Kellwasser Extinction (UKE). *Pyramidaspirifer* is first known from the Early Frasnian of south China, and migrated into North American equatorial and subtropical carbonate platforms during the Late Frasnian. The last North American *Pyramidaspirifer* survived in Canadian near-equatorial shelves and became extinct during the UKE. The Spinocyrtids *Orthospirifer* and *Eosyringothyris* carry over from Givetian faunas in the Iowa basin, with the latter restricted to the Early Frasnian. *Orthospirifer* ranges through the entire Early Frasnian in the Iowa basin, and dispersed to western Canada during the Early Frasnian. Prior to its extinction in Iowa, *Orthospirifer* migrated into the Appalachian basin where it occurs in Middle-Late Frasnian. In the Iowa basin, *Orthospirifer* gave rise to *Platyrachella* during the Middle Frasnian and it became extinct in the Late Frasnian prior to the LKE.

30: 9:45 AM-10:00 AM
Presenter: BUSH, ANDREW M.

CHANGES IN BRACHIOPOD ASSEMBLAGES ACROSS THE FRASNIAN/FAMENNIAN BOUNDARY IN VIRGINIA: AN ANALOGUE FOR CHANGES IN MODERN COMMUNITIES

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In southwest Virginia, USA, the Frasnian/Famennian (F/F) transition is preserved in shallow-water, siliciclastic sediments. Brachiopod diversity fell from the Blizzard Member of the Foreknobs Formation (upper Frasnian) to the lower Red Lick Formation (lower Famennian), reflecting the effects of the F/F extinction. Here, we examine changes in brachiopod fossil assemblage structure across the F/F boundary. Non-metric multidimensional scaling of late Frasnian assemblages demonstrates two gradients in species composition, which may represent the control of substrate and disturbance rate/intensity on assemblage composition. In the earliest Famennian, the fauna was dominated by Frasnian holdovers, and few new species had evolved yet. The early Famennian data show the same two ecological gradients that were evident in the Frasnian, suggesting that the same physical parameters generally controlled species' distributions after the extinction. However, species' ranges on the gradients differed in notable ways between the late Frasnian and early Famennian; for example, species that essentially never co-occurred in the Frasnian expanded on the ecological gradients and co-occurred commonly in the Famennian. Several causes can be postulated for the changes in brachiopod assemblage structure: 1) The extinction of some brachiopods allowed competing brachiopods to expand their niches. This scenario requires strong competition among brachiopods on the seafloor, a debatable proposition. 2) The

extinction of predators, biological bulldozers, and/or other agents of disturbance led to changes in brachiopod niches. 3) Environmental conditions in the late Frasnian and early Famennian were different enough that species formed different associations (similar to Pleistocene plant assemblages). Further studies could help narrow these possibilities, but regardless of the cause, the shift in assemblage structure between the Frasnian and Famennian reflects expectations for the modern world: communities in the coming decades or centuries will contain new combinations of species as a result of extinction and environmental change.

30: 10:30 AM-10:45 AM
Presenter: FALL, LEIGH M.

CONSISTENCY IN ECOLOGICAL PROCESSES OF LOCAL BRACHIOPOD PALEOCOMMUNITIES IN THE DELAWARE BASIN (WEST TEXAS)

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Local community diversity reflects a balance between several important interconnected ecological processes. Dispersal from the regional species pool can inflate local diversity by introducing new species. However, dispersal can be limited by dominant incumbent taxa reducing the likelihood of successful invasion. How the relationship between local communities and the regional species pool influences ecological diversity is not well understood in the fossil record. This study tests whether changes in local brachiopod paleocommunity diversity are influenced by dispersal in the Pinery, Rader, Lamar, and Reef Trail Members of the Permian Bell Canyon Formation (Guadalupe Mountains National Park, Texas). Two third-order sequence boundaries are recognized within the Bell Canyon Formation, indicating episodes of environmental perturbation within the basin accompanied by changes in community diversity. Brachiopod abundance data are partitioned into within-community and among-community components of diversity for each member to determine the contribution of each component to overall diversity. High values of the within-community component and low values of the among-community component within each member would suggest that dispersal is a primary influence on the overall diversity of local communities. Taxa would be able to disperse into communities because incumbent taxa are not barriers to immigration. Changes in the relative proportion of the diversity components between members would indicate a shift in the influences of dispersal and incumbent dominance. Initial results indicate that while taxonomic composition and diversity changes with time, the relationship between incumbent dominance and dispersal does not change. This indicates significant consistency in the ecological processes controlling brachiopod paleocommunity organization, both with time and across major environmental perturbations.

30: 10:45 AM-11:00 AM
Presenter: BUTTS, SUSAN

THE SCHUCHERT COLLECTION OF BRACHIOPODS AT THE YALE PEABODY MUSEUM: DEVELOPMENTS AND NEW INITIATIVES

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As part of a National Science Foundation Biological Research Collections grant (Award No. 0545210) all the brachiopods and some associated specimens in the Yale Peabody Museum stratigraphic collections are being incorporated into the systematic brachiopod collection. Brachiopods are well represented in the nearly four thousand drawers of material in the stratigraphic collection and the Yale Peabody Museum has a prolific history of research on this group. At the nucleus of the systematic brachiopod collection is material collected or acquired by Charles Schuchert (Yale University, 1904-1942) but the museum also holds important private collections as well as the products of field excursions and the research projects of many curators, staff, and graduate students. The project has three main objectives: a curatorial assessment of the stratigraphic collection, which involves ranking drawers for incorporation into the systematic collection; a curatorial upgrade of the collections (including electronic cataloging and imaging); and making object data available to researchers worldwide. We have developed an equation that creates a hierarchy for removal of individual drawers from the stratigraphic collection. Object records and locality information conform to the Darwin Core standard and can be migrated and merged with other databases (along with image files) and accessed using a DiGIR portal and locally developed electronic catalogue. We have adopted a best practices approach, including rapid image processing with voice recognition and quantifying a hierarchy for systematic collections.In addition to the obvious benefits of making this material more accessible for systematic study and analysis for stable isotopes and climate data, the project allows the collections data to be used for broad-scale projects in paleobiogeography and for public education initiatives (e.g., the data are merged with datasets from other participating institutions on the PaleoPortal platform).

30: Poster
Presenter: SCHEMM-GREGORY, MENA

ECOLOGY OF THE PARASPIRIFER-LIKE MORPHOTYPES (BRACHIOPODA, LOWER AND MIDDLE DEVONIAN). For full abstract, see *8: 2:00 PM, Booth 16*

30: Poster
Presenter: SCHEMM-GREGORY, MENA

THE OLDEST *SPECIES* OF CYRTOSPIRIFER (BRACHIOPODA, MIDDLE DEVONIAN). For full abstract, see: *17: 2:00 PM, Booth 21*

Session No. 31, 1:30 PM; Friday 26 June 2009
Topical Session T8. Life in the Neoproterozoic and Cambrian

31: 1:30 PM-1:45 PM
Presenter: ANDERSON, EVAN P

CHUARIA ULTRASTRUCTURE AND MORPHOLOGY AND ITS IMPLICATIONS ON THE TAPHONOMY OF CARBONACEOUS COMPRESSIONS

ANDERSON, EVAN P, Geosciences, Virginia Tech, 400 Houndshcase Lane, Apartment K, Blacksburg, VA, 24060, United States, aevan7@vt.edu; XIAO, SHUHAI, Geosciences, Virginia Tech, 4044 Derring Hall (0420), Blacksburg, VA, US, 24060

Carbonaceous compressions are a common mode of fossil preservation throughout the Proterozoic and are the mode of fossilization for the famous Lagerstatten of the Cambrian. Despite its fame, little is known about how the taphonomic process happened, or why the preservational style largely disappeared after the Cambrian. This study is a twofold effort to deduce the details of carbonaceous compression taphonomy while reexamining the morphology and chemical structure of a typical Proterozoic carbonaceous compression fossil: *Chuaria*. Like its carbonaceous mode of compression, *Chuaria* is a genus of well-known, but little understood, Proterozoic macrofossils. They have a huge range, from the Mesoproterozoic into the late Neoproterozoic, but their simple morphology, a mere carbonaceous circle, has not lent itself to advanced research over the years. In the current study, however, *Chuaria's* simple morphology makes it the perfect candidate for analysis, since its single tissue type eliminates the variables inherent from analyzing an organism with multiple tissues, each of which may be preserved differently. To gain a clearer picture of *Chuaria's* morphology and taphonomy, they will be analyzed elementally with ESEM-EDAX, isotopically with SIMS, and with traditional thin sectioning and light microscopy. Also, Raman microprobe will be used to analyze the degree of graphitization of the *Chuaria*, and their microscopic structure will be examined externally with ESEM, and internally with a TEM.

Since location-specific and taxon-specific taphonomic variables are sure to be present, *Chuaria* in three different sites from two localities in the Doushantuo Formation of South China are being compared. With such a large amount of data from several different localities, we will be able to offer a more complete picture of the structure and chemistry of *Chuaria* than has been offered before. At the same time, we will be able to piece together the diagnostic details of carbonaceous compression taphonomy.

31: 1:45 PM-2:00 PM
Presenter: COHEN, PHOEBE A.

APATITE MICROFOSSILS FROM THE PRE-STURTIAN AGED LOWER TINDIR GROUP, YUKON TERRITORY

COHEN, PHOEBE A., Department of Earth and Planetary Sciences, Harvard University, 26 Oxford St, Botanical Museum, Cambridge, MA, 02138, United States, pacohen@fas.harvard.edu; SCHOPF, J. WILLIAM, Department of Earth and Space Sciences, University of California, Los Angeles,595 Charles Young Drive East, Box 951567, Los Angeles, CA 90095-1567; KUDRYAVTSEV, ANATOLIY, Institute of Geophysics & Planetary Physics, University of California, Los Angeles, 595 Charles Young Drive East, Box 951567, Los Angeles, CA 90095-1567; MACDONALD, FRANCIS A., Department of Earth and Planetary Sciences, Harvard University, 20 Oxford St, Cambridge MA 02138

Diverse microfossils have previously been described from cherts of the pre-Sturtian Lower Tindir Group of the Yukon Territory. These microfossils fall into two main groups - those ovate, often perforated fossils with a mineralized and partially hyaline appearance, and more traditional organic walled microfossils, including coccoids, acritarchs, and filaments. While the unique perforated “scale” type microfossils from the Tindir group had previously been interpreted as mineralized forms, their actual composition and structure remained enigmatic due to the limitations of traditional light microscopy. Here we have applied confocal laser scanning microscopy and confocal Raman spectroscopy to these microfossils to better determine their composition and structure. CLSM results reveal a greater amount of detail on their three dimensional structure, information which bears on interpretations of their original biological function and taxonomic affinity. The Raman analysis shows that the fossils are persevered as a combination of apatite and kerogen. While difficult to prove given their small size and the limits of analytical chemical techniques, we believe that the distribution of apatite in these distinctive microfossils and a lack of apatite in any other organic phases in the same thin sections implies that the formation of the phosphatic mineral phase was biologically mediated. If this is the case, the Tindir microfossils may be the oldest evidence of intercellular eukaryotic biomineralization in the fossil record. Alternately, they could represent an example of highly selective sub-micron scale phosphate preservation of an intricate and unique organic structure.

31: 2:00 PM-2:15 PM
Presenter: DOMKE, KIRK L.

PALEOECOLOGICAL AND GEOCHEMICAL SETTING FOR THE EVOLUTION OF THE EARLIEST BIOMINERALIZERS IN WESTERN NORTH AMERICA

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Biomineralized skeletons of benthic organisms are first recorded in the latest Neoproterozoic with the appearance of *Cloudina* (~548 Ma), a small (length up to 1 cm; 2-4 mm diameter) tube-dwelling organism. *Cloudina* from the Precambrian Reed Formation and overlying lower member of the Deep Spring Formation from eastern California and western Nevada were examined from five localities. *Cloudina* preservation varies significantly at these study sites, from relatively complete tests to fractured debris, occurring primarily in shell beds with varying evidence for transportation before final deposition. In addition to paleoecological analyses, this study also provides concentrations and isotopic analyses of carbonate-associated sulfate, which gives insight to the redox conditions of the oceans during this critical time in Earth history. Samples collected at high stratigraphic resolution from the aforementioned *Cloudina* localities in the Reed and Deep Spring Formations provide a record of latest Neoproterozic d34S. Using sulfate as a proxy for changing atmospheric and oceanic conditions, we gain insight into how oxygenation of the oceans played a role in the Cambrian radiation. A broader context of these cloudiniids is necessary for establishing a baseline towards understanding how early biomineralizers evolved in response to the ongoing "agronomic revolution" of increasing bioturbation that was occurring during the Neoproterozoic-Cambrian transition (~542 Ma). These *Cloudina* occur before the Precambrian-Cambrian boundary, and hence before the appearance of significant vertical bioturbation. The thick Lower Cambrian sections in the study area provide numerous carbonate intervals from which to assess the context of succeeding early biomineralizers. This stratigraphic interval in eastern California and western Nevada thus provides a basis on which to determine how the first biomineralizing organisms evolved as part of the "Cambrian substrate revolution."

31: 2:15 PM-2:30 PM
Presenter: PETRYSHYN, VICTORIA A.

PETROGRAPHIC ANALYSIS OF NEW SPECIMENS OF *VERNANIMALCULA GUIZHOUENA* (DOUSHANTUO FORMATION, SOUTH CHINA)

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The Neoproterozoic Doushantuo Formation contains some of the earliest evidence for animals and animal embryos, including the putative bilaterian *Vernanimalcula guizhouena*. While this formation crops out over much of Southwest China, samples from this study come from the lower black facies of the Weng'an Phosphorite Member in Guizhou, which was deposited in a shallowing upward, nearshore marine environment. The black facies has been estimated to be near 580-600 Ma based on carbon and sulfur isotope stratigraphy and radiogenic dating, placing the age of these microfossils well before that of the Ediacara biota. Samples were disaggregated in a weak formic acid solution in order to concentrate microfossils, and mounted in epoxy. These grain mounts were made into thin sections and examined petrographically. Measurements of body length and morphological features were made on five new specimens, and are found to be within the range reported for the original specimens, even for samples that have undergone significant taphonomic degradation. Results also indicate two main phases of phosphatization. The first phase quickly replaced original organic matter. A second distinct phase occurs where much larger botryoidal cements grew outward from the first cement, filling in void space. While under plane polarized light, there appear to be several generations of cement; crossed polarized light reveals a sweeping extinction characteristic of a single growth event. Not all phases of phosphate precipitation are present in all samples. While this study cannot rule out an abiotic origin for these morphologies, it seems unlikely that phosphatization alone could be responsible for a large number of specimens with the same repeated morphology.

31: 2:30 PM-2:45 PM
Presenter: LANDING, ED

FROM EXTREME SEA LEVELS TO GLOBAL HYPERWARMING, SLOPE–EPEIRIC SEA DYSOXIA/ANOXIA, AND BURGESS FAUNAS: EARLY PALEOZOIC EVIDENCE FROM EAST LAURENTIA

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With the opening of Iapetus after Late Ediacaran rifting, a late Early Cambrian–early Late Ordovician passive margin developed in NE Laurentia. The passive margin facies include tropical platform (ca. 30o S) sandstone and carbonate and slope–rise mudstone. A "modern" ocean existed in the Early Paleozoic, as shown by persistent dysoxia/anoxia (d/a) on the upper slope (i.e., terminal Lower Cambrian–Lower Ordovician black mudstone of the Franklin Basin, NW VT–southern Quebec) and by well-oxygenated (red and purple), lower slope–rise mudstone in interior parts of the Taconian allochthons. Mid-slope mudstones are green and strongly burrowed from New Jersey to west Newfoundland, but have seven macroscale, black mudstone intervals that reflect deposition with intensification and thickening of the low-oxygen mid-water mass. Black mudstones yield the majority of body fossils in the Taconian allochthons [Cambrian shelly fossils in bedded, shelf-derived carbonate; Ordovician conodonts and graptolites]. The black mudstones correlate with eustatic highs that drove shorelines across Laurentia and shed carbonate muds and sands onto the slope in the late Early Cambrian (Browns Pond interval), terminal Early Cambrian–earliest Ordovician (Hatch Hill interval), late early Tremadocian, late Tremadocian, early Arenigian/Floian, late Arenigian/Whiterockian, and early Late Ordovician ("Chazyan"). As during Cretaceous high eustatic levels, hyperwarming resulted from increased insolation by extensive seas on equatorial continents and consequent decreased latitudinal climate contrasts. Hyperwarming reduced oceanic circulation, and allowed development of d/a platform water. Cambrian soft-bodied fossils form two groups; the older (Chen Jiang and approximate equivalents) and younger (Burgess–Utah faunas) reflect persistent or episodically decreased bottom oxygenation on the platform in the Browns Pond and early Hatch Hill intervals. High eustatic levels in the middle–late Caradocian (Black River, Trenton, Utica) and, potentially, increasingly murky waters with erosion of the Taconian orogen led to development of d/a seas that spread into the Laurentian midcontinent.

31: 2:45 PM-3:00 PM
Presenter: BOTTJER, DAVID J.

TRENDS AND TRANSITIONS IN THE EARLY EVOLUTION OF ANIMALS: TOWARDS A PALEOGENOMIC SYNTHESIS

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The early history of animals on Earth is characterized by geologically long intervals with similar biotic trends punctuated by geologically short transitions to the next interval. Recent biomarker data places the origin of sponges in the Cryogenian before the end of the Marinoan glacial event (635 mya). Microscopic fossils of metazoan affinity in the Doushantuo biota (580-600 mya), and the lack of macroscopic animal fossils before the onset of the Ediacara biota, indicate that this first interval, which trends through the initial part of the Ediacaran, is

one of microscopic animals, characterized by abundant sponges as well as the likely presence of animals with bilaterian affinities. The transition to the Ediacara biota, which first appeared 575 mya, marks the first evolution of macroscopic animals. This interval, characterized by many intriguing and large soft-bodied animals such as the extinct rangeomorphs, also includes the first macroscopic bilaterians, such as *Kimberella*. The transition at the end of the Ediacaran into the Cambrian marks the initiation of the third interval, where the fossil record shows the appearance of biomineralized animals and a proliferation of crown group bilaterians. Indeed, this interval should more properly be called the "Cambrian crown group explosion". These patterns of trend and transition from the fossil record of early animals are best understood within the context of changing environments, taphonomy and evolution. The relative contribution of evolutionary processes determining size increase and the proliferation of crown group bilaterians, each of which marks a major transition, needs to be assessed against a backdrop where the various superclades into which Modern metazoa fall were likely extant through much of the Ediacaran. Ultimately, combination of data from the fossil and stratigraphic record with modern studies in molecular biology will provide the paleogenomic synthesis necessary to most fully understand early animal evolution.

31: 3:00 PM-3:15 PM
Presenter: DORNBOS, STEPHEN Q.

SENSORY ECOLOGY OF EARLY ANIMALS

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The Ediacaran to Cambrian interval is characterized by the profound environmental and biological changes associated with the bilaterian radiation. These include the advent of macroscopic predation, an increase in the size and energy content of organisms, and the transition in seafloors from laminated matgrounds to mixgrounds. The overall effect of these transitions was to markedly increase the spatial complexity of the marine environment. This increased spatial complexity likely drove the evolution of macroscopic sense organs in mobile bilaterians, leading to their first appearance during the Cambrian. The morphology and distribution of these sense organs should therefore reflect the life habits of the animals that possessed them. In order to explore the distribution of sensory organs during the Cambrian radiation, 5,597 specimens of 31 mobile epifaunal and nektonic genera were examined from the early Cambrian Chengjiang biota. Presence/absence data of macroscopic sensory organs (eyes and antennae) were collected from these genera, and these data were mapped onto the relative abundance and life mode data. Antennae are ubiquitous in both mobile epifaunal and

nektonic genera (95.7% of mobile epifaunal and 97.9% of nektonic specimens have antennae), but only nektonic genera are dominated by forms with eyes (98.0%). Just 25.5% of mobile epifaunal specimens possess eyes. This difference may be attributable to the need by nektonic organisms to visually detect flow direction in order to navigate toward the source of an odor plume. Epifaunal organisms can achieve similar results through mechanosensory. These preliminary results support two general hypotheses: that essentially modern sensory systems evolved very early in animal evolution; and that sensory systems differed between epifaunal and nektonic forms. Even by the early Cambrian, there does appear to be a difference in the selective pressure to develop certain sensory organs based on the local environment of an organism and its life mode.

31: 3:15 PM-3:30 PM
Presenter: CLITES, ERICA C.

A NEW MULTI-ELEMENT FOSSIL FROM THE EDIACARA MEMBER, RAWNSLEY QUARTZITE OF SOUTH AUSTRALIA

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Within the Ediacara Member of the Rawnsley Quartzite, external molds and casts of soft-bodied organisms occur on the underside of bedding surfaces. Unlike most Ediacaran organisms, a previously undescribed fossil, informally known as “pincushion” typically disarticulates into two parts. As preserved in negative hyporelief, “pincushion” consists of pits with attached hooks and thin knitting needle-like groove structures, which typically disarticulate from the pit. “Pincushion” can be described as a shallow subcircular pit, often with a protruding boss in the center, associated with ruler-straight to slightly curved needles. Pits range in depth from 1-15 mm, with a maximum diameter of 22 mm. Pits occur in clusters of two or three and rarely in contiguous pairs. Narrow (< 1 mm) needles of constant width are directly associated with pits, however, they are only rarely preserved articulated. Needles can be up to 37 cm long. Multiple needles and short hooks radiate from a single pit. Most well-preserved pits exhibit at least one hook. Most hooks are 2 – 10 mm in length. This organism can best be reconstructed as a thimble-like morphology protruding up from the seafloor with long thin rigid structures extending from the thimble. On one bed in particular, “pincushion” is abundant, with over 300 specimens on about 7 square meters of bedding plane. Of these, 19 are complete, 256 include pits with hooks but no needles and 33 are disarticulated needle. This indicates that three quarters of the needle specimens on this bed have been transported. Disarticulated needles are also found on other beds, sometimes abundantly. There are no indications that pit has been transported, as pits do not overlap, are not deformed, and no traces from rolling or dragging were discovered.

31: 4:00 PM-4:15 PM
Presenter: DROSER, MARY L.

THE ROLE OF FACIES IN THE DISTRIBUTION AND TAPHONOMY OF THE EDIACARA BIOTA

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Ediacaran-aged strata in the vicinity of the Flinders Ranges, South Australia, offer the opportunity to study fossils in a variety of facies. Bedding plane surfaces of 10 discrete beds, many of which are sequential, occur commonly within the typical rippled sandstone interpreted as a relatively low energy conditions shallow marine facies. Body fossil genera include *Dickinsonia*, *Spriggina*, *Aspidella*, *Parvancorina*, *Conomedusites*, *Tribrachidium*, *Eoporpita*, *Rugoconites*, *Conomedusites, Yorgia*, and forms typical of the White Sea assemblage. Even within this single facies, there is a strikingly significant level of heterogeneity between beds in terms of composition, evenness, and relative abundance. Only some of the heterogeneity can be attributed to taphonomic differences, the rest is likely a result of reflecting varying communities across small-scale environmental gradients within the shallow marine setting. Incised channel fill deposits and associated facies preserve two additional different discrete assemblages - one dominated by large fronds and organisms with a fractal morphology occurring within well-defined meter-10 meter scale discrete channel fill deposits within a larger incised valley fill and another dominated by *Parvancorina*, *Tribrachidium*, and several previously undescribed fossils - all of which are minor elements of rippled sandstone facies - occurring as laterally extensive beds within the incised channel. A fourth facies preserves fossils on bed tops that exhibit oversteepened ripples and evidence of firmgrounds. The fossils represent a new complex Ediacaran morphology. The facies dependence of most Ediacara genera bears on our understanding of their global distribution as well as biostratigraphic models.

31: 4:15 PM-4:30 PM
Presenter: SAPPENFIELD, AARON

A NEWLY DESCRIBED TUBULAR FOSSIL FROM THE EDIACARA MEMBER (SOUTH AUSTRALIA) AND ITS ROLE IN THE EDIACARAN ECOSYSTEM

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Recent work on new Neoproterozoic fossils from globally dispersed localities has shown that organisms with a tubular structural organization were considerably more common in the Ediacaran and Cambrian than previously appreciated. However, taxa within this structural group remain largely undescribed, for the most part, because of poor preservation. Excavation of successive beds of the Ediacara Member of the Rawnsley Quartzite (South Australia) reveals a number of tubular organisms. In particular, well-preserved structures, previously interpreted as microbial in origin, reveal distinct body fossil traits such as sediment infill, folding, and current alignment. These specimens occur on the base of beds as wavy casts and molds approximately 2-7 mm wide and 3-14 cm long. Reconstruction of these structures suggest a tubular organism with an overall loosely spiraled corkscrew shape. Approximately 150 specimens of this fossil have been recovered from the more than 200 m2 of reconstructed bedding surface within the Ediacara Member. The ability to view large quantities of reassembled bedding surface show low taphonomic grade specimens commonly occurring on the same bedding surface as those few exceptionally preserved specimens providing insight into different preservational styles of this fossil. In light of the description of exquisitely preserved specimens and identification of taphonomic variants of this newly described constructional morphology, the organism that produced this fossil is likely to have been a widespread and abundant macroscopic element of the Ediacara biota.

31: 4:30 PM-4:45 PM
Presenter: NAKAGAKI, MICHAEL M.

MORPHOLOGIC RANGE OF THE PROBLEMATIC GROUP SPHENOTHALLUS FROM THE SHUIJINGTUO FORMATION (EARLY CAMBRIAN) IN SOUTHEAST CHINA

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New specimens of the problematic fossil *Sphenothallus* Hall, 1847, have been found in the Shuijingtuo Formation (early Cambrian) in Southeast China. *Sphenothallus* is a conotubular fossil common throughout the Paleozoic of North America, but its earliest occurrences have been found in China. Though the phylogenetic affinities are still in debate, its morphology and evidence of asexual budding suggest a cnidarian relative. *Sphenothallus* is distinguished from other small shelly fossils by a pair of longitudinal thickenings; however, apart from these, few characters are consistently used to differentiate species. A one-way ANOVA found no statistically significant difference in mean length ($p=0.616$) or mean angle ($p=0.756$) of *Sphenothallus* from three locations of the Shuijingtuo Formation. Since the two described Cambrian aged species from China (*S. taijiangensis* and *S. songlinensis*) are differentiated by angle of expansion, maximum length, and amount of curvature, it is likely there is only one

species in the Shuijingtuo Formation. The mean lengths and angles suggest all specimens are *S. songlinensis* but several specimens show curvature similar to *S. taijiangensis*. Curvature is not described in any *S. songlinensis* specimen, making the assignment of the new material into a described species is difficult. The curvature may be influenced by abiotic factors and not taxonomically important, indicating the species should be assigned to *S. songlinensis*. The specimens of *Sphenothallus* have been collected from three outcroppings of the Shuijingtuo Formation in Siduping of Hunan Province (outer ramp), Changyang and Yanjiahe of Hubei Province (both inner ramp). These three sites have lithologies ranging from shale (Siduping) to fine siltstone (Changyang and Yanjiahe), giving a transect from deep to shallow shelf environments. By comparing the range of curvature to the taphonomic state and paleoenvironment of the localities, the abiotic influences on the range of preserved morphology of *Sphenothallus* can be explored.

31: 4:45 PM-5:00 PM
Presenter: KLOSS, TRISTAN

COMPARATIVE PALEOECOLOGY OF CHANCELLORIIDS IN THE EARLY CAMBRIAN MAOTIANSHAN SHALE BIOTA AND THE MIDDLE CAMBRIAN WHEELER SHALE BIOTA: NON-ADAPTATION TO THE CAMBRIAN SUBSTRATE REVOLUTION

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Chancelloriids were a taxonomically enigmatic group of early and middle Cambrian animals noted for their unusual morphology. They lived in the midst of the Cambrian substrate revolution, when increasing bioturbation in shallow subtidal unlithified seafloors led to a transition from firm Proterozoic-style substrates to soft Phanerozoic-style substrates with a well-developed mixed layer. Paleoecological studies of the exceptionally preserved chancelloriid *Allonnia* from the early Cambrian Maotianshan Shale biota of southwest China suggest that *Allonnia* was a shallow sediment sticker adapted to firm Proterozoic-style substrates, and that this lifestyle partly contributed to its morphology. Extremely low bioturbation levels within the Maotianshan Shale (average ii=1) and specimens of*Allonnia* exhibiting tapered blunt basal ends, while lacking structures for attachment to hard substrates, support this interpretation. Specimens of the chancelloriid *Chancelloria eros* and the rocks in which they are preserved were collected from the middle Cambrian Wheeler Shale of Utah for comparative analysis. The morphology of *Chancelloria* shows similarities with *Allonnia*, exhibiting a blunt basal end and lacking attachments for hard substrates, making it likely that *Chancelloria* was a shallow sediment sticker. Several meters of strata from the Wheeler Shale were analyzed using the ichnofabric index (ii) method. Results indicate extremely low levels of bioturbation (average ii = 1), suggesting that firm Proterozoic-style substrates still dominated this environment during the middle Cambrian. These results suggest that *Chancelloria* is morphologically very similar to *Allonnia*, probably due to adaptations to

firm Proterozoic-style substrates that were still present in some settings during the middle Cambrian. The adaptations of *Chancelloria* also suggest that middle Cambrian chancelloriids had not adapted to the changing substrate conditions of the Cambrian substrate revolution. It is possible that this non-response to changing substrates contributed to the extinction of chancelloriids by the late Cambrian, although this hypothesis remains to be tested.

31: 5:00 PM-5:15 PM
Presenter: MACGABHANN, BREANDÁN A.

THEY'RE NOT WHAT YOU THINK: *DISCOPHYLLUM*, *PAROPSONEMA* AND THEIR FRIENDS: *ELDONIA'S* MISUNDERSTOOD COUSINS

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Eldonia ludwigi, described by Walcott in 1911, is one of the most common fossils found in the Burgess Shale, and is immediately recognizable due to the presence of a coiled structure interpreted as a digestive tract. It has also proved to be a very difficult animal to classify, having been cited in the past as a scyphozoan medusa, a siphonophore, a holothurian, a pre-echinoderm deuterostome, and a lophophorate. More recent opinions have centered on the two latter interpretations, aided principally by the discovery of three related species in the Chengjiang and Kaili lagerstatte of South China - *Rotadiscus*, *Pararotadiscus*, and *Stellostomites*. Other Cambrian members of the group are much more poorly known, including *Velumbrella czarnockii* from Poland, and *Eomedusa datsenkoi* from Russia. However, this group is not limited to the Cambrian. Indeed the first known member of this group, *Discophyllum peltatum*, was described as far back as 1847 from the Ordovician of New York, and specimens are also known from the Silurian of Australia (*Discophyllum mirabile*) and England (*Pseudodiscophyllum windermerensis*), and the Devonian of New York (*Paropsonema cryptophya*). These latter species, which are collectively referred to as the paropsonemids, are often mistaken for 'chondrophorines' (athecate hydrozoans). Indeed they have, in the recent past, been described as such, and used to further theories on the evolution of this group. However, the presence of the coiled digestive structure as well as other anatomical details confirms that they are unequivocally not chondrophorines.Recently, several new sites have been discovered in Ordovician sandstones of the Tafilalt region in south-eastern Morocco, which preserve thousands of specimens of non-mineralized paropsonemids in at least two new species. The preservation of specimens in this Tafilalt lagerstatte, as molds and casts on bed surfaces or within shallow marine sandstone beds, is strikingly similar to Ediacaran styles of preservation.

31: 5:15 PM-5:30 PM
Presenter: CHEN, XIAOZHENG

EUKARYOTE FOSSILIZATION PROCESS IN LABORATORY: ONIONSKIN CELL IN SILICA SOLUTION

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Research on the origin of eukaryotes often focuses on the exceptional preservation found in silicified Precambrian fossils. Nuclei like subcellular structures in well preserved fossils become confused and there are arguments that focus on whether the partial degradation of prokaryotes produce artifacts that resemble a 'nucleus', or fossilized nuclei of eukaryotes. In order to understand the mechanisms of silicification and identify the fossilized subcellular microstructures in rocks, a series of laboratory controlled experiments were performed for simulating the silicification process. The effects of different silica solutions in eukaryote fossilization were studied in our experiments by exposing onion skin cells (epidermis) to silica solutions. Onion skin provides a good experimental model because of its well characterized cellular structures which are easily observed. The experiment reveals that interactions between silica and the onion skin cell wall surface functional groups were weak. The preservation of nuclei in the onion skin model was due to precipitation in highly supersaturated silica solutions rather than simply the high silica concentration. When the silica gel precipitates slowly at low supersaturation states, the nuclei were not well preserved, but the rapid precipitation at high supersaturated silica conditions preserved nuclear structures. A better understanding of the processes involved in onion skin fossilization will further contribute to issues concerning the silicification of other eukaryotic materials.

Session No. 32, 1:30 PM; Friday 26 June 2009
Topical Session T9. Organism-Environment Interactions

32: 1:30 PM-1:45 PM
Presenter: HEMBREE, DANIEL I.

NEOICHNOLOGY OF SCORPIONS AND WHIPSCORPIONS: INTERPRETING THE ROLE OF PREDATORY ARTHROPODS IN EARLY SOIL ECOSYSTEMS

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Soils are highly buffered environments and were one of the earliest terrestrial environments to be colonized. Modern soils contain diverse ecosystems that include micro- and macrofauna with a number of different feeding strategies. Among these animals are arthropod predators. Our knowledge of arthropod predators in Paleozoic soil ecosystems, however, is limited. Continental ichnofossils are well known from Paleozoic paleosols although many are of uncertain origin. Interpretation of these ichnofossils, including their tracemakers, behaviors involved, and environments that influenced their production requires the study of modern organisms. This project involved the study three burrowing predatory arthropods including two scorpions, *Pandinus imperator* and *Hadrurus arizonensis*, and a single whip scorpion, *Phrynus marginemaculata*. The animals were placed into large, sediment-filled terrariums for two-week periods during which time their burrowing behaviors and resulting biogenic structures were observed. After the animals were removed, open burrows were cast with plaster, excavated, and described. Detailed descriptions of the subsurface structures included basic architecture, bioglyphs, complexity, and tortuosity. Additional experiments were run with variations in soil composition, density, and moisture to determine thee animal's behavioral response to different environmental conditions. The biogenic structures produced by the scorpions included shallowly dipping ramps, helical shafts and tunnels, and broad, flat dwelling chambers. The biogenic structures produced by the whip scorpions consisted of large boxworks composed of branching, interconnected shafts and tunnels with multiple surface openings. Scorpions and whip scorpions produce unique three dimensional biogenic structures that can be distinguished from other soil organisms. Data collected from these and similar experiments can be applied to ichnofossil assemblages found in Paleozoic paleosols in order to better interpret the paleoecology of these ancient soil ecosystems. Examination of variations in trace morphology due to environmental change will also allow for the interpretation of soil consistency, soil moisture and water-table level, and sedimentation rates.

32: 1:45 PM-2:00 PM
Presenter: MARTIN, ANTHONY J.

BURROWS OF UNUSUAL SIZE: ENORMOUS DECAPOD TRACE FOSSILS IN FRESH-WATER FACIES OF EARLY CRETACEOUS POLAR ENVIRONMENTS, VICTORIA, AUSTRALIA

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Bergmann's Rule held that high latitudes correlated with larger body sizes in animals, a relationship influenced by area-volume ratios and heat conservation. Numerous exceptions to this “rule” have been noted, yet it applies well to marine crustaceans in circumpolar environments, which are significantly larger than lower-latitude taxa. The giant Tasmanian crayfish *Astacopsis gouldi* (> 80 cm long, 5 kg mass) also exemplifies this principle as the largest fresh-water crustacean, and it overwinters in streams that reach < 0°C. Unfortunately, *A. gouldi* does not burrow, and thus cannot provide a modern analog for unusually large fossil burrows made by fresh-water decapods or other crustaceans. Nonetheless, trace fossils attributable to decapod burrow systems from circumpolar fresh-water facies can reflect tracemaker body sizes, thereby testing whether Bergmann's Rule applies to ancient circumpolar fresh-water environments. With that paradigm in mind, this study presents evidence of unusually large burrows in fresh-water facies from the Strzelecki and Otway Groups (Aptian and Albian, respectively) of Victoria, Australia. Facies from both groups are interpreted as fluvial-lacustrine complexes that formed in circumpolar environments at paleolatitudes of about 78°S. The burrows, preserved in fluvial sandstones, are the largest *Thalassinoides* yet reported from fresh-water facies: in some instances, burrow diameters are 20-30 cm, and branching horizontal networks cover more than 25 m^2. *Thalassinoides* is nearly always ascribed to crustacean and decapod tracemakers, which is likewise interpreted for these specimens. Based on burrow allometry, tracemaker body masses were likely 10-15 kg, or 2-3 times larger than modern *A. gouldi*. The recent discovery of crayfish body fossils and trace fossils in the Otway and Strzelecki Groups lends credence to the presence of other, much larger burrowing astacideans, and hints at a diverse yet mostly undocumented fossil record for Mesozoic astacideans in southeastern Australia that included very large species adapted to circumpolar environments.

32: 2:00 PM-2:15 PM
Presenter: SMITH, JON J.

DESCRIPTION AND PALEOHYDROLOGICAL IMPLICATIONS OF EXCEPTIONALLY WELL PRESERVED FOSSIL ANT NESTS IN CALCIC PALEOSOLS OF THE OGALLALA FORMATION (MIOCENE), SCOTT COUNTY, KANSAS, USA

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Ogallala Formation strata in Scott County, Kansas, are composed of pedogenically modified silts, sands, and gravels interbedded with massive calcretes. Though ichnofossils are present throughout, the best examples are preserved within and below calcrete beds as carbonate-

filled casts weathering in full relief. One abundant group of ichnofossils is composed of vertically tiered, horizontally oriented chambers, typically wider than they are tall; these are linked vertically together by one or more small-diameter (<1 cm) shafts. At least three distinct morphotypes are distinguished based on systematic differences in chamber shape and architectural morphologies. Type A is most abundant and is composed of flat-bottomed, horizontally oriented, lobed chambers ranging in plan view from small teardrop-shapes to larger heart-shaped or multi-lobed chambers. Lobed chambers radiate from and are connected at their sides to a central, helical shaft. Type B chambers are circular to oblate in plan view and intersected by vertical shafts towards the center of the chamber or entering from above and exiting from below at opposite chamber edges. Type C is least common and is composed of spherical to ovoid chambers with vertically-oriented long axes connected from above to one or more vertical shafts. Lobate type A ichnofossils are nearly identical to the nests of extant harvester ants; specifically the genus *Pogonomyrmex*. Such ants are highly specialized granivores and prefer arid to semi-arid regions and sandy soils. Type B is most similar to the nests of extant funnel ants (*Aphaenogaster* sp.) which are fairly cosmopolitan with a wide range of habitats. Type C ichnofossils are most similar to fungus-gardening chambers of attine ants. Stratigraphic intervals with high fossil nest densities and architectural complexity suggest relatively stable paleosurfaces and water table positions. Differences in carbonate precipitation in nests of the same stratigraphic interval imply paleotopographic and paleohydrologic variability on the Ogallala floodplain.

32: 2:15 PM-2:30 PM
Presenter: SOUTO, P. R. F.

INFERENCES ABOUT A MEGA-ICHNOZONE OF SPIRAL COPROLITES FROM THE PERMIAN-TRIASSIC

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The bioturbation and micro-coprolites of invertebrate trace fossils are frequently used in biostratigraphic research due to their importance in sedimentological studies. Therefore, interest in the use of ichnofossils in paleogeographic and paleoenvironment reconstructions have expressly increased in stratigraphic research. Only in the end of last century, spiral coprolites are mentioned in sediment layers forming an ichnozone in the Lower Permian of the United States (New Mexico and Texas), Russia and India. In this study, spiral coprolites were analyzed in two units; the Pedra de Fogo Formation (Parnaíba Basin) and Corumbataí Formation (Parana Basin) both of Permian age, from Brazil. The coprolites are present in well defined layers made of fine sandstone from a stratigraphic horizon that, if compared to the

global record, would reveal the evidence that it is a global-scale event, with the possibility of being classified as a mega-acme zone of coprolites. In similar condition to the described events in other places abroad, the preservation conditions of spiral coprolites of these units confirm a depositional environment of medium to low energy formed by rivers and lakes, indicating a swampy environment. It is important to mention concerning the paleobiologic aspect, that in this circumstance and others the amounts of osteoclasts, teeth and scales of the *Xenacanthus* and *Ctenacanthus*, are dominant, where they can be found. Therefore the possibility is accepted of a trophic control of this group and a cosmopolitan dispersion during the transition from the Paleozoic to the Mesozoic.

32: 2:30 PM-2:45 PM
Presenter: CSONKA, JAYME D.

RUSOPHYCUS BIOSTRATINOMY AND IMPLICATIONS FOR DEPOSITIONAL DYNAMICS OF THE MIDDLE CAMBRIAN GROS VENTRE FORMATION OF THE BIG HORN MOUNTAINS IN WYOMING, USA

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Rusophycus is an ichnofossil with a stratigraphic range from the Cambrian to the Permian. Its excavation is commonly attributed to the resting and feeding behaviors of trilobites. Exposures of the Middle Cambrian Gros Ventre Formation located in Burgess Junction of Wyoming's Big Horn Mountains is an ichnofossil Lagerstätte for *Rusophycus* and offers insight as to how these ichnofossils were excavated and preserved. A large abundance of *Rusophycus* ichnofossils ranging in size from 0.9cm x 0.4cm x 0.2cm to 11.5cm x 5.2cm x 4.1cm (length, width, height) is indicative of a trilobite population. The level of preservation ranges from bilobed forms with poorly defined structures made by appendages of the trace-maker to bilobed traces with very fine detailed scratch marks. Previous researchers have suggested that the *Rusophycus* trace-maker burrowed to the sand-mud interface and actively backfilled the trace during excavation. However, cross-sections and thin sections of these specimens show that the *Rusophycus* were filled during multiple sedimentary events separate from the excavation, contrary to previous interpretations. The fine detail in many of the *Rusophycus* implies a cohesive substrate and suggests the presence of bacterial mats, which is supported by the presence of *Kinnaea* and stromatolite-like structures in surrounding strata. These *Rusophycus* occur as discrete sand lenses within beds of micaceous mudstone, as well as casts on the sole of sandstone beds. The isolated *Rusophycus* in mudstone beds provide evidence of episodic storms that swept arkosic sands from nearby exposed Precambrian granitic shorelines into this shallow littoral environment. The stratinomy of the Gros Ventre *Rusophycus* provide a tool for investigating depositional dynamics of the Middle Cambrian

Sauk Sea. The intensity and depth of biogenic structures in the Gros Ventre Formation potentially provide data that bear on the Agronomic Revolution, which resulted in the change of marine substrates from matgrounds to mudgrounds.

32: 2:45 PM-3:00 PM
Presenter: TETREAULT, DENIS K.

POSSIBLE EURYPTERID FEEDING TRACES FROM THE SILURIAN ERAMOSA KONSERVAT-LAGERSTÄTTE OF ONTARIO, CANADA

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Although rare as fossils, eurypterids commonly exhibit exceptional limb preservation, enabling their detailed morphology to be among the best known of any extinct Paleozoic organisms. Based on that information, substantial interpretive autecological and paleophysiological work has been done in the past. However, with the exception of walking traces from peripheral environments, most eurypterid faunas have little to no associated ichnological evidence. Therefore, there is no direct evidence of their other behaviors. Eurypterids occur as a component of the Silurian Eramosa Konservat-Lagerstätte from the Bruce Peninsula, Ontario, Canada. Most exceptionally-preserved biotas are of an atypical composition and often interpreted as representing rare and unusual environments. The Eramosa biota is particularly remarkable in that it not only contains exceptionally preserved marine invertebrates, vertebrates, and plants, but is also associated with shelly biotas, and a sometimes extensive ichnofauna. Among the many forms of trace fossils found within the fine-grained dolostones of the Eramosa Formation is a previously unknown spider-shaped trace. Ranging in width from 2 to 12 cm, the bilaterally symmetrical traces most commonly consist of 4 pairs of appendage marks, curving forwards and penetrating into the sediment. The central region of the trace is often characterized by disrupted sediment, possibly caused by the extraction of the appendages (and enclosed prey), arguing against a simple resting-trace origin. In the largest examples, the central region may be dominated by a subtriangular outline coherent with carcinosomid prosomal morphology, body fossils of which are found within the Lagerstätte. Although difficult to conclusively determine concommitant interaction, the traces are often in direct contact with the near-termination of associated *Planolites*-type traces. While the appendage morphologies of eurypterids have always been clearly interpreted as indicative of a predatory nature, the Eramosa traces may be the first direct ichnological evidence of eurypterid predatory feeding behavior.

32: 3:00 PM-3:15 PM
Presenter: BOYER, DIANA L.

HIGH RESOLUTION BIOTIC AND GEOCHEMICAL DATA FROM DEVONIAN DYSAEROBIC SHALES OF NEW YORK STATE

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Relative bottom water oxygen levels can be recognized from body and trace fossil data preserved in Devonian aged black shales of central and western New York. Using ichnological data including burrow size, relative amount of bioturbation (ichnofabric index), and ichnogeneric diversity in combination with species richness data, high-resolution variation in relative oxygen is recognized. These units are interpreted from a preserved fabric of commonly laminated sediments punctuated by uncommon trace and body fossilsto be persistently anoxic with brief intervals of dysoxia. Predictable taxonomic and paleoecological patterns are recognized in association with variable oxygen levels through the dysaerobic zone. Relative oxygen curves derived from the combined trace and body fossil signal allow a range of geochemical proxies to be calibrated for sensitivity through a range of reduced but non-zero bottom water oxygen levels on a cm scale through multiple units. Results support that the biological data allows for the distinction of variable relative oxygen levels through the dysaerobic zone while little variability is recognized from geochemical proxies including several iron proxies, sulfur isotope data and a range of trace metals including Mo and Mn.

32: 3:15 PM-3:30 PM
Presenter: NEBELSICK, JAMES H.

PALEOECOLOGY AND TAPHONOMY OF AN EARLY MIOCENE TURRITELLINE GASTROPOD MASS OCCURRENCE (NORTH ALPINE FORELAND BASIN, GERMANY)

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Although gastropod mass occurrences can be common in the fossil record, their paleoecology and taphonomy of are poorly understood. Turritelline gastropods are known to form high density, low-diversity accumulations from the Cretaceous until today. Present-day turritelline gastropods are suspension feeders living partly submerged in the substrate. These snails show a wide distribution and occur from shallow to deeper water settings. Recent mass occurrences have been described in shallow-subtidal, siliciclastic, nutrient-rich environments. A spectacular example of a fossil turritelline mass occurrence is the so-called “Erminger Turritellenplatte” west of Ulm. This occurrence is part of the Early Miocene “Upper Marine Molasse” unit in SW

Germany and represents a siliciclastic dominated marine unit of the North Alpine Foreland Basin. These sediments were deposited relatively close to the northern shoreline and are supposed to have developed during the maximum flooding of the Molasse Sea. The “Erminger Turritellenplatte” forms an at least 3.5 m thick, indurated bed with a lateral extension of a few square kilometers. The succession is dominated by sandy limestones, sandstones and sands with the gastropod *Turritella turris* occurring in rock-forming quantities. Oysters, aragonitic shelled bivalves, barnacles as well as fish and shark teeth also occur. Based on detailed sedimentological, palaeontological and taphonomic analysis we will explore: 1) the biological and sedimentary dynamics leading to this unique mass occurrence of gastropods; 2) the diagenetic pathway leading to the preservation of these aragonitic shelled organisms in such coarse, siliciclastic sediments and 3) the potential for using this occurrence for interpreting the paleoenvironment of the North Alpine Foreland Basin.

32: 4:00 PM-4:15 PM
Presenter: SORAUF, JAMES E.

PLEISTOCENE *MANICINA AREOLATA* FROM BERMONT STRATA IN SOUTH FLORIDA, I: COLONIAL MORPHOLOGY AND ENVIRONMENTAL IMPLICATIONS

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Massive, free-living, colonial corals, such as *Manicina areolata*, reflect differences in their environment by their size and other morphological characters, e.g. colline complexity in meandroid forms, as well as their colonial shape, concave or convex base and apex and, height, as well as volume (thus weight of colonial skeleton). This coral is well adapted for life in shallow, wave-swept waters due to its self-righting capabilities, resulting in colonies having either flat, concave, or cuneiform bases. All of these morphotypes are present in Pleistocene *M. areolata* from Florida and Cuba, and reflect adaptation to differing environmental conditions. Pleistocene faunas from roughly coeval strata at two localities in southern Florida (PBA Quarry and Holey Land Canal) provide excellent examples of flat-based colonies from lime mud and sandy, apparently sea-grass-rich environments. Complexity of confluent corallites increases with increasing size and colony volume. Analysis of corallum size, shape, oral complexity, and epibiont and macroborer community composition allows clear differentiation between more lime-mud-rich and more siliciclastic-rich environments. Corallum sizes tend to be larger with increasing substrate firmness, and shape differs; greater height is reached on firmer substrates. The area of flat-based coralla and colony weight appear to be primary limiting factors in *M. areolata's* growth, by limiting the coral's ability to self-right after overturning or causing sinking into soft substrate. Complexity of pattern of valleys and collines on the oral surface increases as area increases, thus collines developed on

smaller, soft-substrate colonies are characteristically straighter than those of larger, higher colonies that characteristically show more complexity. This is confirmed by the configuration of modern, deeper-water *M. areolata*.

32: 4:15 PM-4:30 PM
Presenter: HARRIES, PETER J.

PLEISTOCENE *MANICINA AREOLATA* FROM BERMONT STRATA IN SOUTH FLORIDA II: PALEOENVIRONMENTAL IMPLICATIONS OF THEIR EPI- AND ENDOBIONT COMMUNITIES

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Exquisitely preserved *Mancina areolata* coralla were studied from two localities in roughly coeval Pleistocene Bermont strata encompassing 30 specimens from the Palm Beach Aggregates (PBA) quarry and an additional 18 corals from a canal in the so-called Holeyland, 50 km to the southwest of PBA. The base of each coral was photographed and then the various groups comprising the epi- and endobiont communities (EEBCs), which include a spectrum of encrusting and boring organisms, were identified. To undertake a more quantitatively rigorous analysis of the EEBCs, the components were digitized, and image-analysis software was employed to calculate areas covered. We also tallied the numbers of individuals per coralla. There is a marked difference between the EEBCs from the two localities. Whereas Canal specimens generally show an equable distribution of EEBC components, with serpulids, spirorbids, and or chamids numerically dominant, and chamids dominating average area covered, the PBA coralla have a much less even distribution and lithophagids dramtically dominate virtually all the bases both in terms of both number and area covered. Given the relative proximity of the two localities, it seems unlikely that any of the EEBC components would have been substantially less common in one locality compared to the other. Therefore, we favor an explanation that focuses on the sedimentologic differences between the two areas to explain this variability. The Canal corals lived within a shelly, carbonate mud, whereas the PBA locality is dominated by shell and coarser-grained siliciclastic sediment. The latter produced a more cohesive substrate and allowed for a substantially greater number of lithophagid borers to enter the coralla. This sedimentologic variability likely reflects the paleosettings of the localities with PBA representing an environment very close to Florida's energetic east coast and the Canal site more akin to a protected, Florida-Bay-type environment.

32: 4:30 PM-4:45 PM

Presenter: RODLAND, DAVID L

FIND IT AND LAND ON IT: EXPLORING THE RELATIONSHIP BETWEEN SHELL SIZE AND EPIBIONT COLONIZATION

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Previous studies have suggested a linkage between the size of host valves and the processes of colonization by epibiont faunas: larger valves tend to show greater frequencies of colonization, with larger mean abundance and species diversity on encrusted shells. However, this relationship varies depending on the size metrics under investigation, and valve surface area appears to be a more meaningful control than simple dimensional measures. In this study we evaluate epibiont colonization on the rhynchonelliform brachiopod *Bouchardia rosea* collected from 15.5 m water depth at Ilha Grande, RJ, Brazil. 1324 valves from the same site and environmental conditions were evaluated, providing a statistically robust sample for evaluating the role of size and host surface area. Dimensional measurements (maximum length, width and height) were collected for each specimen, and a surface area model constructed for comparison using measurements from specimens of known size. Encrustation frequency, epibiont abundance, and species and class level diversity were evaluated for each brachiopod valve using a binocular microscope. Results are compared to data from the region of Ubatuba Bay, SP, Brazil, which indicate an increase in encrustation frequency (the percentage of shells colonized by epibionts) as a function of shell size, and a corresponding increase in mean per-valve abundance and richness measures. These results were used to develop a probabilistic model for shell colonization based on host surface area. However, larval settlement selectivity produces differences in interior and exterior colonization that cannot be attributed to differences in surface area alone.

32: 4:45 PM-5:00 PM
Presenter: ARMYNOT DU CHATELET, ERIC

SEDIMENT (GRAIN SIZE AND MINERALOGY) AND ORGANIC MATTER QUALITY CONTROL ON LIVING BENTHIC FORAMINIFERA. IMPLICATION OF THEIR USE TO SEDIMENTARY DEPOSITS RECONSTRUCTIONS. EXAMPLE OF THE CANCHE ESTUARY (FRANCE)

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The paleoecological interpretation of foraminiferal assemblages depends on an understanding of the ecological processes operating at the present. The evolution of the sediment infilling of the Canche estuary (France) since the 15th century was undertaken by using present and fossil (reworked from Mesozoic rocks) foraminifera and thecamoebian database interpretation in sedimentary cores. This reconstruction was based on observations of present assemblages. Proportion of thecamoebian, foraminifera, and fossil foraminifera indicates respectively freshwater, oceanic and rapid runoff on the study area. The variability on the foraminiferal assemblages was calibrated by using investigation on the quality of organic matter (OM) by elemental analysis, the sediment grain size, the clay and other grains mineralogy and the oceanic influence. After salinity that exercise one's main influence on the nature of the protists (foraminifera or thecamoebians), the results indicate that grain size is the most limiting parameter. Living (stained) benthic foraminiferal density and species richness are both very low within coarser sediments. OM is the second limiting factor. The density of foraminifera is the lowest and the species richness is the highest with the lowest organic carbon (C_{org}) contents and C/N < 12. Conversely, when the C_{org} is very high and C/N > 12, the density is high and the species richness medium. A high smectite proportion within the clay-size fraction seems to favor the development of *Miliammina fusca*. *Trochammina inflata* and *Jadammina macrescens* are both favored by increased organic carbon proportions but *Trochammina inflata* preferentially feeds on algal-derived OM when compared with *Jadammina macrescens*. This study clearly shows that environmental reconstructions need to take into account precise ecological processes to interpret any variation in foraminiferal assemblages.

32: 5:00 PM-5:15 PM
Presenter: SCOTT, DAVID B.

MARSH FORAMINIFERA AND SEA LEVEL: THE MANY APPLICATIONS

SCOTT, DAVID B., Earth Sciences Dept, Dalhousie University, Halifax, Nova Scotia, B3H3J5, Canada, dbscott@dal.ca; LIPPS, JERE H., Department of Integrative Biology and Museum of Paleontology, University of California, Berkeley, CA 94720 USA

It was proven more than 30 years ago that marsh foraminifera provided the most accurate means to relocate former sea levels. Here we present a summary of some sea-level curves and other methods to determine sea levels using foraminifera other than marsh foraminifera. But more importantly if sea level can be accurately located, many opportunities for solving other geologic problems present themselves because so many geologic problems occur along

coastlines and involve movements of sea level or require the knowledge of where sea level was. Knowing the sea-level position helps determine exactly what the signature of the event was. Some examples are earthquakes, tsunami, and hurricanes. All these phenomena leave traces in coastal deposits and all leave a record that can be traced by knowing the sea level at the time. Other things also occur in marshes because marshes occur at the upper end of the tidal range and hence contaminants that float (e.g. oil spills) often end up in the upper reaches of marshes-one example is an experiment done that showed a certain species of marsh foraminifera started to produce deformed tests (shells) within 3 days of a spill and continued to produce deformities until the oil residual went to zero. This means we can trace the decay time of an oil spill just by looking at the marsh foraminifera.

Session No. 33, 1:30 PM; Friday 26 June 2009
Symposium S19. Biological Response to Devonian Sea-level and Paleoclimate Changes

33: 1:30 PM-1:45 PM
Presenter: VER STRAETEN, CHARLES A.

BIOFACIES AND DELINEATION OF MULTIPLE EMSIAN T-R CYCLES, APPALACHIAN BASIN

VER STRAETEN, CHARLES A., New York State Museum, The State Educ. Dept., Albany, NY, 12230, United States, cverstra@mail.nysed.gov

New studies indicate that the Emsian sedimentary record is comprised of five third order sequences, deposited over approximately 17 million years. These represent five subdivisions of Devonian T-R Cycle Ib, which was over-generalized by Johnson et al. (1985). Along the Appalachian basin outcrop belt, new lower Emsian T-R cycles Ib1, Ib2, and Ib3 occur in the Esopus Formation in New York, and the Beaverdam Shale Member and lower Huntersville Chert in the central to southern part of the basin. New T-R cycles Ib4 and Ib5 occur in upper Emsian strata of the Schoharie Formation of New York, and the correlative strata in the middle Needmore Formation and upper Huntersville Chert. Distinctive, relative changes in biofacies, ichnofacies and degree of bioturbation help delineate sequence development throughout the basin. Specific changes vary according to relative depth. The succession begins with a sharp shift from an uppermost Pragian/low Emsian “big brachiopod” community in the Oriskany Sandstone to basinal dark gray/black shales, with little/no macrofauna. Goniatites and other pelagic fauna, not uncommon in lower and upper Emsian strata in the southern part of the basin (VA, WV, MD), are rare in the northern part of the basin (NY, PA). In deeper Emsian facies across the basin, degree of bioturbation and relative changes of ichnofacies (laminated rock-*Chondrites*-*Planolites*) are the best biological indicators of relative sea level change. In intermediate depth facies (argillaceous limestones, calcareous shales), low diversity benthic faunas (e.g., brachipods *Atlanticocoelia*, *Orbiculoidea*, and *Eodevonaria*, +/- phacopid

trilobites, and *Planolites* to *Zoophycos* traces) distinguish cycle caps from deeper, burrowed shales with little/no benthic macrofauna. In shallower water facies, where normal shelly benthos are common, more specific taxa (e.g., corals, brachiopods *Etymothyris*, *Amphigenia*, *Pseudoatrypa*, phacopid and dalmanitid trilobites) help distinguish relative sea level. Shallowest water Emsian biofacies occur in the Skunnemunk outlier of New York.

33: 1:45 PM-2:00 PM
Presenter: ELLWOOD, BROOKS B.

A CLIMATE-DRIVEN MODEL AND DEVELOPMENT OF A FLOATING POINT TIME SCALE FOR THE MIDDLE DEVONIAN EIFELIAN STAGE

ELLWOOD, BROOKS B., Geology and Geophysics, Louisiana State University, E235 Howe Russell Geoscience, Baton Rouge, LA, 70803, United States, ellwood@lsu.edu; TOMKIN, JONATHAN H., School of Earth, Society, and Environment, University of Illinois, 428 Natural History Building, 1301 W. Green Street , Urbana, IL 61801; EL HASSANI, AHMED, Institut Scientifique, Université Mohammed V Agdal, B.P.703, Rabat-Agdal, 10106 Rabat - Morocco; BULTYNCK, PIERRE, Department of Paleontology, Royal Belgian Institute of Natural Sciences, rue Vautier 29, BE-1000 Brussels, Belgium

We have developed a composite data set for the entire Eifelian Stage of the Middle Devonian from three biostratigraphically well-studied localities. From samples collected at 5 cm intervals throughout these sections, we measured the magnetic susceptibility (MS) and use these data as the basis for fitting a climate model to the Eifelian Stage. We establish a Milankovitch ~405 Ka eccentricity climate model and test the model using MS data pinned to time-series analysis from outcrop samples (1) from its lower (Emsian-Eifelian, Germany) and (2) upper (Eifelian-Givetian, Morocco) Global Boundary Stratotype Sections and Points (GSSPs), and (3) for Eifelian samples from Jebel Bou Tchrafine near Erfoud, Anti-Atlas Morocco. Using time-series analysis of these data we construct a uniform cyclicity model designed to conform to a ~405 Ka cyclicity with a duration corresponding to the published duration for the Eifelian of ~ 5.7 Ma (Ogg et al., 2008). To this model we fit a well-established conodont zonation developed independently using graphic correlation, thus allowing time estimates for conodont ranges for the Eifelian. This comparison yields a range from ~2.8 Ma (*costatus* zone) to ~50 Ka (*kockelianus* zone) for individual conodont zones. These zones allow high-resolution correlation among sections to better resolve timing of major bio-events, and provide a Floating Point Time Scale to which absolute ages can be applied. In addition, these data allow direct evaluation of sedimentation rates throughout the Eifelian Stage in those sections studied.Ogg, J.G., Ogg, G., and Gradstein, F.M., 2008. The Concise Geologic Time Scale. Cambridge University Press.

33: 2:00 PM-2:15 PM
Presenter: LINDEMANN, RICHARD H.

EIFELIAN THROUGH LOWER GIVETIAN (LOWER MIDDLE DEVONIAN) DACRYOCONARID SUCCESSIONS, NORTHERN APPALACHIAN BASIN

LINDEMANN, RICHARD H., Geosciences, Skidmore College, 815 North Broadway, Saratoga Springs, NY, 12866, United States, rlindema@skidmore.edu; VER STRAETEN, CHARLES A., NY State Education Department, New York State Museum, Albany, NY, USA 12230

Whereas *Styliolina fissurella* and *Viriatellina gracilistriata* are the only dacryoconarid species that have traditionally been reported from Eifelian through lower Geivetian strata of the northern Appalachian Basin, recent high-resolution SEM observations have shown that most reports of both are incorrect. Several undescribed forms of at least five dacryoconarid genera are now known to occur in the section and their successions are linked to each of three 3rd order depositional sequences: T-R Cycle Ic (basal to mid- upper Onondaga Fm.), T-R Cycle Id (upper Onondaga Fm. and Union Springs Fm.), and T-R Cycle Ie (Oatka Creek Fm.). Sandwiched between the base of the Eifelian Stage and teh Cycle Ic maximum flooding surface, the Nedrow Member of the Onondaga contains a unique fauna of *Styliolina*, *Striatostyliolina*, and *Costulatostyliolina* along with two species of *Viriatellina* that also occur higher in the section. Another species of *Striatostyliolina* first occurs at the base of the Cycle Id maximum flooding surface. The first occurrence of *Nowakia* is coincident with the Cycle Id falling stage systems tract. Lowermost strata of the Cycle Ie warm-water Stony Hollow fauna include a second *Nowakia*, the region's first occurrence of *Homoctenus* and new forms of *Viriatellian*. Within the Cycle Ie highstand systems tract another unique dacryoconarid fauna is succeeded by yet another that is dominatd by *N. halihanensis* within the Halihan Hill Bed, which is understood to lie at, or near, the base of the Givetian Stage. The Cycle Ie falling system tract strata contain a sparse dacryoconarid fauna that includes a fourth species of *Nowakia* and the uppermost known occurrence of the *Striatostyliolina* that first appears at the base of Cycle Id. It appears that, with the exception of one species of *Styliolina*, the dacryoconarid species of Cycles Ic-Ie do not occur higher in the section.

33: 2:15 PM-2:30 PM
Presenter: ZAMBITO, JAMES J.

PULSED FAUNAL CHANGES IN THE TYPE AREA OF THE LATE MIDDLE DEVONIAN (GIVETIAN) GLOBAL TAGHANIC BIOCRISIS: BIOFACIES COMPRESSION, RESTRUCTURING, AND EXPANSION

ZAMBITO, JAMES J, Department of Geology, University of Cincinnati, Cincinnati, OH, 45221-0013, United States, zambitjj@uc.edu; BRETT, CARLTON E., Department of Geology, University of Cincinnati, Cincinnati, OH USA 45221-0013; BAIRD, GORDON C., Department of Geosciences, SUNY College at Fredonia, Room 109 Houghton Hall, Fredonia, NY USA 14063-1021

The late Middle Devonian “Taghanic (*Pharciceras*) Event” was originally named by M. House for goniatite turnovers in the New York Appalachian Basin during the deposition of the Tully Limestone; subsequently it was associated with extermination of most of the long-lasting 'Hamilton Fauna' in this region. Further research into the fate of the 'Hamilton Fauna' in the type area identified three pulses of the Taghanic Biocrisis: 1) replacement of much of the endemic 'Hamilton Fauna' with the previously equatorial 'Tully Fauna'; 2) subsequent extermination of the 'Tully Fauna' and return of the 'Hamilton Fauna'; and 3) extinction of much of the 'Hamilton Fauna', at least locally, during a rise in global sea level in conjunction with global warming and black shale deposition, in what is referred to as the 'Taghanic Onlap'. The Taghanic Biocrisis is now recognized globally as a series of pulsed biotic transitions and extinctions. Development of a high-resolution stratigraphic framework for the type area has revealed the persistence of modified 'Hamilton Fauna' biofacies in nearshore settings while Hamilton elements were absent offshore during the Taghanic Onlap. Quantitative analysis of bulk-sampled biofacies along an onshore-offshore gradient throughout the Taghanic Biocrisis reveals a restructuring of the biofacies spectrum during this crisis as the habitable area within the basin was greatly reduced between an exceptionally elevated oxycline and drastically increased sediment input during renewed Acadian tectonic activity. Most noticeable is the permanent exclusion of diverse coral-dominated assemblages from the New York basin following this biocrisis owing to increased sediment input. Biofacies were further altered by the immigration of Old World Realm taxa during the Taghanic Onlap. Furthermore, study of the post-biocrisis fauna in the type area shows that a surprising complement of Hamilton taxa survived in nearshore settings and later reoccupied the basin when hospitable conditions returned to offshore settings.

33: 2:30 PM-2:45 PM
Presenter: BECKER, R. THOMAS

STRANGE TIMES: SEA-LEVEL AND CLIMATE RELATED UPPER GIVETIAN EVOLUTIONARY EXTREMES

BECKER, R. THOMAS, Institute für Geologie und Paläontologie, WWU Münster, Corrensstr. 24, Münster, NRW, D-48149, Germany, taghanic@uni-muenster.de; ABOUSSALAM, ZHOR SARAH, Institute für Geologie und Paläontologie, WWU Münster, Corrensstr. 24, Münster, Germany, D-48149

Recent geochemistry and geochronology data suggest that the Upper Givetian was a very unusual period in Earth history. It was sandwiched between two major, second order global perturbations associated with severe stepwise extinctions: the Taghanic Crisis and the Frasnes Events. Brachiopod and conodont oxygen isotopes suggest a sudden global warming of low latitudes between 6° and 14° around the Taghanic Crisis. This is supported by the extension of warm-water biota into high palaeolatitudes of South America and South Africa. The global climatic overheating was interrupted around the Middle/Upper Devonian boundary but

continued subsequently in the Frasnian. The scaling of the Devonian timescale gives only ca. 1.3 Ma for all of the Upper Givetian. This suggests an extremely rapid sequence of evolutionary events (post-Taghanic re-radiation) and eustatic fluctuations since there are six internationally recognizable conodont and ammonoid zones/subzones and at least six re-transgression couplets in the hermanni to norrisi Zones. It seems that strong climatic and eustatic pulses accelerated the overall evolutionary speed and pushed total diversity between two extreme periods that caused severe faunal overturns. Reefs flourished globally and their Phanerozoic maximum was initiated. The spread of oldest forrests may not be a coincidence. Marine extremes are indicated in ammonoid evolution by the sudden phylogenetic trend to develop gradually extraordinarily complex septa. In comparison to the Middle Givetian (ca. 7) and post-event Lower Frasnian (8), the average lobe numbers of genera rose from 9.3 to 15.7 towards the pulsed Frasnes Event. The complex Pharciceratacea sutures mirror increased vertical mobility and may reflect a trend to migronektonic life-style in times of eustatic rises and improved escape movements necessitated by the lowering of storm wave level on pelagic platforms during eustatic falls and temperature rises. Descendants of the unique pharciceratids favoured in the Middle Frasnian rather shallow pelagic or hemi-pelagic settings.

33: 2:45 PM-3:00 PM
Presenter: DAY, JED

GLOBAL SEA LEVEL AND CLIMATE CHANGE: MAIN CONTROLS OF ON THE EVOLUTION AND EXTINCTION OF UPPER DEVONIAN (GIVETIAN-FRASNIAN) NORTH AMERICAN TROPICAL CARBONATE PLATFORM BRACHIOPOD FAUNAS

DAY, JED, Department of Geography & Geology, Illinois State , Normal, IL, 61790-4400, United States, jeday@ilstu.edu

As many as ten sea level events were the primary controls on timing of stepped dispersal and speciation bioevents in numerous clades of Devonian Old World Realm (OWR) brachiopods that immigrated into central and eastern North American shelves. Progressive and total collapse of western Laurussian faunal provincialism was the consequence of repeated migrations of tropical OWR taxa during transgressions coinciding with warming subtropical sea surface temperatures (SSTs) that began in the Middle Givetian, cintinuring into the Frasnian. Many OWR taxa that became widespread in central and eastern North American shelves initially evolved in western Canadia or made first arrivals in western Canadian platforms in the NWT and western Alberta-BC from eastern Laurussia, then expanded ranges during stepped migrations from the low-latitude shelves into subtropical platforms during subsequent transgressions. Few if any former Eastern America Realm (EAR) Givetian endemic taxa migrated into central and western North America shelves, indicating that seaway circulation was not favorable for out-migration from central and eastern North American shelves. Continued warming in the tropics are evidenced by SSTs that peaked near 32-33 °C during the latter part of the Frasnian and was coincident with the most significant Frasnian seaway

expansion during the semichatovae transgression. This event resulted in the widespread dispersal of tropical middle shelf faunas in nearly all North American platforms marking the culmination of Frasnian cosmopolitanism. Significant and rapid SST cooling events coincided with the Lower and Upper Kellwasser extinction bioevents (LKE & UKE). Platform drowning during the very late Frasnian IId-2 transgression appears to coincide with the LKE in central and western North American shelves. Subtropical platform faunas experienced significantly higher alpha diversity extinction rates than low latitude faunas during the LKE, and extinction of typical Frasnian brachiopod taxa and the stromatoporoid-coral reef biota across the tropics during the very latest Frasnian LKE.

33: 3:00 PM-3:15 PM
Presenter: SAVAGE, NORMAN M.

LATE FRASNIAN TO LATE FAMENNIAN CONODONTS AND ASSOCIATED ISOTOPE GEOCHEMISTRY FROM NORTHWESTERN THAILAND

SAVAGE, NORMAN M., Geological Sciences, University of Oregon, 1942 Kimberly Drive, Eugene, OR, 97405, United States, nmsavage@uoregon.edu; RACKI, GRZEGORZ, Institute of Paleobiology, Polish Academy of Sciences, Twarda St. 51/55, Warsaw, Poland, PL 00-818; LUTAT, PETRA, Palaeontological Research and Education Centre, Mahasarakham University, Mahasarakham, Thailand 44150

An eleven-meter vertical section near the town of Mae Sariang, northwestern Thailand has yielded conodont faunas of late Frasnian to latest Famennian age. The section appears to include the Upper Kellwasser Event and the Hangenberg Event, as indicated by the conodonts and ^{13}C and ^{18}O isotope excursions. The faunas are mostly cosmopolitan but include several new species.

33: 3:15 PM-3:30 PM
Presenter: HARTENFELS, SVEN

THE GLOBAL *ANNULATA* EVENTS IN GERMANY AND SE MOROCCO - IMPLICATIONS FOR UPPER FAMENNIAN (DEVONIAN) EUSTASY AND CHRONOSTRATIGRAPHY

HARTENFELS, SVEN, Institut für Geologie und Paläontologie, Westfälische Wilhelms-Universität, Corrensstr. 24, Münster, Nordrhein-Westfalen, 48149, Germany, shartenf@uni-muenster.de; BECKER, R. THOMAS, Institut für Geologie und Paläontologie, Westfälische Wilhelms-Universität, Corrensstr. 24, Münster, Nordrhein-Westfalen, Germany, 48149

The hypoxic to anoxic *Annulata* Event was named by House (1985). Originally it referred to a couplet of intercalated fossiliferous black shales in the northern Rhenish Massif (Germany) with mass occurrences of the clymenid *Platyclymenia*, including the name-giving index species *Platyclymenia annulata*. It falls in the *annulata* Zone (*Prionoceras* Genozone) at the base of the Upper Devonian IV-A of classical German stratigraphy. Almost none of the ammonoids of Upper Devonian III survived into the Lower *Annulata* Event beds, suggesting significant extinction and re-population by faunal immigration. In the conodont scale both black shales fall in the Upper *trachytera* Zone and are often followed by goniatite-rich limestones (*Annulata* Limestone or "Wagnerbank") of the highest Upper *trachytera* Zone. The lithological and faunal changes suggest transgressive pulses within the top part of the overall shallowing T-R Cycle IIe of Johnson et al. (1985) as has been observed in various regions throughout the globe (Becker et al. 2004).There is evidence for a significant extinction of some important conodont taxa in the northern Rhenish Massif in association with the *Annulata* Events. Whilst alternognathids survived variably for a short time and still can be found in subsequent beds, *Scaphignathus velifer velifer*, *Palmatolepis rugosa trachytera*, *Palmatolepis glabra lepta*, as well as *Palmatolepis minuta minuta*, don't pass the event interval layers. The last *Scaphignathus velifer velifer* and *Palmatolepis rugosa trachytera* are separated from the first *Polygnathus styriac*us s. str. by a short *velifer/trachytera-styriacus-interregnum* (4-10 limestone/nodule levels). *Polygnathus* n. sp. aff. *styriacus* represents a transitional form between *Polygnathus granulosus* and *Polygnathus styriacus* and may co-occur with youngest *Palmatolepis rugosa trachytera*. Unfortunately, *Palmatolepis rugosa trachytera* as well as *Polygnathus styriacus* are missing in studied Moroccan sections, but, comparable to the northern Rhenish Massif, *Scaphignathus velifer velifer* and *Palmatolepis minuta minuta* become extinct straight below the Annulata Event interval.

33: 4:00 PM-4:15 PM
Presenter: BAIRD, GORDON C.

LATE FAMENNIAN STRATIGRAPHY AND PALEONTOLOGY IN NORTHWEST PENNSYLVANIA: POTENTIAL LINKS TO GLOBAL BIOEVENTS AND PALEOCLIMATE CHANGES

BAIRD, GORDON C., Dept of Geosciences, S.U.N.Y. Fredonia, Fredonia, NY, 14063, United States, Gordon.Baird@fredonia.edu; OVER, D. JEFFREY, Geological Sciences, S.U.N.Y. Geneseo, Geneseo, NY USA 14454; MCKENZIE, SCOTT S., Geology, Mercyhurst College, Erie, PA USA 16546; SULLIVAN, JOSEPH S., Buffalo Geological Society, 293 Burch Avenue, West Seneca, NY USA 14210

Recent mapping of end-Devonian units in Crawford County, Pennsylvania has been undertaken to reassess the problemmatic area stratigraphy, to reexamine the succession of neritic faunas identified by Caster (1934), and to establish a conodont chronostratigraphy for this section. Given the developing recognition of end-Devonian global paleoclimatic changes and biotic crises, the northwest Pennsylvania section needs refinement. Additional, potentially

correlative, enigmatic, regional features (Spechty Kopf diamictites, “Haystacks Sandstone” in eastern Pennsylvania; megadeformed Berea Sandstone in Ohio) further indicate such a need. We have found that key Upper Devonian units (Cleveland Member, Bedford Member-equivalent succession), known to be absent near the PA/Ohio state line due to pre-Berea (sub-Cussewago Sandstone) erosion, progressively reappear eastward below the base-Cussewago contact from the French Creek Valley eastward to the meridian of Union City. A condensed unit (Cleveland Member?), characterized by dark, bioturbated siltstone and black shale partings and floored by a detrital pyrite/bone lag (probable Skinner Run Bed), is succeeded by a higher, discontinuity (“Syringothyris Bed”), which Caster (1934) equated to the base of the Bedford succession in Ohio. Succeeding units (“Drake Well Formation”, “Tidioute Shale” sensu Harper, 1998), up to the Corry Sandstone, are herein believed to be Bedford Shale equivalents. The Drake Well Formation is notable for the occurrence of inadunate and camarate crinoids, plus clusters of the echinoid *Hyattechinus*. Preliminary conodont analysis has, respectively, yielded *Bispathodus bispathodus* and *Polygnathus symmetricus*? (M-U expansa zones) in the Cleveland Member-equivalent Bed, *Bispathodus bispathodus* and *Polygnathus communis communis* (M-U expansa zones) in the base-Drake Well “*Syringothyris* Bed”, and *Bispathodus aculeatus anteposicornis*, *Bispathodus stabilis*, *Bispathodus aculeatus aculeatus*, and *“Icriodus” raymondi* Sandberg and Ziegler, 1979 (M-U *expansa* and *praesulcata* zones) in upper Drake Well strata.

33: 4:15 PM-4:30 PM
Presenter: SALLAN, LAUREN

THE IMPACT OF THE LATE DEVONIAN BIOTIC CRISIS ON GLOBAL VERTEBRATE DIVERSITY: RESULTS FROM A NEW PALEOZOIC DATABASE

SALLAN, LAUREN, Organismal Biology and Anatomy, University of Chicago, 1027 E 57th Street, Chicago, IL, 60657, United States, lsallan@uchicago.edu

While numerous studies have focused on the effect of the Late Devonian crisis on marine invertebrates, none have quantified impacts on the vertebrate fauna. This oversight is related to undersampling of Paleozoic marine and freshwater vertebrates in paleobiological databases. A new global vertebrate occurrence dataset has now been compiled for the interval around the Devonian-Carboniferous boundary (Givetian-Serpukhovian). Diversity curves reconstructed from these data for higher taxonomic groups, and binned by stage, reveal a sudden and major turnover in the total vertebrate biota. This signal is retained in subsampling analyses. Placoderms and sarcopterygians (excluding limbed tetrapods) reach peak numbers during the Late Devonian, dominating the majority of sites. The diversity of both groups falls off drastically into the Carboniferous, representing the permanent loss of more than 70% of sarcopterygian genera and the extinction of all placoderms. While scarce Devonian forms (chondrichthyans, limbed tetrapods, and actinopterygians) diversify slightly in the Late Devonian, they all radiate into and during the Mississippian, with an average increase

of 150% in levels of generic diversity from the Famennian to Visean. The turnover coincides with the Hangenberg extinction event of the end-Devonian, rather than the more widely known Kellwasser events of the Frasnian-Famennian. Hangenberg black shales were deposited during a period of dramatic sea level instability. Eustacy is inferred as a primary driver of patterns of extinction because of differential effects on mostly marine groups (e.g. placoderms). Clades with a plurality of euryhaline and freshwater taxa (e.g. chondrichthyans, actinopterygians, and limbed tetrapods) evidently show greater resilience to this crisis and radiate in the aftermath of the event. Since these clades dominate all succeeding vertebrate faunas, the Hangenberg extinction had a major, and thus far neglected, role in shaping modern biodiversity. The new dataset will be expanded and will play a part in analyses of other macroevolutionary phenomena.

33: Poster
Presenter: ABOUSSALAM, ZHOR SARAH

NEW CONODONT FAUNAS FROM AROUND THE MIDDLE/UPPER DEVONIAN BOUNDARY OF THE MONTAGNE NOIRE (S. FRANCE). For full abstract, see *17: 2:00 PM, Booth 3*

33: Poster
Presenter: CASIER, JEAN-GEORGES

OSTRACODS, LITHOFACIES AND MAGNETIC SUSCEPTIBILITY OF THE GIVETIAN/FRASNIAN PARASTRATOTYPE AT NISMES (DINANT SYNCLINORIUM, BELGIUM). For full abstract, see *17: 2:00 PM, Booth 5*

33: Poster
Presenter: BRETT, CARLTON E.

TAPHONOMY OF RHYTHMIC TRILOBITE BEDS IN THE LOWER DEVONIAN OF MOROCCO: THE PARADOX OF “CYCLIC EVENT BEDS”. For full abstract, see *25: 2:00 PM, Booth 26*

Author Index

Entries in the author index are based on the codes preceding each abstract as explained at the beginning of the volume.