Hilton University of Florida Conference Center
1714 SW 34th Street
Gainesville, Florida
February 15th – 18th, 2014

Abstract Book

The Paleontological Society Special Publications

Volume 13
Welcome from the Organizing Committee for NAPC 2014

It is our great pleasure to welcome you to Gainesville for the 10th North American Paleontological Convention (NAPC 2014). Since its inception in 1969, NAPC has evolved into a highly successful quadrennial meeting that brings together those who study the fossil record: professionals, students, and avocational paleontologists. NAPC meetings are organized under the auspices of the Association of North American Paleontological Societies, but their scope is global. Indeed, paleontologists from all continents, except for Antarctica, are in attendance at this NAPC conference.

This meeting attests to the impressive topical breadth of NAPC, with sessions and presentations covering all major groups of organisms and the entire span of the fossil record, from the Archean to the Anthropocene. Also, critical themes that motivate the science of paleontology and novel methodological advancements in our field are well represented at this conference. We are thus confident that all of us will emerge from this meeting energized and inspired by advancements and discoveries unveiled here in Gainesville over the next four days.

We are delighted by the strong presence of students at this convention. You are the future of our discipline and we extend our warmest welcome to you all. We look forward to learning about your current research and hope that this meeting will prove to be a truly transformational career experience for you. Also, we are pleased to announce the launching of a new award program dedicated to students: the NAPC Student Awards.

Likewise, we are elated by the active participation of avocational paleontologists who are well represented at this gathering. You are an important part of our profession, and we hope that this meeting will facilitate networking and scholarly interactions between you and professional paleontologists. You are most welcome here!

We hope that you will enjoy the venue of this convention. The University of Florida is one of the largest academic, research, and cultural centers of the southeast, the Florida Museum of Natural History houses a vibrant paleontology program and immense research collections, and the state of Florida is a mecca for avocational fossil collectors. Let us enjoy it while sea level remains relatively low.

This conference could not have happened without generous support from our sponsors and the selfless efforts of numerous volunteers who participated behind the scene in various organizational aspects of this convention. We owe them our deepest gratitude.

Welcome, again, and enjoy the meeting!

The Organizing Committee of the 10th North American Paleontological Convention
Florida Museum of Natural History, Gainesville, Florida
NAPC 2014 Organizing Committee

Michal Kowalewski, Chair | Florida Museum of Natural History
Troy Dexter, Associate Chair | Florida Museum of Natural History
Barry Albright | University of Northern Florida
Richard Aronson | Florida Institute of Technology
Jonathan Bloch | Florida Museum of Natural History
Jon Bryan | Northwest Florida State College
Laurel Collins | Florida International University
Peter Harries | University of South Florida
Austin Hendy | Florida Museum of Natural History
Greg Herbert | University of South Florida
Richard Hulbert | Florida Museum of Natural History
Douglas Jones | Florida Museum of Natural History
Bruce MacFadden | Florida Museum of Natural History
Steve Manchester | Florida Museum of Natural History
Jim Mead | East Tennessee State University
G. Harley Means | Florida Geological Survey
Arnie Miller | University of Cincinnati
Roger Portell | Florida Museum of Natural History
Mike Savarese | Florida Gulf Coast University
David Steadman | Florida Museum of Natural History
Peter Swart | University of Miami
Hongshan Wang | Florida Museum of Natural History
Aaron Wood | Florida Museum of Natural History
Peg Yacobucci | Bowling Green State University

NAPC 2014 Student Organizing Committee

Sarah Allen | Florida Museum of Natural History
D. J. Buren | University of Florida
Sahale Casebolt | Florida Museum of Natural History
Paul Morse | Florida Museum of Natural History
Map of Gainesville Area
(including Florida Museum of Natural History and Hilton UF Conference Hotel)
Hilton University of Florida Conference Center Floor Plan
Florida Museum of Natural History Floor Plan
10th North American Paleontological Convention List of Sessions

Opening Ceremony
Saturday Morning, 9:00–10:00 AM, Century Ballroom A, B, and C

Opening Plenary Session
Saturday Morning, 10:00–11:30 AM, Century Ballroom A, B, and C

Saturday Oral Sessions

Session 1: Ecological fidelity and resolution of the fossil record across broad spatial and temporal scales

Chairs: Adam Tomašových, Joshua Miller, James Nebelsick, and Martin Zuschin

Session 2: The microfossil record: The past is the key to the future (or present) in conservation paleobiology

Sponsor: The Cushman Foundation
Chairs: Pamela Hallock and Laurel S. Collins

Session 3: Phylogenetics, systematics, paleoclimatology, paleoceanography, paleobiogeography

Chairs: Javier Luque and Sarah Allen

Session 4: Pantropical Cenozoic reefs

Chairs: James Klaus, Kenneth Johnson, and Willem Renema

Session 5: New advances and applications in sclerochronology

Chairs: Donna Surge and David Goodwin
Saturday Poster Sessions

Session 6: Pantropical Cenozoic reefs

Session 7: Phylogenetics, systematics, paleoclimatology, paleoceanography, paleobiogeography

Session 8: Biostratigraphy, paleoecology, taphonomy, and extinction

Session 9: New advances and applications in sclerochronology

Sunday Oral Sessions

Session 10: Reconstructing past continental environments from the biogeochemistry of fossils

Chairs: Yurena Yanes and Brooke Crowley

Session 11: Form and function: Tracing the foundations of animal diversity, ecology, and functional morphology

Chairs: Mike Meyer and James Schiffbauer

Session 12: From macroecology to macroevolution: the ecological context of extinction and origination

Chairs: Seth Finnegan and Carl Simpson

Session 13: Conservation paleobiology: Ecosystem, community, and species response to environmental change

Chairs: Carrie L. Tyler, Sahale N. Casebolt, and Rebecca Terry

Session 14: The Cretaceous–Paleogene Gondwanan expressway

Chairs: Maria A. Gandolfo and Elizabeth J. Hermsen
Sunday Oral Sessions, continued

Session 15: Modern approaches to educational outreach in paleontology

Chairs: Peg Yacobucci and Christy Visaggi

Session 16: Diversity, origination, and extinction

Chairs: Kristopher Rhodes and Blaine Schubert

Session 17: Morphological Patterns

Chairs: Kristin Polizzotto and Troy Dexter

Sunday Poster Sessions

Session 18: Diversity, origination, and extinction

Session 19: Morphological patterns

Session 20: Reconstructing past continental environments from the biogeochemistry of fossils

Session 21: Modern approaches to educational outreach in paleontology

Session 22: From macroecology to macroevolution: the ecological context of extinction and origination

Session 23: Form and function: Tracing the foundations of animal diversity, ecology, and functional morphology

Session 24: Conservation paleobiology: Ecosystem, community, and species response to environmental change
Monday Oral Sessions

Session 25: Celebrating public participation in paleontology

*Sponsor:* The Florida Paleontological Society

*Chairs:* Austin J.W. Hendy and Bruce J. MacFadden

Session 26: Critical paleobiological transitions in Earth history: The value of multidisciplinary approaches

*Sponsor:* STEPPE

*Chairs:* Sandra J. Carlson and Philip D. Gingerich

Session 27: The Cenozoic assembly of the grassland biome: pattern and process in ecosystem evolution

*Chairs:* Caroline Strömberg and Bonnie Jacobs

Session 28: Exceptional Records: Evolution and ecology of microfossils

*Chairs:* Gene Hunt and Pincelli Hull

Session 29: What comes after death: current topics in actualistic taphonomy and integrative paleobiology

*Chairs:* Emma R. Locatelli, Madeline S. Marshall, Marc Laflamme, James D. Schiffbauer, and Simon Darroch

Monday Poster Sessions

Session 30: Ediacaran environments and ecosystems

Session 31: What comes after death: current topics in actualistic taphonomy and integrative paleobiology

Session 32: Stratigraphic paleobiology: Integrating sedimentary and fossil records

Session 33: Digitization in vertebrate paleobiology
Monday Poster Sessions, continued

Session 34: Celebrating public participation in paleontology

Session 35: Critical paleobiological transitions in Earth history: The value of multidisciplinary approaches

Tuesday Oral Sessions

Session 36: Ediacaran environments and ecosystems

Chairs: Lidya Tarhan and Marc Laflamme

Session 37: Stratigraphic paleobiology: Integrating sedimentary and fossil records

Chairs: Jackie Wittmer and Daniele Scarponi

Session 38: Digitization in vertebrate paleobiology

Chairs: Aaron R. Wood and P. David Polly

Session 39: Paleoecological patterns

Chairs: Richard Hulbert and Adiël Klompmaker

Closing Ceremony and Plenary Session

Tuesday Afternoon, 3:00–4:45 PM, Century Ballroom A, B, and C

Banquet

Tuesday Afternoon, 5:00–8:00 PM, Touchdown Terrace,

Ben Griffin Stadium, University of Florida
Sandra J. Carlson, Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616

Serving as President of the Paleontological Society for the past year has been a great honor for me, in part because it has presented me with many opportunities to ponder The Big Picture in Paleontology: Where are we now? Where are we going? How do we get there? I have come to realize that a useful role of leadership is the willingness to step back and assess challenges and opportunities that face all of us in this discipline, beyond those in our individual labs or offices. Rather than try to summarize where we are now (although I certainly have opinions I could share), and acknowledging that we all want to be headed toward a “better place” in the future—with better research funding, better education, better employment, better public awareness, and better political representation for science—I would like to focus primarily on the last of these three questions. How do we get from here to there? Several different approaches seem particularly effective and potentially valuable; most are quite obvious but bear repeating from time to time. I plan to expand on each of these in my address:

- Strive for excellence: in our research, teaching, and professional service.
- Respect diversity: disciplinary, gender, racial, philosophical, ideological.
- Appreciate paleontology: both our subject matter and its practitioners and cultures.
- Communicate with each other: about how to both sustain science and catalyze change.
- Work together: to maximize effectiveness and minimize divisive words and actions.
- Think big: view science as a complex system of interactions in which paleontology forms a critical link in the network.

I will illustrate a few of these approaches by discussing examples from my research on brachiopods, in order to share my particular experiences relevant to this general discussion of the evolution of our discipline. Specifically, how has an appreciation of evolutionary biology and modern systematic methods, advances in imaging technology (2D images of 3D models of microCT scanned, extant brachiopod specimens are illustrated on the following page), stable isotope geochemical analysis of carbonate shell material, and modeling of phylogenetic tree shape using methods adapted from geomorphology and geophysics, played a role in paleontological research?

In this age of limited (and shrinking) funding in the continually changing context of our profession, it is ever more imperative that the paleontological disciplines join together more effectively to work on strengthening our shared interests: increase funding for paleontological research; improve the quality of graduate, undergraduate, and K–12 education; enhance the public appreciation of science; better inform policy makers about the paleontological aspects of public policy issues. I think it is counterproductive for us to continue to divide ourselves into factions: geological vs. biological, vertebrate vs. invertebrate, Paleozoic vs. Cenozoic, etc. We all study the history and evolution of life on Earth as revealed in the fossil record—that common focus unites us and gives us strength to fight for issues that are important to all of us. Let's work together as we move from the present to the future of paleontology.
Compsothyris racovitzae, crura

Chlidonophora incerta, short loop

Chlidonophora incerta, spicules
Despite dire predictions of the imminent demise of vertebrate paleontology (VP) by the rise of molecular biology, we remain alive, well, and looking to the future. Many changes have occurred in our field over the past 100 years as we moved from a purely morphology-based field rooted in comparative anatomy and gross observation to one that employs a variety of techniques, technologies, and analyses from the molecular to organismal levels.

Some of the future change in VP can be predicted by trends to the present. One of the primary changes occurring in our field, as in many science disciplines, is the increase in the percentage of women entering and remaining active in VP. Women now form a large portion of the Society of Vertebrate Paleontology (SVP) membership, particularly among younger members. Nowhere is this trend more pronounced than in the leadership of SVP, where four of the past five presidents have been women.

The second major trend in VP is the increase of the number of students entering our field. Student membership in SVP has been steadily climbing for many years. For example, the number of students rose from 23% of total membership in 2006 to 28% in 2012. This increase in VP students seems to be the inverse of the trends in the availability of traditional VP jobs at universities and museums. Are we training too many students to replace the present number of available positions, and should we be rethinking the training of PhD students in the future to include preparation for other essential non-research positions such as mitigation, museum education, government and state positions, and even secondary and community college-level education?

Imagine having had a high school teacher who not only understood the process of science, but could illustrate it with examples from paleontology. We need to recognize these non-traditional positions as valuable to science and reason, and that our time training such students is time well-spent.

VP has long been a cross-disciplinary field integrating geology and biology. We need to continue to encourage this cross-disciplinary training to combat the tendency for students to remain rooted in only one field. VP will only become more collaborative in the future, partnering with stratigraphers, taphonomists, geochronologists, histologists, molecular biologists, biomedical researchers, and invertebrate paleontologists and paleobotanists. To understand our fossils and their context we need to understand them as organisms that lived in a particular environment at a particular time with a finite assemblage of other organisms. They lived lives in context. Evolution proceeded through time and across a changing context. To unravel this evolution we need increased dialogue among these disparate fields, to cross different paleontology disciplines, and to delve deeply into all thing geologic and biologic. We must continue to mine available technology. Great strides are being made in VP through synchrotron and CT imaging, Finite Element analysis, histological investigations of life history traits, digital fossil preparation, stable isotope work, molecular biology, and a host of other techniques and technologies borrowed from other fields. All this increases the amount of information we can derive from our fossils with regard to phylogeny, ontogeny, growth, taphonomy, paleoecology, and biogeography.

For VP to continue for the next 100 years, we need fossils. We must remain vigilant regarding the protection of our fossil resources here and in other countries. We need to ensure that fossil repositories continue their stewardship of these resources. Reproducibility is a crucial component of science, and can be lost through attrition of valuable and referenced specimens. Increasingly, part of this stewardship is the development of digital repository databases and images of specimens. This opens exciting new pathways for global data and specimen availability and distribution. We will be able to share data like we used to share the fossils themselves, increasing the availability of their data for all.

We need to continue to advocate for our science among neontologists. The record of evolution is long and complex and cannot be told through the few taxa alive today. There’s still a big, wide world of evolution in the geologic record waiting to be revealed. The future of VP is wide open.
BRINGING PALEONTOLOGY'S ‘DARK DATA’ TO LIGHT

Shanan E. Peters¹, Christopher Ré², Miron Livny³,⁴, Ce Czhang⁴, Vidhya Govindaraju⁴, Michael McClennen¹, John J. Czaplewski¹

¹Department of Geosciences, University of Wisconsin-Madison, Madison, WI 53706; ²Department of Computer Science, Stanford University, Stanford, CA 94305; ³Morgridge Institute for Research and Wisconsin Institute for Discovery, Madison, WI 53715; ⁴Computer Sciences Department, University of Wisconsin-Madison, Madison, WI 53706

Paleontology is fundamentally based on the description and biological classification of fossils, an enterprise that over the past four centuries has spawned countless field expeditions, museum trips, and hundreds of thousands of publications. The construction of databases that aggregate these descriptive data on fossils in a way that allows large-scale, synthetic questions to be addressed has greatly expanded the intellectual reach of paleontology, and has led to many important new insights into macroevolutionary and macroecological processes. Nevertheless, paleontology, like many geoscience disciplines, remains comparatively data-limited, both in terms of the pace of discovery and description of new fossils and in terms of the ability of researchers to find, access, and utilize existing data in a large, widely disseminated, and heterogeneous literature.

One of the largest compendia of fossil data assembled to date is the Paleobiology Database (PBDB), founded in 1998 by John Alroy and Charles Marshall (the former of whom was instrumental in sustaining the effort technically and intellectually for almost two decades). These two pioneers assembled a small team of scientists who were motivated to generate the first geographically-explicit, sampling standardized global biodiversity curve (Alroy et al., 2001, 2008). The PBDB has since grown to include an international group of more than 150 contributing scientists with diverse research agendas. Collectively, this body of volunteer and grant-supported investigators have spent more than nine continuous person-years entering more than 280,000 taxonomic names, nearly 500,000 published opinions on the status and classification of those names, and over 1.1 million taxonomic occurrences (geographically and temporally explicit instances of taxonomically classified fossils). Some PBDB data derive from the original fieldwork and specimen based studies of the contributors, but the majority of the data were extracted from the text, figures, and tables of over 48,000 published papers, books, and monographs that span the range of topics covered by paleontology. Their efforts have been well rewarded by enabling new science. As of December 2013, the PBDB had produced 191 official peer reviewed publications, all of which address scientific questions that cannot be adequately answered without such a database.

In addition to being a scientific asset to the field of paleontology, the PBDB and other databases like it provide an addition means by which to participate in rapidly emerging initiatives and developments in cyberinfrastructure. To increase its reach in this area, the PBDB now has an Application Programming Interface (API), which makes data more easily and transparently accessible, both to individual researchers and to applications, such as the open source web application PBDB Navigator (Figure 1) and the Mancos iOS mobile application. Both of these applications are built on the public API and are designed to allow the history of life and environment documented by the PBDB to be more discoverable. These new modes of interactivity and visualization highlight unintended, but potentially useful, aspects of the PBDB. For example, the combined efforts of the database contributors have generated the first large-scale crowd sourced geologic map. The PBDB API also facilitates loosely coupled integration with other related but independently managed biological and paleontological database initiatives and online resources, such as the Neotoma Paleoecology Database, Morphobank, and the Encyclopedia of Life. The PBDB API can also be harnessed by geoscientists
outside of paleontology, thereby facilitating the integration of paleontological data with diverse types of data and model output, such as paleogeographic plate rotation and geophysical models in GPlates (http://www.gplates.org) (Seaton et al., 2012). This type of interoperability and data access is important because it can facilitate fundamentally new science and because it expands the reach of paleontology to a broader community of researchers and educators than is possible via any single website or application.

Despite the significant effort and commendable commitment of the PBDB contributors, the database remains rather incomplete in its coverage of even the existing published body of all paleontological knowledge, a fact which is partly attributable to the laborious task of finding and entering data from the literature into the database and by the types of data that it can currently accommodate. Our EarthCubeDeepDive team, recently formed as part of NSF’s EarthCube initiative, seeks to leverage advanced machine reading, vision, and learning techniques, along with a powerful computational infrastructure, to help overcome some of these limitations and to significantly increase the rate of bringing more and different types of data to the PBDB. Specifically, we aim to build a system that automatically finds and then systematizes data and information from the entire body of published geological, paleontological, and biological literature. To do this, we are leveraging DeepDive, a trained computing system developed as part of DARPA’s machine reading grand challenge, to build a new system, PaleoDeepDive. Trained computing systems like PaleoDeepDive are not search engines, which require a priori knowledge of what to look for, and even then only return documents/text snippets based on string pattern matching. Instead, trained systems cognitively read documents in order to recognize and extract from them information, the general nature of which is defined a priori by only a few relatively simple rules. These computing systems are, therefore, capable of finding the relevant literature and then generating a posteriori lists of “search terms” (e.g., biological species, named geological formations). Additional synthetic information about each of these terms can be derived on the basis of how they are used and what information they are associated with in text, tables, and figures (e.g., taxonomic names and opinions, geological units in which taxa occur, their geological ages, body sizes, etc.). Locating, extracting, and understanding the context of facts in hundreds of thousands of documents, all of which require application of optical character recognition and language parsing approaches, is a computationally demanding task. To meet these computing needs, we are leveraging the dependable and cost effective High Throughput Computing capabilities provided by HTCondor and the Open Science Grid.

Our multidisciplinary team is currently recreating components of the PBDB by deploying PaleoDeepDive to read the same documents and extract the same facts and relationships among them as the human experts that assembled the database. This critical first step allows us to efficiently train PaleoDeepDive

![Figure 1—Screenshot of PBDB Navigator, an open-source web application built by the UW-Madison team that uses the public PBDB API and the GPlates API for paleogeographic reconstruction.](http://paleobiodb.org/navigator)
and to quantitatively assess its ability to produce results that are at least as scientifically valid and useful as a human-generated database. Training PaleoDeepDive with human expert feedback is a key component of its development and improvement, so this system does not obviate the need for human intervention. It does, however, shift the focus away from finding and keystroking data and towards higher-level assessment of their context, quality, and relationships. In addition to generating a new and expanded PBDB that incorporates different types of data and that provides direct accreditation and access to the underlying literature upon which it is built, we aim to turn PaleoDeepDive and its associated modules into a dependable EarthCube Building Block; one that can be used by the paleontological community, as well as other geoscientists, as a tool to more rapidly discover, access, and utilize the existing data that are required to address specific scientific questions. In so doing, we hope to more completely expose and bring to light the scientifically indispensable, but often underutilized, ‘dark data’ that has been and continues to be produced by specimen- and field-based paleontology.

REFERENCES


THE MILLION KID MARCH AND OTHER ASPIRATIONS FOR PALEONTOLOGY

Kirk Johnson, Smithsonian’s National Museum of Natural History (NMNH), P.O. Box 37012, Smithsonian Institution, Washington, D.C. 20013-7012

Fossils have always aroused curiosity, but it was not until the 19th century that they were tapped as scientific tools to understand Earth’s history. The processes of erosion and deposition allow Earth to be its own undertaker, and it has regularly buried and fossilized its dead. The resulting stacks of lost worlds continue to reveal insights as we enter the 21st century. Paleontology is ‘time travel with a shovel,’ and, as such, remains fully relevant as the articulate archivist of our past and the harbinger of our future. Without fossils, we would have no clue that this planet once hosted lycopod swamplands, brachiopod reefs, crocodile-rich polar forests, and herds of sauropods. And while we would have some understanding of the process of evolution, we would not have much to say about extinction. Empowered by plate tectonics, geochronology, and geochemistry, we now have the ability to use fossils to measure ancient temperatures and to map biomes through time, thus seeing the impact of climate change on past worlds. The immense volume of the Earth’s sedimentary carapace and its peculiar paucity of paleontologists is an equation that suggests that the vast majority of fossils remain to be discovered, and the best fossils and their embedded data are still in the ground.

In addition to these merits, paleontology also offers a potent tool for the rest of science through its inherent accessibility and the celebrity status of dinosaurs. The community of paleontology is small, but paleontologists are disproportionately common as public scientists. From Waterhouse Hawkins to Cope and Marsh to Roy Chapman Andrews to the Sinclair dinosaur to Jurassic Park to Dinosaur Train, dinosaurs and their boosters have roused public ardor more than 150 years. And dinosaurs are merely the loss-leaders for the rest of paleontology’s traditional role as baseline metabolism for natural history museums. Approaches such as social media, citizen science, mobile apps (e.g., Mancos), crowdsourcing, 3D scanning, drone-based prospecting, and short-form online videos point to a bright future for both the science and the popularization of paleontology; while the ubiquity of GPS technology, aggressive poaching, and an active online fossil market threatens some of our more significant sites. Kids are our most avid consumers and also our most important target audience. Paleontology and paleontologists are already making a very positive impact on the public awareness of science and it is clear that fossils will be part of the tool kit that we will use to solve and survive the next century. In this context, the Smithsonian Institution is planning to completely renovate the Nation’s Fossil Halls and create a compelling new exhibit experience that offers a Deep Time narrative for Earth, and frames a proactive approach to the Anthropocene. Imagine the impact of a million-kid march on the Washington Mall to celebrate the opening of this new exhibit.
We are awash in evidence that human activities have resulted in massive changes to the bio/geosphere. We know that even relatively low human population densities can lead to significant ecological change. Even if our goal is at the bare minimum to write an obituary for ecosystems past, the least we can do is suggest a cause of death. If our goals are somewhat nobler, then our duty is to reach back into the depths of time to determine which of our activities are responsible for the changes and extinctions we observe. For the sake of simplicity, let’s consider three classes of activities: 1) Direct harvesting of biomass (e.g., fishing), 2) Acceleration or amplification of fundamentally natural processes (e.g., land clearing and farming leading to increased sedimentation and nutrient loading), 3) Introduction of essentially novel toxic substances (e.g., industrial chemicals and metals). Each of these activities have largely independent histories, and they are typically independently regulated. To make a useful contribution of conservation policy efforts, we must bring to bear methods, hypotheses and sedimentary records capable of distinguishing the impacts associated with these distinct activities even if the current state of the ecosystem is the result of cumulative impacts. In Australia this means distinguishing impacts associated with events happening within the last 200 years. In North America, this means distinguishing impacts associated with events happening within the last 300 years. Old World records have longer timescales, but workers must deal with a more gradual onset of impacts. So to reach the nobler goal, we must overcome some difficulties associated with the temporal resolution of the sedimentary records. Advances in dating methods have made it (almost) cost effective to do large time-averaging studies, but we still find large differences in chronologies determined by AAR/C-14 and Pb-210 that must be sensibly resolved. To achieve the noble goal in the New World we need reliable decadal to bidecadal resolution from ‘normal’ sedimentary records. After nearly a decade of fairly bleak news, there may be hope. While sediment cores from Rib and Bramble reefs (central Great Barrier Reef, Australia) yielded time homogenous fossil assemblages spanning ~3,000 years and over a meter of core depth, a 2012 core from the One Tree Reef lagoon contains a well ordered stratigraphic record and centennial to bicentennial resolution. A 2013 core from Sydney Harbour also contains a well-ordered stratigraphic record, but is also suggestive of size-biased mixing even within the molluscan macrofauna.
Historical samples. While changes in sampling are likely important during the 120 combined interval, much of the observed variation is the result of changing mammal community composition over a ~century of ecological time. Since the late 1800s, and particularly since 1950, these ecosystems have experienced many changes including increasing human impact and decreasing area for wildlife. Analysis of a sub-sample of six of the sites has shown that overall species richness was stable or increased from historical to modern times but beta-diversity decreased across these sites. Testing for and eliminating potential sampling biases, we found that this pattern is caused primarily by an increase in occupancy of the six sites by common species across all body size classes. The changes in Kenya’s mammal communities over the last 120 years may or may not be typical of what occurs during the formation of a time-averaged mammalian fossil assemblage, but it is clear that longer periods of time-averaging can inflate species richness relative to shorter intervals, particularly if ecosystems are subject to environmental and ecological change over this time scale.

Session 1-3: Saturday, 2:15 PM
Presenter: Joshua H. Miller

ECOLOGICAL FIDELITY OF FUNCTIONAL TRAITS BASED ON SPECIES PRESENCE-ABSENCE IN THE MAMMALIAN BONE ASSEMBLAGE OF AMBOSELI NATIONAL PARK, KENYA

Miller, Joshua H., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Behrensmeyer, Anna K., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; Du, Andrew, Homid Paleobiology Doctoral Program, Center for the Advanced Study of Homid Paleobiology, Department of Anthropology, The George Washington University, Washington, DC 20052; Lyons, S. Kathleen, Department of Paleobiology and ETE Program, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013; Patterson, David, Homid Paleobiology Doctoral Program, Center for the Advanced Study of Homid Paleobiology, Department of Anthropology, The George Washington University, Washington, DC 20052; Tóth, Anikó B., Department of Paleobiology and ETE Program, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013; Villasenor, Amelia, Homid Paleobiology Doctoral Program, Center for the Advanced Study of Homid Paleobiology, Department of Anthropology, The George Washington University, Washington, DC 20052; Kanga, Erustus, Ecosystems Conservation and Management Department, Kenya Wildlife Service, Post Office Box 40241, 00100, Nairobi, Kenya; Reed, Denne, Department of Anthropology, University of Texas at Austin, Austin, TX 78712.

Paleobiologists and neontologists are increasingly concerned with understanding functional aspects of species and their ecosystems. Fossil records offer unique and valuable opportunities to test 1) how ecosystem functioning responds to environmental changes and 2) how functional responses (including the development of novel functional types) change through deep time. When analyses include species across a wide range of body-sizes and trophic guilds, this functional approach to paleoecology may provide unique information about the evolution of ecosystems. However, skeletal remains from multiple orders of body-size are generally subject to differential preservation and/or collection biases that can dramatically skew representation of functional ecological traits and interpretations of the source community. Here, we use a Live-Dead approach to quantify the functional ecological fidelity of the death assemblage from a diverse non-volant mammal community (87 species; Amboseli National Park, Kenya). We test this fidelity across the entire range of available body-sizes, directly assessing the impacts of size-bias on the recovery of functional ecological data. Using published literature we characterize species with four separate variables describing the functional ecological setting of the community; i) dietary mode (11 categories, e.g., browser, grazer), ii) preferred feeding habitat (16 categories, e.g., grassland, woodland), iii) preferred sheltering habitat (17 categories, e.g., grassland, underground cavity), and iv) activity time (7 categories, e.g., diurnal, nocturnal, nocturnally-dominated crepuscular). Functional characteristics of species are ascribed to both ‘living’ and ‘dead’ representatives. For each ecological variable we compare the death assemblages’s recovered richness of constituent ecological traits (and frequency distributions of species with those traits) to those of the source community using standard comparative ecological metrics (Jaccard, PIE, Spearman rho). We use Monte-Carlo simulations to evaluate whether these empirical comparisons are significantly different from a random sample of species from the source community. Results show that although the Amboseli death assemblage is significantly size-biased, it captures the functional dimensions of the ecosystem within expectations of a random species sample. Logistic regression and additional resampling simulations further illustrate that this size-bias is not a major driver of deviations between the functional ecological properties of the living community and the death assemblage. Thus, we demonstrate that terrestrial mammalian death assemblages can faithfully record functional properties of the source community. The Amboseli death assemblage also added nine species and two functional traits that were previously unknown from live censuses of the mammal community, highlighting the value of conservation paleobiology for broadening understanding of modern ecosystems.

Session 1-4: Saturday, 2:30 PM
Presenter: John D. Orcutt

PLEISTOCENE PRESERVATION POTENTIAL, PALEOENVIRONMENT, AND PALEOECOLOGY IN WESTERN NORTH AMERICA

Orcutt, John D., Department of Geology, Cornell College, 600 1st St. SW, Mt. Vernon, IA 52314

The Pleistocene fossil and paleoclimatic records have become critical tools for observing biotic responses to past climate change and for predicting, calibrating models of, and mitigating the effects of similar change in the future. The advent of large, publicly available databases of fossil occurrences (such as FAUNMAP and NOW) has made large-scale paleoecological studies more feasible than ever before.
such studies must be able to distinguish true ecological patterns from geological and taphonomic signals. For example, Pleistocene mammals in North America have been recovered from sites representing a wide range of environments. If different taxa are preferentially preserved in certain types of environments, any geographic patterns might reflect the distribution of those environments rather than the organisms themselves. I have tested the assumption that preservational differences do exist between four of the most widespread sedimentary environments in North America (cave, wetland, fluvial, and lacustrine). Relative abundances within each environment were calculated for Rancholabrean mammals from across western North America using data from museum collection catalogs. Unsurprisingly, these data show that abundances vary widely between environments. Caves and wetlands preserve mammal taxa in proportions comparable to one another and to modern mammal faunas; even here, though, differences do exist (for example, artiodactyls are more abundant in wetlands, while carnivorans are rarer). Somewhat more surprisingly, the preservational patterns in lakes and streams are vastly different from one another. Some of these differences can be explained by differing physical conditions: large-bodied taxa such as artiodactyls, proboscideans, and Panthera atrox, for example, occur much more frequently in high-energy fluvial deposits. In other cases, an ecological explanation is more likely, as in the case of cave-dwelling taxa such as Neotoma and Nothrotheriops being most abundant in subterranean deposits. In some cases, such as the superabundance of perissodactyls in lacustrine sites, differences may be partially due to collection bias. Regardless of its cause, this variability in preservation potential underscores that, as important and as necessary as large-scale paleoecological analyses are, they must be conducted with an eye towards paleoenvironment in order to tease apart biological and preservational signals.

Session 1-5: Saturday, 3:15 PM
Presenter: Andrew Du

DEGREES OF BIAS IN THE COLLECTION OF VERTEBRATE PALEOECOLOGICAL DATA: COMPARING AND RECONCILING DIFFERENT SCALES FROM MULTIPLE COLLECTION METHODS

Du, Andrew, Hominid Paleobiology Doctoral Program, Center for the Advanced Study Hominid Paleobiology, Department of Anthropology, The George Washington University, Washington, DC 20052; Behrensmeyer, Anna K, Department of Paleobiology and ETE Program, National Museum of Natural History, Smithsonian Institution, Washington, DC 20013; Bobe, Rene, Center for the Advanced Study of Hominid Paleobiology, Department of Anthropology, The George Washington University, Washington, DC 20052

Paleoecological reconstructions and inferences are dependent upon the quality of collected fossil data and their fidelity to the ancient living community. Paleontologists have traditionally employed different methods of data collection (e.g., excavations, surface surveys), each of which record paleoecological data at different temporal and spatial scales and thus may represent biased and unique aspects of the ancient community. For example, excavations provide high temporal and spatial resolution data but usually small sample sizes of taxonomically identifiable specimens. Surface surveys, on the other hand, offer large sample sizes which are temporally and spatially averaged. Here, we test the correspondence of paleoecological signals between three different modes of fossil data collection in a 1.5 million year old terrestrial vertebrate ecosystem in the Turkana Basin, northern Kenya. Data were collected in the same area and time interval by 1) systematic surface surveys, 2) surface square surveys (where all specimens in a spatially delimited area are collected/recorded), and 3) excavations. As expected, results show surface surveys yielded the highest number of fossils (median=68 minimum number of elements [MNE] per surface survey transect), excavations provided the second highest MNE (median=45.5 per excavation), and surface squares produced the lowest MNE (median=7 per surface square). These results were paralleled by number of taxonomically identifiable elements (median=44 MNE per surface survey transect; median=5 MNE per excavation; median=2 MNE per surface square) and taxonomic richness (median=9 per surface survey transect; median=2 per excavation; median=1 per surface square), both at the family level. Rarefaction analyses show, contrary to expectations, that surface squares produced the highest diversity of families with surface surveys and excavations recovering lower levels of diversity. Monte Carlo analyses reveal that taxonomic composition between all three methods of fossil data collection are not significantly different from each other despite different degrees of temporal and spatial averaging. This suggests stability of faunal composition and limited turnover across time and space during the studied time interval (10^6 years). This study demonstrates the advantage of using multiple fossil data collection methods to reveal different scales of the paleoecosystem which may complement each other and result in a more holistic understanding of the paleoecosystem.

Session 1-6: Saturday, 3:30 PM
Presenter: Carrie L. Tyler

ASSESSING THE FIDELITY OF BETA DIVERSITY: MARINE BENTHIC ASSEMBLAGES ON THE INNER SHELF OF NORTH CAROLINA, USA

Tyler, Carrie L., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Kowalewski, Michal, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Beta diversity (β) is often used to explore spatiotemporal components of biodiversity within and across habitats. Although widely used in paleontological studies, applications of β rely on the assumption that β represents a meaningful ecological metric when applied to time-averaged and inherently biased fossil assemblages. Recent studies suggest that, although biased, β diversity patterns may be preserved in the fossil record. However, direct fidelity tests in present-day environments are lacking. Here we examine the fidelity of β-turnover (change in composition along a gradient) and β-variation (within-habitat heterogeneity) using benthic invertebrate communities of coastal North Carolina (USA), utilizing multiple higher taxonomic groups. β-turnover was measured as change in species composition between
localities along an onshore-offshore gradient. β-variation was measured as dissimilarity within habitats. The fidelity of β was explored via analyses using all taxa, preservable taxa, robust taxa, and robust mollusks to imitate common types of paleontological data. Preservable taxa included all species with preservable hard-parts (e.g., chitinuous exoskeletons). Robust taxa included only species with heavily biomineralized skeletal components (e.g., thick, calcium carbonate shells). Pairwise comparisons were also made between the live community and concurrent recent death assemblages. β-turnover increased with increasing difference in depth and geographic distance between localities, suggesting that habitat variation is a driving factor affecting marine community structure. Estimates derived from preservable taxa, robust taxa, and robust mollusks yielded comparable, but marginally lower values of β-turnover, indicating that the preservable part of benthic communities can provide meaningful estimates of β diversity. Comparing live and death assemblages, the intercept and slope were comparable for the death assemblage and live communities, suggesting that original community patterns have not been destroyed by time-averaging processes. Estimates of β-variation derived from preservable taxa, robust taxa, and robust mollusks also yielded equivalent estimates of β. Lower values for preservable, robust and higher taxonomic groupings (e.g., mollusks) may reflect preservation biases; higher values for preservable vs. robust taxa suggests that higher quality fossil assemblages may provide a better estimate of β. Despite such biases, high fidelity between the living and death assemblages is consistent with previous work on live-dead comparisons of mollusks, and suggests that time averaging may smooth “noise” generated by short term fluctuations (e.g., seasonal variation), while preserving spatial biodiversity patterns. These results support the applicability of β metrics to the fossil record, and suggest that recent death assemblages may provide a useful baseline for conservation and resource management.

Session 1-7: Saturday, 3:45 PM
Presenter: Troy A. Dexter

INTENSE PREDATION ON MEOMA VENTRICOSA BY CASSIS TUBEROsa, SAN SALVADOR ISLAND, THE BAHAMAS

Dexter, Troy A., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Schimmel, Majken K., Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Kowalewski, Michal, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

This project assessed modern predation rates on echinoids in a tropical environment to determine how predation might influence taphonomy and bias the preservation potential of echinoids incorporated into the fossil record. Specimen tests of the irregular echinoids Meoma ventricosa and Leodia sexiesperforata were collected from a shallow tropical marine beach in San Salvador, the Bahamas, over multiple field seasons. All deceased specimens were removed entirely from the locality at each collection interval. Tests were measured and analyzed for predation traces. A significant number of tests (96.8% for M. ventricosa and 85.5 for L. sexiesperforata) displayed lethal predation (drillhole) markings. Drillholes were found primarily on the oral side (85.2% for M. ventricosa and 96.2% for L. sexiesperforata), however landmark analysis displayed no stereotypy. In this study the predator can be constrained to a single species, CASSIS TUBEROsa, through observational and experimental (wet lab) data. The deceased echinoids tests were found partially buried under sediment during collection. Observations of live predatory interactions in the field demonstrate that Meoma ventricosa is fed upon by the predatory Cassis while still in the shallow sediment subsurface. This suggests that the preservation potential of M. ventricosa and other similar species may be taphonomically biased toward a higher number of drilled specimens versus non-drilled specimens in the fossil record. The drillholes observed on the echinoids made by this predator are distinctive and could be recognizable in fossil material. Constraining the predator down to the species level can have implications for our interpretation of other ecological interactions in both fossil and modern material.

Session 1-8: Saturday, 4:00 PM
Presenter: Adam Tomašových

DEATH ASSEMBLAGES AS PROXIES OF LOCAL AND REGIONAL DIVERSITY: EVALUATING THE EFFECT OF DIFFERENT PRESERVATION SCENARIOS

Tomašových, Adam, Geological Institute, Slovak Academy of Sciences, Dubravská cesta 9, 84005, Bratislava, Slovakia; Kidwell, Susan M., Department of Geophysical Sciences, University of Chicago, 5734 S. Ellis Avenue, Chicago, IL, 60637

Direct-dating of molluscan death assemblages from shallow-marine study areas has shown that carbonate shells can persist for hundreds to thousands of years in the upper mixed layer of the seabed. Given the very high rates of shell loss documented in short-term experiments (days to a few years), the observed long-term preservation of shells within death assemblages (DA) implies that disintegration rates decline markedly postmortem, for example owing to diagenetic stabilization or burial to subzones with slower disintegration processes. Our previous modeling has shown that a decline in disintegration rate can produce the long tail of old shells that is frequently observed in shell age-frequency distributions (AFDs) in tropical and temperate settings. Here, we use models to simulate the effect of this long tail of old shells on the capture of species richness by DAs at both local and regional scales, using the continental shelf of the Southern California Bight as our model system. We use a metacommunity model where species abundance at small scales (0.1 m²) is determined by 1) its depth-specific average abundance, and 2) depth-specific variability in abundance as observed in living communities (827 Van Veen grab sites). Local sites are subjected to changes in species composition such as would occur with sea-level rise since the Last Glacial Maximum and are then time-averaged: each site starts at 0-m depth at the time at which sea-level was 0 m at that position on the Southern California shelf. When the sea level reaches its present-day position, the pooled list of dead individuals is subjected to sampling according to three preservation scenarios: 1) a uniform preservation function that...
NEBELSICK, James H.,
ASSESSING COMPONENT DIVERSITY AMONG
Presenter: James Nebelsick
Session 1-9: Saturday, 4:15 PM

scenario with negligible shell loss. and is, remarkably, as efficient in sampling diversity as a thus best accounts for the observed richness of shelf DAs, the uniform and two-phase models. The two-phase model DAs is actually slightly higher (76 species) than predicted by lower richness (65 species). The species richness observed in loss via a taphonomic half-life—captures a significantly species. In contrast, sampling using a one-phase exponential uniform AFD in capturing rare and temporally ephemeral species. The species richness observed in DAs is actually slightly higher (76 species) than predicted by the uniform and two-phase models. The two-phase model thus best accounts for the observed richness of shelf DAs, and is, remarkably, as efficient in sampling diversity as a scenario with negligible shell loss.

Session 1-9: Saturday, 4:15 PM
Presenter: James Nebelsick
QUANTIFICATION OF MICROPARTICLES: ASSESSING COMPONENT DIVERSITY AMONG PALEOGENE AND NEOGENE CARBONATES

Nebelsick, James H., Department of Geosciences, Sigwartstrasse 10, 72076 Tübingen, Germany. Bassi, Davide, Università degli Studi di Ferrara, Via Saragat 1 1 - 44100, Ferrara, Italy. Rasser, Michael W., State Museum of Natural History, Rosenstein 1, D-70191 Stuttgart, Germany

Microfacies analysis performed on thin sections allows data concerning component distributions from indurated shallow-water marine carbonates to be gained where surface collections of discrete floral and faunal elements are often impossible. The quantification of components in thin section has primarily been used to delineate microfacies types, deduce component relationships, as well as trace ecological gradients. The disadvantage of such methods (besides being often time-consuming and necessitating a detailed knowledge of specific skeletal morphologies) is that a broad range of taxonomic ranks are included ranging from phylum or class levels to generic or even species identification of such components as smaller and larger benthic foraminifera as well as dasycladalean and coralline algae. This study explores extensive quantitative and semi-quantitative data sets from Paleogene (middle Eocene to late Oligocene) and Neogene (lower Miocene) carbonates from the circumalpine regions of the western Tethys. These data sets allow for component distributions to be assessed across temporal borders as well as along geographic (latitudinal) gradients. The limits of taxonomic identification for specific groups are explored with respect to inherent morphological features that can potentially be recognized in thin section, to taphonomic processes such as fragmentation and disarticulation, to early diagenetic features affecting the diverse mineralogies of skeletons. Relevant issues explored include how the taxonomic resolution is affected by factors affecting facies distribution patterns, such as terrigenous input or exposure gradients on the carbonate ramps, how taxonomic resolution is related to preservation potentials, and if there are any overriding patterns with respect to diversity patterns that transcend temporal and geographic borders.

Session 1-10: Saturday, 4:30 PM
Presenter: Andrzej Kaim
FIDELITY OF THE FOSSIL RECORD OF THE CHEMOSYNTHESIS-BASED COMMUNITIES—ARE WE ASSESSING A FULL IMAGE OF THEIR EVOLUTION AFTER 30 YEARS SINCE DISCOVERY?

Kaim, Andrzej, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024

Modern chemosynthesis-based communities were discovered in the late 1970s and early 1980s, although the fossils derived from such ecosystems were long known in the literature from a number of localities worldwide awaiting proper interpretation. The discovery of modern counterparts also prompted a quest among paleontologists to look for additional fossil examples in order to decipher the evolutionary pathways of chemosynthesis-based communities. That is why the knowledge of such communities has significantly increased in recent years. We know now that the early assumption that hydrothermal vent invertebrate faunas are "a glimpse of antiquity" is largely incorrect. Many groups known from recent hydrothermal vents and cold seeps are relatively modern waves of immigration. Over the years the preservation of fossils from chemosynthesis-based communities was a major issue and it is still so. For example Neomphalina, the flagship gastropod group for hydrothermal vents, considered as possible living fossils, still remains poorly understood in the fossil record, mainly due to difficulty in the identification and general paucity of hydrothermal vent deposits and poor preservation of vent fauna. On the other hand another gastropod group endemic to the chemosynthesis-based communities, the Provannidae, is now quite well researched due to finding well-preserved silificied specimens from ancient methane seeps. Such materials, however, are restricted so far to the Cretaceous and younger deposits of this type. The earlier examples are too few and too badly preserved to withdraw firm conclusions. Nevertheless, it seems that in these Early communities, dimereoid brachiopods were the most common animals, while mollusks were only subordinate. The same seems to be true for the Paleozoic counterparts, which are very rare and poorly preserved. Fossil wood-fall communities are uncommon but it seems to be clear that their emergence was related to the first appearance of xylophilagous wood-boring bivalves. Earlier, Jurassic associations were apparently not based on chemosynthesis. The only link between Jurassic and Recent wood-fall associations lies in the presence of the polyplacophoran mollusk *Leptochiton*. Fossil vertebrate-fall communities are not common, but fossil examples of whale-fall communities are known from a period shortly after the appearance of whales. In the Mesozoic, vertebrate-fall communities are represented by Late Cretaceous pleiosaurus-fall associations that are more similar to coeval seep faunas than to later whale-fall faunas.
**Session No. 2: The microfossil record: The past is the key to the future (or present) in conservation paleobiology**

**Chairs:** Pamela Hallock and Laurel S. Collins

Saturday Afternoon, 1:30 PM to 4:45 PM

**Session 2-1: Saturday, 1:30 PM**
Presenter: Pamela Hallock

**WHY HAS OPTIMUM HABITAT FOR STONY CORALS DIVERGED FROM THAT FOR FORAMINIFERS WITH ALGAL SYMBIONTS ON THE FLORIDA REEF TRACT?**

**Hallock, Pamela,** College of Marine Science, University of South Florida, 140 7th Ave. S., St. Petersburg, FL 33701

*Amphistegina* spp. are common symbiont-bearing foraminifers associated with tropical reefs and carbonate shelves worldwide. Thirty years ago a reliable way to find and collect *Amphistegina*, and other benthic foraminifers that host algal symbionts, was to collect from the most prolific coral reef in the clearest waters that one could access. This generality remains useful for many Indo-Pacific reefs. However, on the Florida reef tract and elsewhere in the western Atlantic and Caribbean, reefs with the highest coral cover now tend to be patch reefs in marginally clear waters. Shelf margin reefs in the clearest waters have lost most of their stony coral cover to disease, bleaching, and other sources of mortality. *Amphistegina*, though often found on such patch reefs, remain most abundant in the shelf-margin habitat from which most corals have perished. Both stony corals and *Amphistegina* expel or digest their algal symbionts, i.e., bleach, in response to photo-oxidative stress. The source of such stress can be elevated temperature, increased solar irradiance reaching the sea floor, or the two in combination. Other factors that have been shown to increase sensitivity to photo-oxidative stress include exposure to herbicides, pesticides or hydrocarbons, or increased nutrient availability that increases densities of zooxanthellae. Paradoxically, *Amphistegina* are more sensitive to solar irradiance, despite their preference for the clearest waters, while stony corals are more sensitive to elevated temperature, despite their higher rates of survival inshore, where temperatures are more variable. What does the divergence of optimum habitat for remaining stony corals from that for *Amphistegina* populations reveal about environmental changes along the reef tract? What physiological and ecological differences between foraminifers dependent upon algal symbionts and zooxanthellate stony corals are revealed by this divergence in suitable habitat? The most obvious differences are in size and life span. *Amphistegina* are, at most, a few mm in diameter and their life span is 1–2 orders of magnitude shorter than for most stony coral colonies. Thus, *Amphistegina* can rebound within a few years from a major stress event, as Florida reef tract populations did following a multi-year bleaching and mortality event in the early 1990s. Stony corals were succumbing to a variety of disease outbreaks during that time, but did not extensively bleach until the 1998 event. Future research will likely reveal differences among coral taxa that can account for why *Acropora* and other taxa that formerly thrived on offshore reefs have declined while *Siderastraea*, *Porites*, and others continue to survive on patch reefs. Nevertheless, detailed research on taxonomically distinct yet physiologically analogous reef dwellers can provide invaluable insights into causes of reef decline and prognoses for future change.

**Session 2-2: Saturday, 1:45 PM**
Presenter: Heidi Toomey

**CHLOROPHYLL FLUORESCENCE AS AN INDICATOR OF THERMAL STRESS IN ARCHAIAS ANGULATUS (CLASS FORAMINIFERA)**

**Toomey, Heidi M.**, College of Marine Science, University of South Florida, 140 7th Ave. S., St. Petersburg, FL 33701

Benthic foraminifers that host algal symbionts are similar to corals in that they rely on their algal endosymbionts for their energy needs, calcify prolifically, and are sensitive to changes in environmental conditions. They are abundant in the benthos of coastal coral-reef areas and are found throughout the tropical and subtropical regions. Pulse Amplitude Modulated (PAM) chlorophyll fluorometry and chlorophyll *a* extraction techniques were used to quantify and compare the photosynthetic responses of *Archaias angulatus* and their isolated endosymbionts, *Chlamydomonas hedleyi*, to short-term changes in temperature. Maximum quantum efficiency (*Fv/Fm*) and rapid light curves (RLCs), from which relative electron transport rates (*rETR*) of photosystem II (PSII) were derived, were investigated over a 31 degree range from 4.4° to 33.9°C in three experiments, 7 to 31 days in duration. Typical *Fv/Fm* means for healthy holobionts (symbionts in hospite) were 0.6–0.7 and for isolated symbionts 0.5–0.6, although they shared the same trends. Photoinhibition, indicated by significant decreases in *Fv/Fm* occurred at temperatures above 31.0°C; there was minimal reduction in efficiency in cooler treatments (4.4°C–18.6°C) compared to 21.3°C and 23.4°C ambient treatment controls. Chlorophyll *a* (*μg*/foram) was negatively correlated with temperature (*r* = −0.37) in Experiments 1 and 2. However, overall *chl* *a* variability was high and enigmatic. Photophysiological stress responses differed between isolated and in hospite symbionts, indicating tight coupling in the host-symbiont response during photosynthesis. This was the first known physiological study of the viable temperature range and photobiology of *Archaias angulatus* using chlorophyll fluorometry methods. Though commonly found in Caribbean and Atlantic waters ranging from 14.0°C–31.0°C, these results indicate a wider thermal-tolerance range for *Archaias angulatus*.

**Session 2-3: Saturday, 2:00 PM**
Presenter: Benjamin Ross

**DORMANCY AS A SURVIVAL RESPONSE TO...**
ENVIRONMENTAL STRESSORS IN THE BENTHIC SYMBIOTIC FORAMINIFER AMPHISTEGINA GIBBOSA

Ross, Benjamin J., College of Marine Science, University of South Florida, 140 7th Avenue S., St. Petersburg, FL 33701

Dormancy mechanisms, including diapause (e.g., suspension of growth and reduced metabolism induced by unfavorable conditions) and cryptobiosis (e.g., propagules or eggs that are essentially ametabolic), are widespread and diverse in the biosphere. Responses in benthic Foraminifera that can be interpreted as dormancy or diapause have been observed and utilized in practical applications for decades, but have rarely been the focus of research. It is now recognized that benthic foraminifers may produce propagules that can remain inactive in a cryptic state for extended periods, existing in a quiescent “dormant” state until environmental conditions are favorable. Dormancy has also been identified as a survival mechanism in the adult stage of some benthic foraminifers when exposed to anoxic conditions. In addition, previous observations have shown that some symbiotic taxa, including Amphistegina gibbosa, are capable of surviving extended periods of darkness without food, regaining symbiont color and reticulopodial activity when returned to a light/dark cycle. Studies of responses to components of hydrocarbon dispersants has led to the discovery of inactivity-enhanced survival of Am. gibbosa. These foraminifers survived 48-hr exposures to propylene glycol and 2-butylthanol added to their seawater culture medium; their response included withdrawal of reticulopodia, loss of normal color, and appearing to be dead. However, when removed from the test media and monitored for recovery, most of the specimens recovered at the intermediate concentrations. This suggests that dormancy mechanisms may be a more widespread survival strategy in the Foraminifera than previously thought, and current research is focused on exploring the physiological characteristics of dormant foraminifers and the range of taxa that can become dormant. Recognition, documentation and elucidation of mechanisms of dormancy in extra-propagule benthic foraminifers have a vast range of implications and applications, including understanding lineage longevity (e.g., selective survival of mass extinction events) and distributions of fossil taxa.

Session 2-4: Saturday, 2:15 PM

Presenter: Melissa K. Lobegeier

USING THECAMOEBIANS AS INDICATORS OF ENVIRONMENTAL IMPACTS IN TENNESSEE AND VIRGINIA

Lobegeier, Melissa K., Department of Geosciences, Middle Tennessee State University, Murfreesboro, TN 37130; Brown, Amanda R., Physics, Geology and Astronomy, University of Tennessee at Chattanooga, Chattanooga, TN 37403; Silveira, Emily I., Department of Geological Sciences, California State University, Fullerton, Fullerton, CA 92831; Watts, Jesse C., Department of Geosciences, Middle Tennessee State University, Murfreesboro, TN 37130

The southeastern region of the United States exhibits globally unparalleled diversity of aquatic mollusks. Of the 297 species and subspecies of freshwater mussels currently recognized, 269 have been recorded from watersheds in the southeast. In particular, Tennessee and Virginia have high species richness with 132 freshwater mussel species recorded from Tennessee and 80 from Virginia. Declines have been observed in the distribution of the mussel fauna over the past century and states in the Tennessee River Basin, such as Alabama, Tennessee and Virginia, have the highest percentages of endangered species. The declines seen are likely due to sedimentation and habitat degradation from urban, industrial, commercial and residential development; agricultural land use; contaminant spills and coal mining. Thecamoebians, microscopic testate amoebae, have been used increasingly in ecological research, mostly in Canada and Europe, where they have proven to be valuable tools for examining the spatial variability of anthropogenic impacts. The fossilization potential of thecamoebians gives them an advantage over other micro- and macroinvertebrates and allows for the collection of quantitative historical data. We have sampled sediment from Todds Lake in the Stones River watershed in Tennessee. This lake was originally a wetland and after two dams were built it is now an artificial lake and reservoir for Murfreesboro, a rapidly growing city in Rutherford County, Tennessee. Sediment was sampled from lakes, rivers and tributaries in the Clinch and Powell River watershed in Virginia, including Wetlands Estonia, which began as a wet cornfield in the early 1900s. It then became a town swimming hole, followed by an illegal trash dump and is now a reclaimed wetland being preserved by high school students in St. Paul, Virginia. The thecamoebian assemblages collected from these locations can be used to differentiate between favorable environments in lakes at high elevations which are remote from urban areas and unfavorable environments in lakes receiving urban runoff and in tributaries that continue to be subjected to acid mine drainage. Small-diameter short cores were collected from the same locations to determine if recent changes in land-use or pollution can be distinguished in the fossil record. The comparison of recent historical thecamoebian assemblages with present day assemblages should help develop methods for using thecamoebians to evaluate the environmental impacts in the southeastern region and provide a tool for aiding in mitigation and restoration efforts in this area.

Session 2-5: Saturday, 2:30 PM

Presenter: Laurel S. Collins

ENVIRONMENTAL IMPACT OF THE DEEPWATER HORIZON OIL SPILL ON DEEP-SEA BENTHIC FORAMINIFERA

Collins, Laurel S., Department of Earth and Environment, Florida International University, Miami, FL 33199; Hallock, Pamela, College of Marine Science, University of South Florida, 140 7th Ave. South, St. Petersburg, FL 33701; Pletka, Crystal R., Department of Earth and Environment, Florida International University, Miami, FL 33199; Beck, Kimberly D., Department of Earth and Environment, Florida International University, Miami, FL 33199

The 2010 explosion of the Deepwater Horizon drilling rig in the Gulf of Mexico caused the world’s largest accidental marine oil spill, which continued for three months. The deleterious effects are being monitored for shallow-water faunas, but studying the deep-sea response of the benthos is less tractable. We determined the response of benthic
foraminifera in a study of four sediment cores collected within six months of the capping of the damaged well. The faunal composition of 54 samples with >300 specimens/sample was determined at 2-mm intervals in relation to the oiled portions of sediments at 202 m, 400 m, 504 m and 1520 m. Research focused on the deepest site, nearest to the 1544-m-deep blown well. We estimated the amount of oil contamination of the sediments from the percentage of tar pieces and tar coatings of grains, which compared well in vertical position to the coloration of the sediments in core photographs. The tar content ranged up to 40%, with the highest values corresponding to intervals containing the darkest sediments. For example, at the 1520-m site, the tar pieces increased from 0% at 40mm core depth to 40% at 18–22mm, and back to 0% at 0mm. Approaches taken to determining the benthic foraminiferal response to the increase and subsequent decrease in oil through the cores include changes in diversity as measured with Fisher’s alpha, test wall composition, and proportions of standard paleoceanographic indicator taxa such as *Cibicides*, *Bolivina*, *Brizalina*, *Bulimina*, *Globobulimina*, and *Uvigerina*. The most extreme patterns of change occurred in the core closest to the well, where taxa with agglutinated walls increased from about 10% below the oiled interval to as much as 60% within the interval, much more than is typical at upper middle bathyal depths in the Gulf of Mexico. We had hypothesized that with oil contamination and the application of chemicals used to disperse surface oil, environmental conditions were adverse and unstable enough to cause lower diversity because fewer species could adapt. However, the opposite pattern occurred. At the 1520 m site, closest to the well, diversity mirrored tar content, largely a result of the increased diversity of the agglutinated taxa. At the other sites the oiled portions included the largest percentage of agglutinants. Factors in the development of agglutinant-dominated biofacies in the Gulf appear to be high depositional rates, water turbidity, and the presence of organic-rich, fine-grained sediments, all of which agree with oil-spill conditions. It seems that the oil spill increased the diversity of the agglutinated taxa that were resistant to its toxic effects, thereby increasing the total diversity, a phenomenon not previously reported.

**SHALLOW MARINE ECOLOGICAL DEGRADATION IN HONG KONG: A PALEOECOLOGICAL APPROACH USING OSTRACODS**

*Hong, Yuanyuan*, School of Biological Sciences and Swire Institute of Marine Science, The University of Hong Kong, Pokfulam Road, Hong Kong, SAR, China; *Yasuhara, Moriya*, School of Biological Sciences, Swire Institute of Marine Science, and, Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, SAR, China; *Iwatani, Hokuto*, School of Biological Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, SAR, China

Hong Kong is one of the largest and most rapidly developing cities in Asia. It is known that the marine ecosystems of Hong Kong have been seriously influenced by a variety of anthropogenic factors, including eutrophication, bottom trawling, coastal reclamation, pollution, etc. However, little is known about long-term history of such human-induced marine ecological degradation in Hong Kong. Here we use microfossil ostracods as a model system and compare among top-1-cm (representing live or recently dead assemblages) and whole (representing averaged state of assemblage for the past several decades) assemblages in grab samples and Holocene background assemblages in a long sediment core. Preliminary results obtained from 55 sites grab samples in Hong Kong waters showed that the most common species are *Sinocytheridea impressa* and *Neomococeratina delicata*. Species diversity was of no significant different between present and past assemblages. Pairwise comparison of Bray-Curtis similarity between top-1-cm and whole assemblages indicated lower similarity in Tolo Harbour and Victory Harbour sites compared with other sites, though further investigation is needed to understand the underlying mechanism. On the basis of MDS (multiple dimensional scaling) analysis, 10 faunal groups (biotopes) were recognized. Full results will be shown in the presentation. Furthermore, species diversity of Holocene background assemblage was much higher than diversities in grab samples. Faunal composition of Holocene sample was also distinct from faunal assemblages of grab samples. These results may indicate serious ecological degradation during the past several decades.

Session 2-7: Saturday, 3:30 PM
Presenter: Rachael Kalin

**USE OF MICROFOSSILS TO DETECT GEOLOGICALLY RECENT ENVIRONMENTAL CHANGES: ST. JOHN, U.S. VIRGIN ISLANDS**

*Kalin, Rachael A.*, Eckerd College, 4200 54th Ave. S., St. Petersburg, FL, 33711; *Kuhs, Chelsea*, Eckerd College, 4200 54th Ave. S., St. Petersburg, FL, 33711; *Wheaton, Cathryn*, Eckerd College, 4200 54th Ave. S. St. Petersburg, FL, 33711; *Larson, Rebekka*, Eckerd College, 4200 54th Ave. S., St. Petersburg, FL, 33711; *Barber, Bruce*, Eckerd College, 4200 54th Ave. S., St. Petersburg, FL, 33711; *Yates, Kimberley*, University of South Florida St Petersburg, 140 7th Ave S., St. Petersburg, FL, 33701; *Brooks, Gregg R.*, Eckerd College, 4200 54th Ave. S., St. Petersburg, FL, 33711

Island development has dramatically increased since the 1950s in the U.S. Virgin Islands (USVI). Two sediment cores extracted from Hurricane Hole, St. John, USVI were analyzed by identifying microfossils to the lowest taxonomical order, which helped to determine changes in biological community structure and biodiversity over time. One core, the most landward, revealed a significant decline in microfossils at depths of 20–21 cm and 25–26 cm downcore, coupled with a large input of gravel and a slight increase in carbonate content. Short-lived radiocarbon geochronology (210Pb) revealed that this decline occurred ~100 ybp. The other core, the most seaward, showed no decline of taxa and individual organisms at these depths. We hypothesize that the decline in number of taxa and organisms may be indicative of a high energy event such as a tropical cyclone or tsunami, which would explain the large grain size and increase in carbonate content. Alternatively, given that it
occurred in the most landward core, it could be attributed to human activities within the contributing watershed, but this would be inconsistent with the increase in carbonate content.

Session 2-8: Saturday, 3:45 PM
Presenter: Wing Tung Chiu

INFLUENCES OF HOLOCENE ENVIRONMENTAL CHANGES ON SUBMARINE CAVE OSTRACODE COMMUNITY AND SPECIES DIVERSITY

Chiu, Wing Tung, School of Biological Sciences, The Swire Institute of Marine Science, The University of Hong Kong, Hong Kong, China; Yasuhara, Moria, School of Biological Sciences, The Swire Institute of Marine Science, Department of Earth Sciences, The University of Hong Kong, Hong Kong, China; Iwataki, Hokuto, School of Biological Sciences, The Swire Institute of Marine Science, Department of Earth Sciences, The University of Hong Kong, Hong Kong, China; Fujita, Kazuhiko, Department of Physics and Earth Sciences, University of the Ryukyus, Okinawa, Japan; Kitamura, Akihisa, Institute of Geosciences, Shizuoka University, Shizuoka, Japan

Submarine caves are a unique environment; for example, they are characterized by an isolated nature, stable sedimentation, and a paucity of light and thus low primary production. To understand ecosystem response to rapid climate change in this unique environment, we investigated fossil ostracode faunal and diversity changes for the last 7000 years in two sediment cores from the Daidokutsu submarine cave, Okinawa, Japan. The Holocene Daidokutsu ostracode fauna includes typical submarine cave taxa (Kasella and Cardobairdia), known as 'living fossils,' but it is mostly composed of tropical shallow-marine species. The preliminary results showed gradual downcore changes in faunal composition and species diversity. In this presentation, we will discuss in full details including possible controlling factors (e.g., temperature, productivity) of the Holocene ostracode faunal and diversity changes in the Daidokutsu submarine cave.

Session 2-9: Saturday, 4:00 PM
Presenter: Heather Bender

PALEOENVIRONMENTAL RECONSTRUCTION USING BENTHIC FORAMINIFERAL ASSEMBLAGES FROM THE PLIOCENE SHELL BEDS IN SOUTHWEST FLORIDA

Bender, Heather L., Geosciences, University of South Florida, Tampa, FL 33620; Herbert, Greg S., Geosciences, University of South Florida, Tampa, FL 33620

There is general agreement that a wide range of paleodepths are represented in the individual shell beds of the Pliocene Tamiami Formation of southwest Florida, but maximum depths remain poorly constrained. Here, we use benthic foraminifera as a paleodepth proxy in comparisons of recent Florida foraminifera from modern coastal, bay and reef habitats, ranging in depth from 0 to 90 m, and bulk sampled foraminifera from exposures of the Tamiami Formation (Pinecrest beds) at APAC and SMR Aggregates quarries. We used ordination techniques and abundance indices to reconstruct the Pliocene environment. Initial work indicates that these Pliocene foraminifera lived in brackish, mangrove, estuarine habitats. Fossil samples were dominated by an Ammonia-Elphidium assemblage and in DCA analyses clumped with modern foraminifera from shallow marine environments (<3 m depth). Foram Index (FI) values for fossil samples are low (<1), indicating high nutrient conditions, while the Ammonia-Elphidium Index (AEI) values are high (>0.75), indicating hypertrophic and poor oxygenated conditions. Ongoing work will examine the paleoenvironmental conditions in greater detail by linking calibrated paleodepth estimates from DCA with stratigraphy and spatiotemporal depositional gradients.

Session 2-10: Saturday, 4:15 PM
Presenter: Briony Mamo

SEA-LEVEL FLUCTUATIONS AND ASSOCIATED PALEOCLIMATES REVEALED BY BENTHIC FORAMINIFERA FROM THE NEW CALEDONIA BASIN

Mamo, Briony L., Biogeos 3, Japan Agency for Marine-Earth Sciences and Technology, Yokosuka, Kanagawa, Japan; Brock, Glenn A., Biological Sciences, Macquarie University, North-Ryde, NSW 2109, Australia; Gretton, Elsie J., Boggabri Coal Pty Ltd., Boggabri, NSW, Australia

Benthic foraminifera are abundant within the marine realm, possess strong preservation potential and due to many species’ ability to exhibit a level of sensitivity to fluctuating environmental conditions, make exemplary tools for paleoceanographic investigations. Foraminiferal assemblage composition reflects connections that exist between sea-surface conditions and the underlying benthos, oceanographic currents that operate within the area and adaptation to changing environmental conditions. In 2001, gravity core GC4 was extracted from the New Caledonia Basin (NCB) and the uppermost 141 cm, representing approximately the last 140,000 years, was investigated for foraminiferal taxa, chemical isotopic, carbonate, non-carbonate, and trace element signatures. 161 species of benthic foraminifera were obtained from the core and changes in foraminiferal distribution down the core can be related to some oceanic and paleoclimatic fluctuations during the last ~140,000 years. Two distinct foraminiferal assemblages were detected using Bray-Curtis cluster analysis and Multidimensional Scaling (MDS) analysis. Foraminiferal Assemblage 1 occurred in lower bathyal to abyssal depths and was largely influenced by high oxygen levels at the sediment-water interface throughout Marine Isotopic Stage (MIS) 6–3 (approximately 128–25 ka). Foraminiferal Assemblage 2 dominated the upper bathyal shelf during MIS 2 (approximately 25–10 ka), with surface waters characterized by high sea surface productivity (SSP) and eutrophic conditions. Factors that influence the foraminiferal assemblages include environmental setting, SSP, oxygen levels at the sediment-water interface and transportation by oceanic current systems operating within the region. Both the flourishing and subsequent waning of Foraminiferal Assemblages 1 and 2 bears potential to shed light on future benthic impacts associated with sea-level fluctuations and changing conditions at the sediment-water interface.
BRIDGER AND KISINGER LAKES FLORAS IN WESTERN WYOMING

Allen, Sarah E., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611;

The Early Eocene Climatic Optimum (~53–50 Ma) and its influence on flora and fauna has been well studied in recent years, however, we are still learning about the ecosystems that followed shortly after this interval (~50–48 Ma). The floras from the Bridger Formation (in the center of the Green River Basin southwestern, WY) and the Aycross Formation (on the margin of the Wind River Basin northwestern, WY) are ideally suited for examining these questions. The mostly fluvial Bridger Formation, deposited from ~49.0–45.5 Ma, preserves a well-known fauna, but little has been documented about its flora. The fossiliferous Blue Rim site in lower Bridger strata is unusual in that it preserves all vegetative and reproductive plant organs. The Kisinger Lakes flora in the Aycross Formation represents a floodplain deposit estimated to be ~48.5 Ma. These two floras are about 200 km apart and topographically separated by the Wind River Mountains which, along with the Absaroka volcanic province, provided much of the source sediment for both the Aycross and Bridger Formations. The taxonomic affinities and climate indications of the plants from these two localities are not identical despite their close age. The Bridger flora is represented by ~2400 specimens including at least 30 leaf morphotypes (in the Florida Museum of Natural History) collected from the Blue Rim locality. The Kisinger Lakes flora was introduced in detail by H.D. MacGinitie in 1974 with specimens housed at the Smithsonian and the University of California Museum of Paleontology. The site was re-located and a collection of ~650 specimens composed of approximately 20 leaf morphotypes is now part of the Florida Museum of Natural History’s paleobotany collections. The Bridger and Kisinger Lakes floras share many taxa, including Lygodium, Populus, Serjania rara, Landeenia aralioides, Aleurites fremontensis, Macginitiea, unidentified “sunburst” flowers, and Chaneya. However, the proportion of each taxon within the two floras is not consistent. For example, taxa such as Lygodium, Populus, and the unidentified “sunburst” flowers are more common in the Bridger flora, while Kisinger Lakes has higher percentages of Macginitiea, Macginiticarpa, Chaneya, and Fabaceae specimens. Unidentified “windmill” flowers and fossil wood are present at Blue Rim, but have not been found at Kisinger Lakes to date. In contrast, the Kisinger Lakes flora has legume pods and several leaf taxa which are not present at Blue Rim. Finally, both localities have a higher percentage of gymnosperms in the palynoflora as compared to the macroflora, likely representative of more regional or upland environments.
**Iodes** (Icacinaceae) is genus of angiosperms including approximately 17 species of woody climbers. Although *Iodes* is today restricted to tropical Africa, Madagascar, and Indo-Malesia, the genus is well-represented in Paleogene fruit and seed floras of North America and Europe, indicating a much broader historical distribution for the genus. We present an overview of the fossil history of *Iodes*, with particular focus on new fossil taxa from the early Eocene Blue Rim flora (Bridger Formation, SW Wyoming) and the late Miocene of Wenshan (SW Yunnan, China). In the Blue Rim flora, both fruits and leaves with affinities to *Iodes* are present, and their co-occurrence at multiple localities suggests that they belong to a single species. In the Wenshan flora, only a single *Iodes*-like fruit has been recovered, but this fossil is nevertheless significant as the first fossil fruit record of *Iodes* (and the Icacinaceae as a whole) from China. We will assess the affinities of these new fossil taxa with other extinct and extant species of *Iodes*, and consider the implications of these fossils for the broader biogeographic history of the genus.

Session 3-3: Saturday, 2:00 PM
Presenter: Boglárka Erdei

**THE FIRST FOSSIL RECORD OF THE GENUS ZAMIA L. (ZAMIACEAE, CYCADALES) EVIDENCED BY EPIDERMAL STRUCTURE FROM THE EOCENE OF PANAMA AND ITS COMPARISON WITH MODERN SPECIES OF ZAMIA.**

Erdei, Boglárka, Hungarian Natural History Museum, Botanical Department, Budapest, H-1476, Pf. 222, Hungary; Hendy, Austin J.W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Calonje, Michael, Montgomery Botanical Center, 11901 Old Cutler Road, Miami, FL 33156; Espinoza, Nicolas, Department of Biological Sciences, FIU, 11200 SW 8th St, Miami, FL 33174

Fossil foliage representing the cycad genus *Zamia* L. as proved by epidermal structure is reported for the first time. The fossil is preserved partly as compression in marine sediments of the Gatuncillo Formation (middle Eocene to early Oligocene), near Buena Vista, Colon Province, Central Panama. Frequent, but poorly preserved plant compressions are found in association with deep-water mollusks and foraminifera in fine-grained siliciclastic facies. Nanoplankton and foraminiferal biostratigraphy at this locality indicate a late Eocene to earliest Oligocene age (P14–P17 and NP18–NP21 zones, respectively). Epidermal characters were studied using light microscopy and scanning electron microscopy. Lamina is lanceolate, entire margined and slightly asymmetrical with an acute apex. Venation is parallel, however, finer details of venation pattern (forkings or anastomoses) are not observable due to preservation. In contrast, cuticles of both sides are well preserved. Adaxial cuticle shows elongate, linear ordinary cells of one kind arranged in a regular manner. Adaxial cuticle is broadened to a lesser extent than those of the upper cuticle. Gross epidermal structure shown by the fossil cuticles is comparable to traits displayed by modern species of *Zamia*, *Ceratozamia* Brongn. and *Microcycas* (Miq.) A.DC. However, the lack of linearly arranged, heavily cutinized short cell rows which in turn are clearly observable in all species of *Ceratozamia* (both abaxially and adaxially) as well as *Microcycas* (adaxially) corroborates its relation to *Zamia*. The majority of fossil foliage assigned formerly to *Zamia* were also revisited and are critically discussed. Morphometric analysis is adopted for the comparison of the fossil epidermal features with those of modern *Zamia* species. Preliminary results seem to suggest a higher epidermal similarity with Caribbean *Zamia* species than other Mesoamerican or South American species. The first fossil record of *Zamia* proved by micromorphology may shed new light on the paleobiogeography of the genus and former conceptions on its evolution.

Session 3-4: Saturday, 2:15 PM
Presenter: Kurt Neubig

**SYSTEMATICS OF ULMACEAE AND PLACEMENT OF THE EXTINCT CEDRELOPSISERMUM**

Neubig, Kurt M., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Herrera, Fabiany, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Manchester, Steven, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Germain-Aubrey, Charlotte, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Abbott, Richard, Missouri Botanical Garden, P.O. Box 299, St. Louis, MO, 63166; Whitten, Mark, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Ulmaceae are a group of tropical and temperate trees. Historically, the family was commonly circumscribed more broadly to include what is now Cannabaceae s.l. Although Ulmaceae includes relatively few species, the phylogenetic relationships of genera such as *Planera* (endemic to North America) and *Phyllostylon* (endemic throughout the Neotropics) have been uncertain. We sequenced a set of nuclear (18S, ITS, and Xdh) and plastid (matK, ndhF, rbcL, and trnL-F) DNA regions to elucidate the phylogeny of Ulmaceae, with an emphasis on generic relationships. The results confirm two main clades: one with the mainly tropically distributed genera (*Ampelocera*, *Holopetela*, *Phyllostylon*), and the other including the North Temperate genera (*Hemiptelea*, *Planera*, *Ulmus*, and *Zelkova*). The north temperate clade has confirmed fossil occurrences for all extant genera except *Planera*. We used morphological and anatomical vegetative and reproductive characters to determine the placement of *Cedrelopsisermum*, an extinct genus with a long fossil history in Europe and North America, within the context of a DNA-based phylogeny. These results show that *Cedrelopsisermum* is a close relative of *Phyllostylon*, a now Neotropical entity. Finally, we selectively examined the rich fossil record of the family, based on well-preserved samaras, leaves, and wood, in combination with DNA-based ultrametric analysis, to estimate dates within the family. The use of
**Cedrelaspernum**, along with the many fossils in the temperate clade, demonstrate that extreme non-clocklike patterns of sequence divergence have occurred within the family.

Session 3-5: Saturday, 2:30 PM

**GLOWING SEASHELLS: ULTRAVIOLET LIGHT REVEALS LARGE DIVERSITY OF PRESERVED COLORATION PATTERNS IN NEOGENE CONUS FOSSILS FROM THE DOMINICAN REPUBLIC**

Hendricks, Jonathan R., Department of Geology, San Jose State University, San Jose, CA 95192

The seemingly endless varieties of coloration patterns exhibited by extant Conus species (cone snails) have captured the interests of collectors and naturalists for centuries. These coloration patterns are among the most useful shell features for discriminating extant Conus species and also appear to have significant phylogenetic signal. Shell coloration patterns are often lost during the process of fossilization. Nearly 50 years ago, however, paleontologist Axel Olsson demonstrated that the original coloration patterns of sequence divergence have occurred within the genus Conus—may sometimes be revealed when illuminated by ultraviolet (UV) light. Investigation and characterization of ancient coloration patterns revealed under UV light has been an integral part of an ongoing species-level systematic revision of Neogene Conus from the Cibao Valley of the northern Dominican Republic (DR). The most diverse Conus assemblages from the DR Neogene are those associated with several coral reef facies in the late Miocene Cercado Fm. and early Pliocene Gurabo Fm. Nearly 30 species have been recognized by the author from these deposits (including over 10 undescribed species) and the ancient coloration patterns of most of these have been observed, photographed, and characterized. Study of these coloration patterns, which range from simple to complex, has proven useful not only for discriminating fossil Conus species, but also in understanding some of their phylogenetic positions relative to extant Conus. In particular, coloration patterns—in conjunction with other shell features—suggest that the reef-associated species occupy multiple cone snail clades and therefore help to illuminate the temporal and biogeographic histories of these clades in tropical America.

Session 3-6: Saturday, 3:15 PM

**THE EARLY EVOLUTION OF FROG CRABS (DECAPODA: BRACHYURA) AND NEW FINDINGS FROM THE CRETACEOUS OF TROPICAL AMERICA**

Luque, Javier, Department of Biological Sciences, University of Alberta, 116 St. and 85 Ave., Edmonton, AB T6G 2R3, Canada

Our understanding of the evolution of Brachyura, or ‘true’ crabs, has changed dramatically during the last decades thanks to the integration of novel approaches and techniques to test phylogenetic relationships. Among extant brachyurans, the Raninoida, or ‘frog’ crabs, have one of the most bewildering body plans, which has puzzled scientists since the days of Linnaeus and Lamarck. Some of their most diagnostic traits (e.g., their elongate and poorly ornamented carapace, narrow sternum and flattened legs) were once considered to reflect an ancestral condition, but are now thought to be derived adaptations for their burrowing lifestyle, and therefore convergent with several non-related families and superfamilies of digging anomuran and brachyuran crabs. The morphological disparity of raninoids during the Cretaceous, however, is considerably higher than today, ranging from broad and heavily ornamented ‘crab’–looking families (Camarocarcinidae, Necrocarcinidae, Cenomanocarcinidae, and Orithopsidae), to elongate and smoother ‘frog’–looking ones (Lyreididae and Raninidae). An ancient Cretaceous–restricted family (Palaeocorystidae) displays a combination of plesiomorphic and apomorphic traits that have led to different hypotheses on its proximity to either clade. Although Late Cretaceous raninoids are diverse and widely distributed, Early Cretaceous records are scarce and sparse, biasing our understanding of the early evolution of raninoid body plans, the polarity of change of some key traits, and their relatedness by common ancestry throughout geological time. Recent fossil findings from the Early and Late Cretaceous of Colombia and Brazil include the oldest Cenomanocarcinidae, Orithopsidae and Palaeocorystidae, as well as several of the oldest Necrocarcinidae, and the oldest members of the subfamily Raninoidinae. Although several genera have pantropical distributions, many others are endemic to Northern South America. These findings not only extend the geographic range of several raninoid clades into the tropics, but also push back their first appearance by many million years, challenging current hypotheses of a high-latitude origin for frog crabs, and suggest that Tropical America played an important role on the origin and early evolution of crabs during Cretaceous times.

Session 3-7: Saturday, 3:30 PM

**BONY TONGUE (TELEOSTEI, OSTEOGLOSSOMORPHA) PALEOBIOGEOGRAPHY—PALEONTOLOGY REFUTING NEONTOLOGY**

Bonde, Niels, Inst. Geoscience, Østervoldg. 10, 1350 Copenhagen K and Fur Museum, 7884 Fur, Denmark

Since 1949, osteoglossids (s. l., and even Osteoglossomorpha) have been considered the prime example of primary freshwater fishes, unable to migrate via the sea. However, 10 genera of marine osteoglossomorphs from the Eocene, including six forms from the Danish basal Eocene, one from Turkmenistan, one from slightly younger deposits in UK, eastern USA, and Africa, and three from Bolca, Italy, were reviewed in 2008. None are each other's closest relatives, with all 10 placed along stem-lineages of recent clades, indicating that the main stem of the group was marine. And so was its origin, as all possible sister-groups and most early teleosteanes are marine. Where are the implied unknown Cretaceous, marine members? Prediction: in the proto-Pacific, perhaps mostly now subducted and destroyed. Confirmation of this hypothesis came in 2009. Three small fossil fishes were found from marine middle Cretaceous strata in Tlayua, Mexico, and are now under description with
Alvarado-Ortega. They are very primitive osteoglossomorphs, the sister-group of all the rest. In 2010, a Hiodon-like form was discovered in marine rocks of Danian (63 m.y.) age from Chiapas, Mexico (thesis material UNAM). Other possible regions: Australia, New Zealand, Andes, western USA, Japan (and Indian Ocean coasts, therefore Himalaya). Assuming a reasonably correct phylogeny, a marine origin and evolution of the main stem is the simplest possible hypothesis implying only 4-5 freshwater invasions (alternative: a dozen migrations from fresh to salt water). Patterson noticed some 30 years ago that cases where paleontological ideas refuted neontological relationships are very rare. Here is presented an idea of relationships based on fossils that apparently refutes a traditional hypothesis of biogeographic relations between living osteoglossomorphs as primary freshwater fishes. Among the Danish Eocene bony tongues, most are carnivorous with strong dentitions, and some like Furichthys and Brychoeta are very big fishes over 2 m long. But the largest and most common, Heterosteoglossum, reached over 3 m and has tiny teeth (and the shape of its lower jaw is like Heterotis, the living plankton eater in freshwater). This Eocene form must have been a plankton eater, and is, in fact, the only species ever among marine teleosts, a group comprising over 20000 living species, to specialize as large plankton eaters, a niche occupied today by the largest members of all other groups of fishes (sharks, rays, sturgeons, holosteans), marine or freshwater. Among the Danish Eocene bony tongues, most are carnivorous with strong dentitions, and some like Furichthys and Brychoeta are very big fishes over 2 m long. But the largest and most common, Heterosteoglossum, reached over 3 m and has tiny teeth (and the shape of its lower jaw is like Heterotis, the living plankton eater in freshwater). This Eocene form must have been a plankton eater, and is, in fact, the only species ever among marine teleosts, a group comprising over 20000 living species, to specialize as large plankton eaters, a niche occupied today by the largest members of all other groups of fishes (sharks, rays, sturgeons, holosteans), marine or freshwater.

Session 3-8: Saturday, 3:45 PM
Presenter: Jorge Velez-Juarbe

FOSSIL PYGMY SPERM WHALES (ODONTOCETI; PHYSETEROIDEA; KOGIIDAE) FROM THE LATE MIocene Of PANAMA AND EARLY PIocene Of FLORIDA

Velez-Juarbe, Jorge, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; De Gracia, Carlos, Smithsonian Tropical Research Institute, Balboa-Ancon, Panama; Wood, Aaron R., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Hendy, Austin J.W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Extant kogiids are represented by two species (Kogia sima and K. breviceps) that are found worldwide in temperate to tropical regions. Their fossil record is first observed from the early or middle Miocene, but only five species have been described so far, with a number of additional records based on family-level diagnostic elements, such as the tympanics and periotics. Here we report the first fossil kogiids from Panama and Florida. The Panamanian fossil consists of well-preserved cranial material collected from the Chagres Formation, exposed on the Caribbean side of Panama; whereas the fossils from Florida consist of 16 isolated periotics from the Upper Bone Valley Formation. Preliminary comparison of the Panamanian kogid with other fossil and extant kogiids and physeteroids, show that it is most similar to Praekogia cedrosensis from the late Miocene of Baja California, and may represent a new species of that genus. We added the Panamanian kogid to a matrix of 41 characters (all treated as unordered) and 18 taxa (2 outgroup + 16 ingroup taxa) in order to perform a phylogenetic analysis of physterooids. The analysis resulted in four most parsimonious trees 100 steps long; the strict consensus tree (107 steps long) places the Chagres kogiid within a group of crown kogiids that include Praekogia cedrosensis, and Scaphokogia cochlearis from the late Miocene of Peru, and Kogia spp. The occurrence of kogiids in the Neotropics expands the historical range of the group, as well as highlights the importance of fieldwork in this poorly explored region in order to further understand the evolutionary history of cetaceans. The Bone Valley periotics display some features similar to other kogid periotics such as those from the early Pliocene of South Carolina, Kogia spp., among others. However, the Bone Valley periotics differ markedly, specially, from Kogia spp., in their larger size (>30% larger) and their large plate-like posterior process. Two morphotypes are present among the Bone Valley material, differing from each other in the size of the posterior process. The difference in length of the posterior process of the Bone Valley specimens is greater than that observed in between and amongst Kogia sima and K. breviceps. Therefore, we hypothesize that these differences indicate the presence of two sympatric species of kogiids in the early Pliocene of the Northern Western Atlantic, similar to what is observed today with extant Kogia.

Session 3-9: Saturday, 4:00 PM
Presenter: Miky Lova Tantely Raveloson

TWO ALLOPATRIC BOTHREMYDIDAE TAXA OF TURTLE IN THE INDIA-MADAGASCAR FAUNAL PROVINCES DURING THE LATE CRETACEOUS: EVIDENCE OF BIOTIC DISPERSAL ACROSS THE MICROCONTINENT.

Raveloson, Miky Lova Tantely, Department of Paleontology, Faculty of Sciences, University of Antananarivo, Antananarivo, Madagascar

The faunal similarities between Madagascar and India by the end of the Cretaceous, specifically the Maastrichtian, has instigated recent biogeographic investigations. The discovery of an ancient microcontinent, Mauritia (Torsvik et al. 2013), may contribute new geophysical and biogeographic insight into the relationship between the faunas of India and Madagascar. Here we study the morphological characters of two Upper Cretaceous bothremydidae turtle taxa, Kinkonychelys rogersi from the Maevarano Formation, Mahajanga Basin, Madagascar, and Kurmademys kallamendensis, recorded from the Kallamedu Formation, Cauvery Basin, India. The phylogenetic position of the Malagasy taxon combined with the basal position of the Indian species, suggest a new biogeographic hypothesis related to biotic dispersal prior to the disappearance of the Mauritia microcontinent. A possible dispersal from India to Madagascar is proposed during the Late Cretaceous, with the corridor provided by Mauritia explaining the paleobiogeographic similarities between the biota of the two landmasses. Thus, the presence of bothremydidae taxa in Madagascar can be explained by a terrestrial route for...
Another reason for the deceased may have been a relationship between the size of the PF to mosasaurs had a bigger PF than other mosasaurs was there localized areas (i.e., endemic). One reason why some test may indicate that individuals of these genera lived in a sizes throughout their latitude gradient. Results of the second test may suggest that individuals of these genera lived in a sizes throughout their latitude gradient. Results of the second test may suggest that individuals of these genera lived in a sizes throughout their latitude gradient. Results of the second test has conflicting evidence to the prediction that the ratio of the length of the PF to the length of the parietal bone (PB) is used as a proxy for the diameter of the PF. This ratio can is used as a proxy for the diameter of the PF. This ratio can be used to compare mosasaurs from different paleolatitudes with varying quality of preservation. The hypothesis to be tested is that the PF/PB increases as paleolatitude increases for both among genera and within genera. The first test is to compare this ratio in specimens—averaged within the same genus—among different genera. The second test is to compare this ratio in specimens within the same genus of varying latitudinal distribution. The first test has conflicting evidence to the prediction that the ratio of the PF/PB increases with increased paleolatitude. Though Plioplatecarpus has the largest PF/PB ratio and the highest the PF/PB ratio, has a higher latitudinal distribution compared to Platecarpus which has a larger PF/PB ratio. The second test did not support the prediction as Clidastes had a smaller PF compared to the supposed deep diver Platecarpus. Another reason for the variety in PF size could be that cool-water dwelling mosasaurs need a large PF in order to regulate their body temperatures better than warm-water dwelling mosasaurs.

Modern vertebrates living in high-latitude environments require a larger pineal complex (consisting of the pineal gland and the parietal eye) than vertebrates living in low-latitude environments. This may be because the pineal complex is important in regulating body temperatures and circadian rhythms. This correlation, however, may not apply to ancient vertebrates because the pineal gland has rarely been researched. The parietal foramen (PF) is the orifice in the skull that connects the parietal eye with the pineal gland. The PF also has a correlation between size and latitudinal distribution in modern lizards. Mosasaurs (Squamata, Mosasauridae) are a group of extinct marine lizards that have a Pf and lived worldwide during the Late Cretaceous. Their global distribution, along with their huge variety of PF size among genera, makes them ideal candidates for testing the biogeographical effects of the PF. In order to test if the size of the PF in mosasaurs follows a latitudinal pattern, the ratio of the length of the PF to the length of the parietal bone (PB) is used as a proxy for the diameter of the PF. This ratio can then be used to compare mosasaurs from different paleolatitudes with varying quality of preservation. The hypothesis to be tested is that the PF/PB increases as paleolatitude increases for both among genera and within genera. The first test is to compare this ratio in specimens—averaged within the same genus—among different genera. The second test is to compare this ratio in specimens within the same genus of varying latitudinal distribution. The first test has conflicting evidence to the prediction that the ratio of the PF/PB increases with increased paleolatitude. Though Plioplatecarpus has the largest PF/PB ratio and the highest the PF/PB ratio, has a higher latitudinal distribution compared to Platecarpus which has a larger PF/PB ratio. The second test did not support the prediction as Clidastes, Platecarpus, Plioplatecarpus, and Tylosaurus had similar PF sizes throughout their latitude gradient. Results of the second test may indicate that individuals of these genera lived in a diverse latitudinal habitat (i.e., cosmopolitan) and not in localized areas (i.e., endemic). One reason why some mosasaurs had a bigger PF than other mosasaurs was there may have been a relationship between the size of the PF to the ability to dive deeply in mosasaurs. A large PF may be used in deep diving in mosasaurs to orient themselves at depth. This could be the reason why the supposed shallow dwelling Clidastes had a smaller PF compared to the supposed deep diver Platecarpus. Another reason for the variety in PF size could be that cool-water dwelling mosasaurs need a large PF in order to regulate their body temperatures better than warm-water dwelling mosasaurs.
Session No. 4: Pantropical Cenozoic reefs

Chairs: James Klaus, Kenneth Johnson, and Willem Renema

Saturday Afternoon, 1:30 PM to 4:30 PM

Session 4-1: Saturday, 1:30 PM
Presenter: Ann Budd

DIVERSIFICATION OF CENOZOIC REEF CORALS AND ITS RELATIONSHIP TO CLOSURE OF THE TETHYS

Budd, Ann F., Department of Earth and Environmental Sciences, University of Iowa, 121 Trowbridge Hall, Iowa City, IA 52242; Bosellini, Francesca R., Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, P.le S.Eufemia 19, 41121 Modena, Italy; Smith, Nathan D., Department of Biology, Howard University, 415 College Street NW, Washington, DC 20059

Traditional morphology-based systematics interpret close evolutionary relationships between Caribbean and Indo-Pacific ‘faviid’ and ‘mussid’ reef corals; however, molecular phylogenies reveal three distinct family-level clades: 1) Caribbean faviids + mussels; 2) Indo-Pacific faviids; 3) Indo-Pacific mussels. The three clades diverged by middle Eocene time and are each regionally restricted. During the early Cenozoic, faviid and mussid corals also occurred in a third region, the Mediterranean, which was part of the westward flowing, pantropical Tethyan Seaway, but they became extinct in that region during the Miocene. These Mediterranean corals have been interpreted as closely related to members of the Caribbean clade. Here we perform morphological phylogenetic analyses including Caribbean, Indo-Pacific, and Mediterranean fossil and Recent taxa to reconstruct the pattern of divergence between the three regions, and examine how it is related to the breakup of the Tethys. Our dataset consists of 77 taxa (67 Recent, 10 fossil) and 38 characters. In addition to traditional macromorphology, the characters include newly discovered micromorphological and microstructural features observed in transverse thin section. The results show that contrary to traditional systematics, the Mediterranean fossils group more closely with Indo-Pacific faviids than they do with Caribbean taxa. Indo-Pacific mussels form a distinct clade, and Caribbean taxa form two distinct subclades. However, Indo-Pacific faviids form numerous unresolved subclades, which are basal to the Caribbean subclades. This pattern suggests that the Caribbean clade diverged from a more cosmopolitan pantropical fauna during one or two early Cenozoic evolutionary events associated with Tethyan breakup and Caribbean isolation, and it confirms that the modern Caribbean clade is evolutionarily unique.

Session 4-2: Saturday, 1:45 PM
Presenter: Viviana Díaz

EVOLUTION OF Plio-Pleistocene Reef Margins in the Caribbean: Results of the Dominican Republic Drilling Project (DRDP)

Díaz, Viviana D., University of Miami (RSMAS), 4600 Rickenbacker Causeway, Miami, FL 33149; Klaus, James S., University of Miami, Coral Gables, FL 33124; Pourmand, Ali, University of Miami (RSMAS), 4600 Rickenbacker Causeway, Miami, FL 33149; McNeill, Donald F., University of Miami, Coral Gables, FL 33124

Fringing reef margins of the Caribbean display a characteristic zonation in which Acropora palmata dominates shallow high-energy reef crests and Acropora cervicornis calmer fore-reef slopes and backreef lagoons. The dominance of acroporids across this zonation has been attributed to growth rates 5-100 times faster than other corals. However, the dominance and high accretion potential of acroporid reefs has a relatively recent geologic origin. Caribbean reefs changed profoundly in taxonomic composition, diversity, and dominance structure during late Pliocene and Pleistocene climatic change. These changes coincide with protracted climatic deterioration and cooling between 2.0 to 0.8 Ma, and the onset of high amplitude sea-level fluctuations. The Dominican Republic Drilling Project (DRDP) was initiated to determine how climate change and global high-amplitude sea-level changes influenced depositional patterns in Pliocene to Recent reef systems of the Caribbean. A transect of 7 core borings (~700 m total depth) were collected along the southern coast of the DR. New age constraints based on U/Th geochronometry and radiogenic Sr isotopes, combined with depositional lithofacies, faunal indicators, and stable isotope profiles have allowed us to correlate between wells and define the internal anatomy and stratigraphic geometry of the individual reef packages.

Session 4-3: Saturday, 2:00 PM
Presenter: Kenneth G. Johnson

OLIGOCENE AND MIOCENE HISTORY OF REEF CORALS AND CORAL REEFS IN EASTERN BORNEO (EAST KALIMANTAN, INDONESIA AND SABAH, MALAYSIA)

Johnson, Kenneth G., Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK; Renema, Willem, Department of Geology, Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, The Netherlands; Santodomingo, Nadiezlda, Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK

Understanding how shallow marine ecosystems respond to global-scale environmental change is notoriously difficult due to the complex dynamics of both environmental and biotic processes. However, long-term records of ecosystem responses can be extracted from the fossil record, and studies of past examples can provide useful information regarding modes and rates of change. The modern coral reefs of Southeast Asia are the most diverse on Earth, but understanding of the origins, maintenance, and ecological context for this diversity has been limited by a lack of information from the geological record of the region. Here
we report on results obtained from analysis of new data resulting from a large-scale integrated study of biota and environments from the Oligocene and Miocene deposits of eastern Borneo. For reef corals, diversity has been relatively high in the region since the Late Oligocene, although extant levels were not reached until the Quaternary radiation of the hyperdiverse genera Acropora and Montipora. However, there was a distinct ecological shift in regional reef systems that occurred gradually across the studied region during the Middle to Late Miocene, and in particular during the Serravalian and Tortonian stages. Reef coral communities in that Late Oligocene to Middle Miocene were developing low-relief reef structures in mesophotic habitats characterized by relatively high turbidity, with significant carbonate production dominated not by corals but by larger benthic foraminifera (lepidocyclinids) abundant on platform interiors and outer reef slopes. In shelf habitats, extensive coral carpets were dominated by a diverse assemblage of ramose corals. In contrast, patch reef development in which corals were the main carbonate producers became more common during the Late Miocene. This shift coincides with changing abundances of reef corals in local assemblages, but not with significant taxonomic turnover in the coral fauna. In contrast, the main clades of intra-reef carbonate producing larger benthic foraminifera became extinct and later epiphytic spinose foraminifera become more common culminating in the typical modern reef-associated LBF fauna. Likewise, the rise of the corals as the dominant carbonate producers in shallow habitats marks the onset of modern carbonate regimes in the region that are characterized by extensive coral reef development. Increased reef building is likely to have facilitated diversification within a broad range of marine taxa and the shifting of the global maximum of marine biodiversity to its present position. The shift coincides with a decline in pCO2 in the oceans during the Middle to Late Miocene, but whether or not it occurred over a large regional scale remains to be determined with new data from elsewhere in Southeast Asia.

Session 4-4: Saturday, 2:15 PM
Presenter: James S. Klaus
DEEP REEFS FROM THE DOMINICAN REPUBLIC
Klaus, James S., Geological Sciences, University of Miami, 1301 Memorial Dr., Coral Gables, FL 33141; Diaz, Viviana, Marine Geology and Geophysics, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149; McNeill, Donald F., Marine Geology and Geophysics, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149

The decline of shallow-water coral reef health and the mesophotic refugia hypothesis (Glynn 1996, Rieg and Piller, 2003) have rejuvenated interest in deeper water mesophotic coral ecosystems (MCEs). Found in low light, low energy environments 30–150 m deep, mesophotic coral reefs are important components of tropical marine ecosystems. Despite growing interest in mesophotic coral communities, few well-studied examples of Miocene to Pleistocene mesophotic coral communities exist from the Caribbean. This is largely due to the fact that deep fore reef environments are rarely exposed and accessible in the field. Here we use collections from the Cibao Basin, northern Dominican Republic (6.6-3.5 Ma) where deep mesophotic reefs are exposed and well-studied and a new seven core transect from the southern coast of the Dominican Republic (2.5-0.125 Ma) that returned abundant mesophotic coral material, to assess the impact of Plio-Pleistocene faunal change on mesophotic reef communities. We evaluate faunal changes in mesophotic coral communities in the context of changing nutrient conditions associated with closure of the Central American Seaway, and the transition to Pleistocene high-amplitude sea level changes.

Session 4-5: Saturday, 2:30 PM
Presenter: Thomas A. Stemmann
THE EARLY PALEOGENE REEF GAP IN THE CARIBBEAN
Stemmann, Thomas A., Department of Geography and Geology, The University of the West Indies, Mona, Kingston 7, Jamaica
Caribbean corals are diverse and abundant in the late Maastrichtian with more than 65 recorded species. This Caribbean fauna is severely affected by the end Cretaceous event, suffering ~95% extinction. The early Paleogene record in the Caribbean is remarkably sparse making it difficult to reconstruct how the region’s corals and reefs re-established themselves after the K-T extinctions and during the period of elevated global temperatures in the early Paleogene. The present study uses new collections from multiple localities in the Paleocene of Jamaica and Colombia, the Lower Eocene of Belize and Jamaica and the Middle Eocene of Jamaica to attempt to piece together the early Paleogene history of Caribbean reef corals. The new sites significantly increase the total number of collected early Paleogene Caribbean coral localities. In the Paleocene and early Eocene sites, corals are scarce, small, rarely in situ and show no evidence of growth fabric. Diversity is low with species richness commonly <6 spp. per sampled locality. These “communities” are made up of cosmopolitan genera and represent a mixture of zooxanthellate and azooxanthellate-like forms. In the middle Eocene, corals are far more common with >1500 identified specimens from the Chapelton Formation of Jamaica. This fauna is moderately diverse (26 spp.), comprised of generally small colonies from elsewhere in Southeast Asia.

Session 4-6: Saturday, 3:15 PM
Presenter: Ethan L. Grossman
LATE NEogene ENVIRONMENTAL CHANGE AND FAUNAL OVERTURN IN THE CARIBBEAN: REVELATIONS USING GASTROPOD STABLE-ISOTOPE PROFILES TO QUANTIFY SEASONAL UPWELLING AND FRESHENING IN COASTAL WATERS
Grossman, Ethan L., Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; Robbins, John A., Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; Tao, Kai, Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; O’Dea, Aaron, Smithsonian Tropical Research Institute, P.O. Box 0843-03092, Balboa, Panama
Faunal overturn in the Southwest Caribbean (SWC) during the Late Neogene has been primarily attributed to either loss in regional productivity associated with uplift of the Central American Isthmus (CAI; ~3.5 Ma) or decline in marine temperature associated with Northern Hemisphere glaciation (NHG) beginning ca. 3.3 Ma. Extinction preferentially selected against taxa adapted to nutrient-rich environments uncommon in the SWC today, but the turnover acme occurred 1–2 myr after the final closure of the CAI, which is coincident with the onset of severe NHG. Our goal is to determine which process was the root cause of the overturn of marine fauna in Late Neogene SWC waters through stable isotope analysis of gastropods. We present δ13C and δ18O data for 30 Conus and Strombus shells from Costa Rica and Panama ranging in age from 12 to 1.6 Ma that help identify sources of nutrients (upwelling and freshwater input) prior to, during, and after the final closure of the Central American Isthmus ~3.5 Ma. Tropical marine surface waters are typically very stable, with conspicuous variability in temperature and salinity (and thus shell δ18O) caused by either upwelling (cool temperature) or freshwater input (low salinity). Correlations between δ18O and δ13C (O-C) provide another test of upwelling (negative) and freshening (positive). Fossil specimen δ18O profiles do not show the strong upwelling and freshening signals found in modern Conus profiles from the Gulf of Panama in the Pacific (shell δ18O range > 2‰). However, SWC specimens older than ~3.5 Ma show δ18O ranges greater than those of modern specimens (> 1‰), suggesting potential refugia where modest seasonal upwelling enhanced productivity. Baseline δ18O values were calculated for each shell based on geochemical data from open-ocean planktonic foraminifera. Profiles normalized to open-ocean conditions reveal the amount of upwelling and freshening experienced by individual SWC gastropods. This approach shows greater freshening from 2.5–3.6 Ma and no upwelling after 3.5 Ma. By 2.5 to 1.5 Ma, shells from the SWC recorded δ18O ranges and O-C correlations representative of modern oceanographic conditions at these localities, suggesting that nutrient-rich refugia were rare or absent by this time. This interval coincides with the delayed extinction, providing a possible causal mechanism to delayed extinction in the SWC.

Session 4-7: Saturday, 3:30 PM
Presenter: Jon Bryan

NORMAL MARINE, SHALLOW SUBTIDAL STROMATOLITES IN THE LOWER MIOCENE CHIPOLA FORMATION, ALUM BLUFF, LIBERTY COUNTY, FLORIDA
Bryan, Jon, Physical Sciences, Northwest Florida State College, Niceville, FL 32578; Means, Guy, Florida Geological Survey, Tallahassee, FL 32304; Portell, Roger, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Low water levels of the Apalachicola River in the fall of 2012 exposed numerous, large, in-situ stromatolites at the classic Alum Bluff section in Liberty County, Florida. Exposed here are approximately 38 meters of Miocene to Quaternary strata. The stromatolites lie within the molluscan-rich, Ophiomorpha-bearing calcareous sands of the Lower Miocene Chipola Formation. Most colonies approach one meter in diameter and are coarsely laminated, with sediments entrapped by a network of calcified tubules or sheaths. Numerous colonies were sampled, and one entire colony (45.5 cm by 41.5 cm) harvested for study. Mesostructure (outcrop scale)—The outcrop is a cut bank, with ~55 linear meters of stromatolite-bearing surface. Sixteen isolated colonies were initially mapped, but many others are laterally linked, forming larger reefal masses. One area exposes 106 m² of contiguous colonies. Macrostructure (gross colony form, decimeters to meters)—All colonies are sub-globular, forming domes or rounded columns/hemispheres. The largest has a diameter of ~2.2 meters; the smallest, 33 cm; most are between 0.5 to 1.0 m. Mesostructure (macroscopic internal structure, hand sample scale, visible to naked eye)—The harvested colony reveals two obvious mesofabrics: 1) a central, well-cemented, bindstone core, composed of a dense network of calcified tubules/sheaths; and 2) an exterior, 4-5 cm-thick, calcareous quartz arenite bafflestone, which surrounds the colony. Fine calcareous tubules randomly penetrate the exterior sandstone, baffling and cementing the quartz sand. The interior section has two subfabrics: a) a tubule/sheath bindstone, composed of randomly-oriented tubules; and b) a central, dense, tubule/sheath bindstone, composed of longitudinally-oriented bundles of calcareous tubules running up the center of the colony. This ‘bundilestone’ also has digitate fabric. The base has a 1.5 cm-diameter bundle, with five or six 1-3 mm-diameter rhizoid-like sheaths radiating from the bundle. Early cementation, multiple generations of vertical and lateral accretion, and episodes of fracturing and bioerosion are evident. Microstructure (microscopic scale)—Polished billets show semi-continuous, wavy/crenulated, porous calcareous laminae, but the pores are tubules that regularly interrupt the laminae. Many of the pores have a well-preserved, delicate, reticulated internal microstructure, which is interpreted as the sheaths of calcifying cyanobacteria. Isolated, laminated, microintraclasts are common and re-bound by later calcification. Marine stromatolites of Cenozoic age are exceptionally rare, but are known from the Late Miocene of Spain; and the Holocene of Shark Bay, Australia, and the Exuma archipelago of the eastern Bahamas. The Chipola stromatolites developed within the mouth of the Gulf Trough during the waning stages of this Eocene to Miocene marine channel.

Session 4-8: Saturday, 3:45 PM
Presenter: Warren D. Allmon

TOWARD A PHYLOGENY OF WESTERN ATLANTIC NEOGENE TURRITELLINE GASTROPODS
Allmon, Warren D., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850; and Dept. of Earth and Atmospheric Sciences, Cornell University, 14853; Anderson, Brendon M., Dept. of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853; Friend, Dana S., Dept. of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853; Onofryton, Katharine, Dept. of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853; Sang, Stephanie, Dept. of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853

Turritelline gastropods (Family Turritellidae, Subfamily...
Turritellinae) are among the most abundant, diverse, and frequently occurring members of Neogene marine faunas in the western Atlantic region. In Florida, the Caribbean, and Central America, more than 60 fossil species and subspecies have been described. At least three species live there today, and at least 7 in the eastern Pacific. Turritellines have long been assumed to be represented among ‘geminate species’ on either side of the Central American Isthmus, and are known to have suffered significant diversity decline in the Plio-Pleistocene regional mass extinction at the end of the Pliocene. At least some forms across the Caribbean, from Florida to Panama, appear closely related. Yet little is known about their phylogenetic relationships, and so these interesting evolutionary questions have not been investigated in any detail. Preliminary phylogenetic analyses—the first for turritellines using both molecular and shell characters—of approximately 30 species from the late Miocene to Recent of the low-latitude western Atlantic region suggests that: 1) one or more lineages have persisted in the region throughout the Neogene, and perhaps longer; 2) at least one and perhaps more geminate species pairs exist across the Isthmus; 3) species diversity has fluctuated over the past 10 million years, prior to the early Pleistocene decline; 4) there is little or no latitudinal diversity gradient in the group in the Neogene; and 5) most species have relatively narrow geographic and stratigraphic ranges, but a few are widespread and long-lived.

Session 4-9: Saturday, 4:00 PM
Presenter: Fabiany Herrera

NEOTROPICAL FLORAS REVEAL THE BIOGEOGRAPHIC EVOLUTION OF PALEOCENE TO MIocene (60 TO 19 MA) FORESTS

Herrera, Fabiany, Florida Museum of Natural History and Department of Biology, University of Florida, Gainesville, FL 32611; Manchester, Steven R., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Jaramillo, Carlos, Smithsonian Tropical Research Institute, Panama City, Panama

Confident identification of ancient floristic components is key to understanding varying biogeographic patterns and the response of vegetation to tectonic changes in the Neotropics. We are investigating well-preserved fruit and seed floras ranging from ~60 to ~20 million years ago, from the Paleocene (Cerrejón and Bogotá floras), Eocene (Tonosí flora), and Miocene (Cucaracha flora) of Central and northern South America (specifically Colombia and Panama), to address the following questions: 1) Was northern South America phytogeographically isolated during the Paleogene? 2) What families first colonized the emergent land in the Panamanian arch during the late Eocene? 3) Did the Panamanian seaway act as a strong geographic barrier between the South and Central American forests in the Miocene? Each of these questions is addressed in numerical sequence below. 1) Preliminary results show that the Paleocene floras in Colombia reached a diverse array of fruit and seed types, sizes, and modes of dispersion after the Cretaceous extinction. Although northern South America was isolated geographically, several fossils (e.g., Menispermaceae, Icacinaceae, Arecaceae, Bombacoideae) show connection with North American paleofloras and extant Old World taxa. 2) The rise of the southern part of Central America has been hypothesized as a result of a volcanic arc. New geological data from Central Panama suggest the presence of large terranes above sea level at least since the late Eocene. Some of the new colonizing plant families/orders identified from disseminules include Arecaceae, the earliest Vitaceae and Humiriaceae in the Neotropics, Anacardiaceae, and Lamiales. At the generic level we have identified Dracontomelon and Leea, both of which are restricted today to Old World tropical rainforests. 3) From the middle Miocene of Panama we have discovered a rich carpoflora that suggests the presence of a rainforests in the region. Some of the new fossils include Sacoglottis, Parinari, Cissus, and Spondias, suggesting that long distance dispersal between Central and South America was very common before the closing of the Panamanian Seaway.

Session No. 5: New advances and applications in sclerochronology

Chairs: Donna Surge and David Goodwin
Saturday Afternoon, 1:30 PM to 4:45 PM

Session 5-1: Saturday, 1:30 PM
Presenter: Michael R. Johnson

STABLE ISOTOPE PROFILES FROM MOLLUSKS (LYMNOCARDIUM) OF THE LATE MIocene LAKE Pannon, CENTRAL EUROPE

Johnson, Michael R., Department of Geosciences, University of Wisconsin-Madison, Madison, WI 53706; Geary, Dana H., Department of Geosciences, University of Wisconsin-Madison, Madison, WI 53706

The retreat of the Paratethys in the late Miocene formed the brackish Lake Pannon in central Europe. Isolations of the lake from the sea allowed for the radiation of many endemic mollusk lineages. Previous work has suggested a number of potential drivers for these radiations, including a reduction of competition or predation, shifts toward fresher lake waters, adoption of new habitats, climate changes toward greater seasonality, and terrestrial influences. We use the stable isotope profiles of two lineages of the endemic clam Lymnocardiium to detect evolutionary patterns, and environmental changes through the late Miocene. Preliminary data suggest that, as Lymnocardiium species increase in size over time, so too does their lifespan increase. Isotope profiles from the snail Melanopsis indicate a similar pattern of increased size through increased longevity that has been hypothesized to result from reduced predation and competition. In addition, these profiles have applications for paleoenvironmental interpretations. Oxygen and carbon values within shells and between shells over time vary with a
number of environmental parameters, including temperature, precipitation, evaporation, and— it has been suggested— runoff from terrestrial vegetation. Intra- and intershell variation over time demonstrates the changing conditions of Lake Pamnon that may be driving mollusk evolution. With this understanding of the lake environment, we investigate the potential for coupling with the terrestrial environment. Not only are significant terrestrial changes expected in the late Miocene—such as the expansion of C4 grasslands—but these changes have been hypothesized to influence the lake environment. We include a preliminary terrestrial isotope record as a test of this influence.

Session 5-2: Saturday, 1:45 PM
Presenter: David Moss
ENVIRONMENTAL CONTROLS ON EXTREME LONGEVITY IN MODERN AND FOSSIL BIVALVES
Moss, David K., Department of Earth Sciences, Syracuse University, Syracuse, NY 13244; Ivany, Linda C., Department of Earth Sciences, Syracuse University, Syracuse, NY 13244

What controls lifespan? Bivalves hold the record for longevity among animal species—Arctica islandica is the longest lived non-colonial animal on the planet, with a maximum reported lifespan of 507 years, and a number of other bivalves are known to live more than a century. This group may therefore provide significant insights into the factors that promote long life, a topic of great interest from our perspective as human beings. While a good deal of attention is being devoted to physiological aspects, very little is known about the evolution of extreme longevity as a viable life history strategy, either within or between species, and virtually no work has been done on its fossil record. Sclerochronological research has the potential to contribute on two key fronts: the role of environment and the influence of phylogeny in facilitating long life. Here, we focus on the former. Anecdotal data suggest that environment is important because no centenarians are known within 40° of the equator because no centenarians are known within 40° of the equator. However, temperature cannot be the whole story. Multiple factors that promote long life, a topic of great interest from our perspective as human beings. Modern coral reef communities in the Caribbean are being threatened by anthropogenic input of nutrients, whereas one to two million years ago, communities in this same region experienced dramatic overturn of corals and mollusks with the uplift of the Central American Isthmus and subsequent reduction of upwelling-derived nutrients. We quantify upwelling and freshwater influences in contrasting tropical ecosystems using stable isotope analyses (δ13C and δ18O) of 13 serially sampled modern Conus shells collected from coastal Panama to identify, and test trace element compositions (Mg, Sr, Ba, Mn, Fe, P, and U) as nutrient proxies. Specimens were collected from waters in the southwestern Caribbean (SWC, non-upwelling) and gulfs of Chiriqui (non-upwelling) and Panama (upwelling) in the tropical eastern Pacific. Most shells’ δ18O profiles reveal seasonal variations in temperature and (or) seawater δ18O. Unusually high or low seasonal δ18O values measure the intensity of seasonal upwelling or freshwater input, respectively. To quantify upwelling and freshening signals, baseline δ18O values free of seasonal upwelling and freshening have been calculated from average temperatures during rainy (non-upwelling) seasons and average salinities during dry (upwelling) seasons. Baseline-normalized δ18O profiles reveal 1) little or no upwelling in the SWC, 2) seasonal shoaling of the thermocline in the Gulf of Chiriqui, and 3) strong upwelling in the Gulf of Panama. This reflects the positive relationship between Sr/Ca and temperature in Conus shells. However, high Sr/Ca values are associated with δ18O minima, suggesting that Sr/Ca may also correlate inversely with salinity. Trace element/Ca ratios for Mg, Ba, Mn, Fe, P, and U show no consistent relationship with δ18O or δ13C. On the other hand, P/Ca ratios in modern Conus shells correlate with general trends in seawater phosphate,

Session 5-3: Saturday, 2:00 PM
Presenter: Ethan L. Grossman
QUANTIFYING UPWELLING AND FRESHENING IN NEARSHORE TROPICAL AMERICAN ENVIRONMENTS USING MODERN GASTROPOD SHELLS—STABLE ISOTOPIC SUCCESSES AND TRACE ELEMENT COMPLEXITIES
Grossman, Ethan L., Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; Tao, Kai, Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; Robbins, John, A, Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; O'Dea, Aaron, Smithsonian Tropical Research Institute, P.O. Box 0843-03092, Balboa, Panama

Nutrient status and stability play key roles in the maintenance of marine ecosystems, both in modern and ancient oceans. Modern coral reef communities in the Caribbean are being threatened by anthropogenic input of nutrients, whereas one to two million years ago, communities in this same region experienced dramatic overturn of corals and mollusks with the uplift of the Central American Isthmus and subsequent reduction of upwelling-derived nutrients. We quantify upwelling and freshwater influences in contrasting tropical ecosystems using stable isotope analyses (δ13C and δ18O) of 13 serially sampled modern Conus shells collected from coastal Panama to identify, and test trace element compositions (Mg, Sr, Ba, Mn, Fe, P, and U) as nutrient proxies. Specimens were collected from waters in the southwestern Caribbean (SWC, non-upwelling) and gulfs of Chiriqui (non-upwelling) and Panama (upwelling) in the tropical eastern Pacific. Most shells’ δ18O profiles reveal seasonal variations in temperature and (or) seawater δ18O. Unusually high or low seasonal δ18O values measure the intensity of seasonal upwelling or freshwater input, respectively. To quantify upwelling and freshening signals, baseline δ18O values free of seasonal upwelling and freshening have been calculated from average temperatures during rainy (non-upwelling) seasons and average salinities during dry (upwelling) seasons. Baseline-normalized δ18O profiles reveal 1) little or no upwelling in the SWC, 2) seasonal shoaling of the thermocline in the Gulf of Chiriqui, and 3) strong upwelling in the Gulf of Panama. Also, most areas show strong freshwater input. Dry-season δ18O values for Gulf of Panama Conus can exceed the baseline by as much as 2‰, which equates to seawater temperatures ~9°C lower than normal. In contrast, rainy season δ18O values can be as low as 1.8‰ below the baseline, equivalent to salinities ~7 psu lower than dry-season values. Of the trace elements analyzed, only Sr/Ca shows a significant correlation with upwelling intervals, as indicated by high δ18O. This reflects the positive relationship between Sr/Ca and temperature in Conus shells. However, high Sr/Ca values are associated with δ18O minima, suggesting that Sr/Ca may also correlate inversely with salinity. Trace element/Ca ratios for Mg, Ba, Mn, Fe, P, and U show no consistent relationship with δ18O or δ13C. On the other hand, P/Ca ratios in modern Conus shells correlate with general trends in seawater phosphate,
with generally higher values in the Pacific relative to the Caribbean. These results show the potential of P/Ca analyses for characterizing the nutrient status of ancient oceans.

Session 5-4: Saturday, 2:15 PM
Presenter: David H. Goodwin

NEW SCLEROCHRONOLOGICAL INSIGHTS INTO HETEROCRHONIC EVOLUTION OF TROPICAL AMERICAN CORBULIDS

Goodwin, David H., Department of Geosciences, Denison University, Granville, OH 43023; Anderson, Laurie C., Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701; Roopnarine, Peter D., Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA 94118

The emergence of the Central American Isthmus as a barrier between the Caribbean/western Atlantic and eastern Pacific has had profound effects on global climate and ocean circulation, as well as on the ecology and evolution of both terrestrial and marine organisms in tropical America. Prior to the emergence of the Central American Isthmus (CAI), equatorial Atlantic and Pacific water mixed freely. Today, however, seasonal upwelling of cold, nutrient-rich water characterizes the tropical Eastern Pacific, whereas warm, nutrient-poor water dominates the Caribbean. Here we document growth patterns from presumed cognate species found on either side of the CAI: Corbula dietziana (Western Atlantic) and C. speciosa (Eastern Pacific). Despite diverging approximately 3.5 million years ago, these species are geometrically nearly identical—differing essentially only in size. Our results suggest this size difference may be a function of heterochrony. Corbulids are small, sturdy-shelled bivalve mollusks that range from the Late Jurassic through the recent. Despite their long geologic range, corbulid morphology remains relatively unchanged. In general, corbulids possess ovate to trigonal inequivalve shells: the right valve tending to be larger than the left. Their conservative morphology notwithstanding, corbulids employ various growth strategies to achieve their adult shape. Our previous sclerochronologic and stable oxygen-isotope analysis indicates that some corbulid species grow isometrically, while others, like C. dietziana and C. speciosa, display anisometric growth, producing a well-defined nepioconch followed by a marked change in the primary growth direction. To understand observed size differences, we documented growth rates by measuring size at specific ages, which were established using oxygen isotope profiles. Because oxygen isotope variation in biogenic carbonates is a function of temperature and the isotopic composition of water, both of which show strong annual cyclicity in tropical American oceans, patterns of within-shell oxygen isotope variation can be used to establish ontogenetic age. Next, the sizes and ages of the nepioconchs were compared to establish differences in growth rates between the juvenile and adult shells of both species. Our data indicate diverging growth patterns following development of the nepioconch: C. speciosa lives longer than C. dietziana. If the ancestral ontogenetic pattern is comparable to that of C. dietziana, then C. speciosa experienced peramorphosis through hypermorphosis. If, on the other hand, the ancestral growth rate is similar to that of C. speciosa, then C. dietziana experienced paedomorphosis through progenesis.

Session 5-5: Saturday, 2:30 PM
Presenter: Tristan Betzner

THE SMALLEST LINES: WHAT MIGHT THE COMPOSITION OF LINGULID GROWTH BANDS TELL US ABOUT PALEOEENVIRONMENT?

Betzner, Tristan, Department of Geologic Sciences, University of Colorado Boulder, Boulder, CO 80309; Chin, Karen, Department of Geologic Sciences, Museum of Natural History, University of Colorado Boulder, Boulder, CO 80309; Schwimmer, David R., Earth and Space Sciences, Columbus State University, Columbus, GA 31907

Analyses of accretionary growth patterns and associated chemical signatures in the shells of marine mollusks have been used to provide insight into paleoenvironmental conditions, with particular emphasis on the utility of shell chemistry in paleo thermometry. Multiple workers have suggested that the width and composition of annual, dark-light growth band couples of mollusk shells are also influenced by environmental stress (both natural and anthropogenic), food availability, spawning, and ontogenetic stage. In contrast, little is known about what the growth patterns and chemistry of brachiopod shells may represent, and the externally-conservative, phosphatic lingulids remain particularly enigmatic. The goal of this study is to examine the utility of growth band composition as an indicator of paleoenvironmental conditions across a latitudinal gradient. Exceptionally preserved lingulids recovered from the Campanian Kanguk Formation of Devon Island, Nunavut, Canada serve as the high-latitude (~70°N) sample population for this study, and coeval specimens from the Blufftown Formation of Stewart County Georgia, USA provide a lower-latitude (~32°N) comparison. The similar diminutive size, gross exterior morphology, and temporal occurrence of these specimens suggest that they represent geographically-distinct populations of Lingulida. Most Arctic lingulids occur fully-articulated, with valves cemented together with glauconitic sand. Thin sections reveal that the secondary shell laminae of these specimens have an intermittent, blocky texture that suggests partial recrystallization. The Georgia specimens occur as singular, commonly fragmented valves encased within a fossiliferous silty sandstone. The organic-rich periostracum is preserved in both sample populations, allowing for observation of light-dark color banding and associated periostracal ridges similar to those of extant lingulids. Shell relief and color variability are more readily observed in the Arctic specimens; however, preliminary petrographic analyses suggest that external shell patterns may not directly correlate to stages of shell growth. Furthermore, the disparity in preservation between the assemblages must be considered during both elemental and petrographic analyses. Microprobe analyses of environmentally-sensitive trace elements incorporated within the lingulid shells will be performed to help resolve the ontogenetic and diagenetic histories of Arctic and Georgia specimens. While care must be taken to understand the effects of taphonomic over-printing on putative composition zones, elemental and petrographic analyses of growth band compositions may provide insight into the effects of different physio-chemical
regimes on the accretionary growth of lingulid brachiopods.

Session 5-6: Saturday, 3:15 PM
Presenter: Bernd R. Schöne

USING THE ELEMENT AND ISOTOPIC CONTENT OF BIVALVE SHELLS AS PALEOENVIRONMENTAL PROXIES: POSSIBILITIES AND LIMITATIONS

Schöne, Bernd R., Institute of Geosciences, Johannes Gutenberg University Mainz, J.-J.-Becher-Weg 21 D-55128 Mainz, Germany

Shells of bivalve mollusks are becoming increasingly recognized as powerful tools for paleoclimate reconstructions. However, it still remains extremely challenging to obtain robust estimates of environmental quantities from this archive. For example, the only well-accepted proxy for temperature in bivalve shells, $\delta^{18}O$ values, is a dual proxy because it simultaneously informs about changes of temperature and the oxygen isotope signature of the ambient water. To reconstruct one parameter requires knowledge of the other. Likewise, variable shell growth rates are controlled by at least two major factors, temperature and food availability/quality, and are therefore not particularly useful for precise environmental reconstructions. Furthermore, shell stable carbon isotope ratios of most bivalve species become shifted to more negative values as the animal ages, because of an increasing contribution of metabolic carbon dioxide to the shell carbonate. Attempts to employ other isotope ratios (e.g., Ca, Mg, Sr) or the element chemistry (e.g., Sr/Ca, Mg/Ca) of the shells to quantify past environmental conditions have largely failed. In fact, the elemental content of the shells remains far below that of the ambient environment. At first glimpse, this is confusing, because bivalves are osmoconformers, i.e., the body fluids are largely isosmotic with the ambient medium. Apparently, their incorporation of these elements is controlled to various degrees by the organism. If the mechanisms and processes of these vital effects were better understood, it may become possible to extract meaningful environmental data from these potential proxies. This presentation expands on the physiological pathways of elements from the ambient environment to the site of calcification in bivalves, i.e., the extrapallial fluids, as well as the fate of elements that never become incorporated into the shells or are subject to diagenetic alterations. The presentation will also demonstrate how closely calcification and detoxification processes are intertwined, and highlight the possibilities and limitations of using the element content of bivalve shells as environmental proxies.

Session 5-7: Saturday, 3:30 PM
Presenter: Michal Kowalewski

JACKKNIFE-CORRECTED PARAMETRIC BOOTSTRAP ESTIMATES OF GROWTH RATES IN BIVALVE MOLLUSKS USING NEAREST LIVING RELATIVES

Kowalewski, Michal, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Dexter, Troy A., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Quantitative estimates of growth rates can augment ecological, geochemical, and paleontological analyses of organisms with accretionary growth patterns. In contrast to body-size estimates, assessing growth rates is often expensive, time-consuming, or even unattainable. We propose an indirect approach for efficient approximation of growth rates using nearest living relatives with known age-size relationships. This multi-step approach involves 1) collecting a sample of growth rates for a set of closely related species, 2) computing the average growth curve using those age-size relationships, 3) resampling growth curves to estimate the standard error around the average growth curve (jackknife-corrected parametric bootstrap), and 4) applying the resulting error estimates to bracket age-size relationships for the targeted species of interest. We applied this approach to three families (Donacidae, Mactridae, and Semelidae) of mollusk bivalves, a group characterized by indeterministic shell growth, but widely used in ecological, paleontological, sclerochronological, and geochemical research. The estimates were tested against two geochemical studies published previously. In both cases, highly congruent age estimates were obtained using our approach. In addition, a case study in applied fisheries was used to illustrate the value of the proposed approach for augmenting management practices in aquaculture. The estimates of growth rates derived from nearest living relatives allow for placing body size data in a constrained temporal context, namely, confidence intervals estimated via resampling allow for assessing the statistical uncertainty in temporal ranges. The indirect approach proposed here is potentially applicable to diverse research questions, from harvest sustainability in shellfish aquaculture to paleoenvironmental interpretations of stable isotope proxies extracted from fossils. The approach proposed here should be transferrable also to other groups of extant organisms.

Session 5-8: Saturday, 3:45 PM
Presenter: Linda C. Ivany

SEASONALITY, CLIMATE CHANGE, AND THE LATE EOCENE INITIATION OF THE MODERN ANTARCTIC BIOTA

Ivany, Linda C., Department of Earth Sciences, Syracuse University, Syracuse, NY 13244; Miklus, Nicole, Department of Earth Sciences, Syracuse University, Syracuse, NY 13244; Aronson, Richard B., Department of Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901; Blake, Daniel D., Department of Geology, University of Illinois, Champaign, IL 61820

The Eocene section on Seymour Island, Antarctica, preserves one of the few records of marine macrofaunal change in the high southern latitudes leading up to glaciation of the Antarctic. Today, the Antarctic fauna is unique, characterized by unusually low predation pressure and an abundance of low-metabolic-rate and suspension-feeding organisms. Those traits are permitted in large part by very cold, invariant thermal conditions. Seasonal variation in water temperatures around the Peninsula today is only a few degrees at most. During the middle Eocene, however, marine faunas were more typically Cenozoic—i.e., modern—in their composition, including durophagous (skeleton-breaking)
predators such as sharks, crabs, and teleostean fishes. The transition to the late Eocene was marked by the loss of durophagous predators and an expansion of the archeaic fauna more typical of the region today, including crinoids, ophiuroids, and other invertebrates of a Paleozoic functional grade. Shell-drilling predation on mollusc prey appears to have declined, as did the frequency of typical antipredatory shell morphologies. Taxonomic turnover among late Eocene mollusks is the highest in the section. Analysis of stable oxygen isotopes in mollusk shells has demonstrated a shift to more positive values, interpreted to reflect cooling during the later part of the Eocene that is likely linked to faunal turnover. More recently, however, clumped isotope work by colleagues at Yale University suggests that the isotope value of local seawater was also becoming more positive during this time, probably in association with the growth of small ice sheets in the continent’s interior. The inferred change in mean temperature is consequently less substantial, leaving open the question of what drove faunal change. We microsampled shells of the bivalve Cucullaea from five stratigraphic horizons throughout the section to reveal the magnitude of seasonal temperature variation in the shallow-marine environment through the middle and late Eocene on Seymour Island. Data reveal strongly seasonal conditions in the lower part of the section that collapse to a seasonal variability of less than 2°C in the late Eocene, with summer temperatures cooling more than winter temperatures. The shift to a cooler, less variable temperature regime marks the initial establishment of conditions more typical of the Neogene, and likely ushered in the retrograde faunas that today characterize the Antarctic benthos. The transition from eurythermal to cool-stenothermal biotas resulted in benthic communities more sensitive to subsequent perturbation. Warming in the Antarctic Peninsula has already raised summer temperatures to the point that invasion by predatory lithodid crabs appears imminent. Continued warming could result in the eventual dissolution of benthic communities in Antarctica, as they are re-modernized and homogenized with the rest of the world’s marine biota.

Session 5-9: Saturday, 4:00 PM
Presenter: Yurena Yanes

CALIBRATING PATELLA SHELLS FROM THE CANARY ISLANDS AS SEASONAL PALEOTHERMOMETERS

Yanes, Yurena, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Mesa, Eduardo M., Departamento de Prehistoria, Arqueología e Historia Antigua, Universidad de La Laguna, La Laguna 38200, Canary Islands; Navarro, Juan F., Departamento de Prehistoria, Arqueología e Historia Antigua, Universidad de La Laguna, La Laguna 38200, Canary Islands; Pais, Jorge, Cabildo Insular de La Palma, Santa Cruz de La Palma 38700, Canary Islands; Little, Nicole, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

The aboriginal people from the Canary Islands, commonly called The Guanches, collected, consumed and accumulated marine mollusks (primarily Patellidae) over time. Prehistoric Patella middens expand back in time from 2,500 cal ka BP to the end of the 15th century, when Spaniards conquered the archipelago. These materials may be used as paleotemperature proxies because the oxygen isotopic composition (δ18O) of the shell is mainly influenced by sea surface temperature (SST) and seawater δ18O values during calcification. To evaluate the potential of Patella species from the Canary Islands as environmental sentinels, live specimens of Patella tenius crenata and P. ulysiponensis asp era, which overlap in ecology and distribution within the rocky intertidal zone, along with SST and seawater samples, were collected regularly for eight months (from July 2011 to April 2012) in SE Tenerife Island. Shell margin δ18O values, which depict the oldest growth episode, varied from +1.9‰ in March to +0.1‰ in September. Shell margin δ18O values correlated negatively with observed SST (R²=0.95; p<0.001; n=98), whereas seawater δ18O values did not vary seasonally. Calculated temperatures from the shell, using the equation by O’Neill et al. (1969), were underestimated by 3.3±0.7°C, as observed for other Patella species from higher-latitude locales. Such temperature offset was constant and predictable through seasons. If shell margin δ18O values are corrected by 0.72‰, then calculated and observed SST overlap. This study shows that the δ18O values of Patella shells from the Canary Islands should be corrected by subtracting 0.72‰ before paleotemperature inferences, in agreement with previous studies on Patella from other regions. Conclusively, after pertinent corrections, fossil and archeological Patella shells are valuable seasonal paleoenvironmental proxies for before and during aboriginal human occupation in the Canary Islands.

Session 5-10: Saturday, 4:15 PM
Presenter: Kathryn D. Nold

ISOTOPIC EVIDENCE OF RECENT, COASTAL PALEOCLIMATE FROM ARCHAEOLOGICAL GASTROPOD SHELLS

Nold, Kathryn D., Department of Geological Sciences, Department of Anthropology, Indiana University, Bloomington, IN 47405; Johnson, Claudia C., Department of Geological Sciences, Indiana University, Bloomington, IN 47405; Elswick, Erika R., Department of Geological Sciences, Indiana University, Bloomington, IN 47405; Conrad, Geoffrey W., Department of Anthropology, Indiana University, Bloomington, IN 47405; Becker, Charles W., School of Public Health, Indiana University, Bloomington, IN 47405

Geochemical analysis of gastropod shells excavated from coastal archaeological middens facilitates investigation of local, shallow-marine paleoenvironmental dynamics. Our study site, La Cangrejera, is a village-shore archaeological site located on the southeastern Caribbean coast of the Dominican Republic. The stratigraphy of La Cangrejera appeared reworked and numerous terrestrial crab burrows were visible at the site. Archaeologists with the Museo del Hombre Dominicano excavated abundant Boca Chica ceramics, including one intact vessel, human burials, ground stone tools, ornaments, vertebrate bones and mollusk shells. Bivalve and gastropod shells were the most abundant faunal remains. We observed 17 species of Bivalvia and 21 species of Gastropoda with 1,311 and 4,630 individuals represented. Fissurella, Strombus, and Brachidontes are the most abundant genera. The goal of our study is to constrain past
temperature and precipitation patterns in littoral to shallow-sublittoral marine settings. We established stable carbon and oxygen isotope profiles for 10 pristine samples of gastropods *Strombus pugilis* and *Echinolittorina tuberculata*. We investigated the mineralogy of shells selected for geochemical analysis using x-ray diffraction. We obtained radiocarbon dates from seven *S. pugilis* shells, which yielded an age range from 1040–1490 AD. The isotope profiles of both gastropod species are relatively static with maximum ranges of 1.0 in oxygen and 1.7 in carbon. These limited ranges reflect low seasonal variation in temperature and salinity in non-upwelling, well-mixed Caribbean settings. The oxygen profiles of *S. pugilis* individuals dated after 1200 AD tend to be more positive and may reflect cooler average temperatures after that time. We obtained isotope results for three *E. tuberculata* shells collected along the beach near our study site. These samples allowed us to establish the range of isotopic values observed in modern shells near La Cangrejera. Inter- and intra-shell variation in isotopic values of modern specimens exceeds those observed in archaeological *E. tuberculata* samples. The narrower range of isotopic values in archaeological specimens may suggest temperature-precipitation conditions were less variable in the past. Thus our results yield insight into coastal paleoclimatic conditions when Native Americans resided at La Cangrejera. These physical parameters establish a framework for interpretation of biological, ecological, and human-environmental interactions at La Cangrejera. Further, our study expands the spatial and ecological scope of Caribbean paleoenvironmental records by contributing data from this shallow, coastal setting to those already established for open-ocean and lake settings.

Session 5-11: Saturday, 4:30 PM
Presenter: Nicole Cannarozzi

**SEASONAL OYSTER HARVESTING RECORDED BY SHELLS OF THE PARASITIC SNAIL *BOONEA IMPRESSA* IN ARCHEOLOGICAL MIDDENS OF FLORIDA AND GEORGIA**

Cannarozzi, Nicole R., Department of Anthropology, University of Florida, Gainesville, FL 32611; Kowalewski, Michal, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Russo, Michael, Southeast Archaeological Center, Tallahassee, FL 32310

*Boonea impressa* is a parasitic pyramidellid gastropod commonly found in oyster reefs on the Atlantic and Gulf coasts of North America. *B. impressa* specimens are frequently found in archeological midden samples processed with fine-mesh screens (1.6mm). A method for determination of archaeological season of oyster collection was developed by Russo to circumvent difficulties in determining seasonal growth in oyster populations from oyster shell morphology. The method compares shell-length measurements of modern *Boonea impressa* throughout an annual growth cycle to that of archaeological specimens. In this study, shell-length measurements of proxy specimens of *B. impressa* from St. Catherines Island, Georgia, were compared to subfossil specimens from St. Catherines Shell Ring, an Archaic Period (2160–1770 cal BC) site located on the island. Samples of modern *B. impressa* from Crescent Beach, Florida, were also used as a sclerochronological reference system to interpret the archeological data from the Florida and Georgia middens. Previous studies compared modal seasonal size classes of a modern sample population to those from archaeological deposits. This research improves upon this method by applying the multi-sample Kolmogorov-Smirnov (K-S) metric, a tool that allows for an analytically efficient exploration of *B. impressa* demography. This approach suggests that oysters from these middens were harvested seasonally (October–March). Additionally, analysis of modern data provides quantitative estimates of growth rates, longevity, and spawning patterns in *B. impressa* suggesting that the sampled populations of this species spawn in April–May and have a maximum longevity of 12 months. Shells of parasitic snails associated with oysters may provide data for evaluating prehistoric oyster harvesting patterns.
Session No. 6: Pantropical Cenozoic reefs
Saturday Afternoon 4:45 PM to 5:45 PM

Presenter: Timothy Fallon

RECONSTRUCTING THE PALEOENVIRONMENT AND PALEOEKOLOGY OF A TURRITELLA-RICH HORIZON IN THE PLIO-PLEISTOCENE JACKSON BLUFF FORMATION OF THE FLORIDA PANHANDLE

Fallon, Timothy J., School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620; Whorley, Theresa L., School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620; Harries, Peter J., School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620; Andres, Brian, School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620; Slattery, Joshua S., School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620

Turritelline-rich assemblages have been traditionally thought to occur in association with upwelling zones; however, this hypothesis has not been extensively investigated for most occurrences. To examine this issue, we undertook a detailed paleoecological, paleoenvironmental, and taphonomic analysis of a Turritella-rich horizon in the Plio-Pleistocene Jackson Bluff Formation of Florida. To do this, we collected a large float block derived from the Jackson Bluff Formation at the Alum Bluff section in the Florida Panhandle. The block displays the contact between the clay-rich Jackson Bluff Formation and the overlying unnamed Sandy Clay unit. We examined the block’s faunal composition and taphonomy of its constituent foraminifers and mollusks to determine the depositional setting and paleoenvironmental conditions that modulated the large concentration of turritellines. This macroinvertebrate assemblage was dominated by the bivalve Mulinia and the gastropod Turritella, whereas the benthic foraminiferal assemblage consisted largely of Elphidium and Bulimina. These together with the organic-rich mudstone-matrix all support a shallow-water, eutrophic, brackish estuary as the depositional setting for this assemblage. The abundance of macroinvertebrate taxa varied both laterally and stratigraphically throughout the block. The abundance of Turritella increases vertically through the sequence grading into a Turritella-rich horizon near the contact with overlying unnamed Sandy Clay unit. The orientation and inclination of Turritella within our assemblage do not support the presence of uni- or bimodal currents during or after deposition. However, imbrication of Mulinia and clustered Turritella grading into the Turritella-rich horizon suggest that shell concentration possibly formed by transportation and winnowing. Typically turritelline-rich assemblages have been interpreted as products of upwelling, however our data suggest that these types of horizons can also form through physical sedimentary processes.

Session No. 7: Phylogenetics, systematics, paleoclimatology, paleoceanography, paleobiogeography

Saturday Afternoon, 4:45 PM to 5:45 PM

Presenter: Ian Cannon

NEW FOSSIL TURTLE MATERIAL FROM THE HEMPHILLIAN PASCAGOULA FORMATION OF SOUTHEAST LOUISIANA

Cannon, Ian M., Louisiana State University, Museum of Natural Science, Baton Rouge, LA 70803; Schiebout, Judith A., Louisiana State University, Museum of Natural Science, Baton Rouge, LA 70803; Ting, Suyin D., Louisiana State University, Museum of Natural Science, Baton Rouge, LA 70803

Two new fossil turtles have been found in the Pascagoula Formation of the eastern Louisiana Tunica Hills/Kerry Site. The fossils derive from blue-green, clayey silt sediments of latest Miocene age that were likely deposited in an estuarine paleoenvironment. Previous identifications of artiodactyls, horses, and a dwarf rhino are consistent with a Hemphillian age for the site. Also discovered in the formation are a mastodon, the rhinoceratid Teleoceras, the rodent Copemys, a natricine snake, and a variety of fish, turtle, and crocodilian fossils similar to those found at the older Miocene site (early late Barstovian) in the Fort Polk region in the western portion of the state. One turtle is fairly complete and referred to the extant taxon Macrochelys temminckii, the earliest occurrence of which is the Hemingfordian of Nebraska, based on comparisons with a modern carapace specimen. Much of the outside section of the carapace, along with the caudal vertebrae, pelvic elements, and hindlimb bones were found in situ. Three of the four feet are present and nearly complete, with a few of the claws and smaller limb bones found in associated sediments through screen washing. The second individual is tentatively identified as a sea turtle in the genus Caretta, and is known only from large fragments of carapace, a single partial limb, and a variety of associated fragments. The estimated width of the complete carapace is approximately 76 cm, based on one of the larger fragments.
EXTINCT GIANT MUD CREEPERS (MOLLUSCA: GASTROPODA) FROM THE OLIGOCENE OF THE SOUTHEASTERN UNITED STATES

Kittle, B. Alex, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Portell, Roger W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

A group of unusual gastropods has been reported from lower Oligocene deposits in southern Georgia and northern and central Florida. The first members of this group were recognized by Dall and described from siliceous, coral-rich boulders along the Flint River near Bainbridge, Georgia. Mansfield later recognized a species group, similar to the Georgia specimens, in limestone quarries near Brooksville, Hernando County, Florida and from Blackwater Creek, Hillsborough County, Florida. To date the group has only been recognized in deposits currently assigned to the Suwannee Limestone and the Bridgeboro Limestone (formerly Flint River Formation). They are conspicuously absent from other Gulf coast Oligocene deposits of similar age (i.e., Glendon Limestone, Marianna Limestone, Byram Formation). The specimens represent a group of large, turreted shells that resemble mud creepers and for that reason have been placed in several different genera, including *Cerithium*, *Telescopium*, and *Campanile*. In hopes of resolving the taxonomic issues associated with this unique group of Oligocene mud creepers, which includes “*Cerithium* halense Dall, 1916, “C.” vaughani Dall, 1916, “C.” hernandoense Mansfield, 1937, and “C.” hernandoense blackwaterense Mansfield, 1937, a review with revised descriptions, current geographic distributions, and modes of preservation is presented.

OSTEOGLOSSOMORPH PHYLOGENY REVISITED: ASSESSING THE RELATIONSHIPS OF THE FOSSIL FORMS *LAELIICHTHYSES* AND *HETEROSTEGLOSSUM* (TELEOSTEI: OSTEOGLOSSOMORPHA)

Leal, Maria E.C., DZ-IBRAG, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brazil; Amaral, Cesar R.L., DZ-IBRAG, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brazil; Bonde, Niels, Inst. Geoscience, Ostervoldg. 10, 1350 Copenhagen K and Fur Museum, 7884 Fur, Denmark; Brito, Paulo, M., DZ-IBRAG, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

A cladistic analysis was conducted based on a morphological data matrix for 31 taxa and 86 characters modified from previous studies for reassessment of osteoglossomorph relationships. New taxon data includes the recently redescribed *Laeliichthys ancestralis* Santos 1985 from the Cretaceous (Aptian) Areado Formation, Sanfranciscana Basin, Southeastern Brazil, and *Heterosteoglossum foreyi* Bonde 2008 from the Early Eocene marine deposits of the Fur and Ølst Formations, North Jutland, Denmark. The analysis produced equally parsimonious trees to which strict consensus were applied. Both the number of trees recovered and their topology showed variation according to the inclusion or exclusion of different fossil taxa. As a result, *Laeliichthys* was recovered as a stem osteoglossomorph, as a stem Osteoglossidae, or as the stem group to the Notopteridae plus Mormyroidei (= Mormyriformes), depending on which fossils were considered. Likewise the marine *Heterosteoglossum* was recovered either as an Osteoglossinae or as the stem group to the Osteoglossidae (s. l. = osteoglossins plus arapaimins). We discuss the efficiency of such analyses in the light of the large number of missing data for several of the fossils and the specific selection of the characters in the matrix.
insectivores thought to belong to Eulipotyphla were added to an existing matrix previously used to test early eutherian relationships, totaling 89 taxa with 415 dental, cranial, and postcranial characters. Using maximum parsimony and forced constraints on extant placental relationships, 85,320 most parsimonious trees were found. In the strict consensus, Nycitheriidae were found to be in a monophyletic group with extant and fossil eulipotyphlans. This does not support the hypothesis based on postcranial morphology that nycitheriids are stem euarchontans and instead indicates that the climbing capabilities of nycitheriids were acquired through convergence.

Session 7-Poster 6: Saturday, 4:45 PM
Presenter: Sarah Sheffield

A REVISION OF THE SYSTEMATICS OF THE GENUS SINOCRINUS (CRINOIDEA)

Sheffield, Sarah L., Department of Earth and Planetary Sciences, University of Tennessee at Knoxville, Knoxville, TN 37996; Sumrall, Colin D., Department of Earth and Planetary Sciences, University of Tennessee at Knoxville, Knoxville, TN 37996

Cladid crinoids have among the highest disarticulation rates of all Paleozoic crinoids; the Atokan Stage within the Early Pennsylvanian has an exceptionally poor cladid fossil record, so systematic studies have been hindered by a lack of specimen availability. Specimens of the genus Sinocrinus from numerous museum collections have been studied in order to determine the intraspecific variation and systematics of the genus and how this variation compares with other genera within the Family Erisocrinidae. The exclusively Atokan-age Sinocrinus Tien 1926 was named from the Taiyuan Series of Northern China from a well-preserved cladid-dominated fauna. The majority of species in the genus have been described from the Taiyuan Series of China, with two exceptions described from localities in Texas and Spain. Sinocrinus differs from the other erisocrinid genera (Erisocrinus Meek and Worthen 1865 and Exaetocrinus Strimple and Watkins 1969), primarily based on its rounded, bowl-shaped cup, impressed sutures, and tumid nature of the plates of the cup. The systematics of the genus Erisocrinus has been recently revised, and a more strict diagnosis has been applied to the genus. This revision has resulted in a number of species named within Erisocrinus being reassigned to the genus Sinocrinus. This systematic study of Sinocrinus evaluates the seven species currently named within the genus by measuring the amount of intraspecific variation between named species, determined by both the analysis of the original species descriptions, the relative size and the scale of persistence of a named morphospecies, both stratigraphically and geographically, remain poorly known, preventing us from a clear understanding of how morphologic and ecologic novelties have arisen in this group and their significance for phylogenetic reconstruction. In this study, to separate morphologic changes due to geographic variation from those controlled by changes that occurred isochronously in geographically distant populations of the lineage, two morphometric methods, outline analysis and landmark morphometrics, are applied to describe the chamber shape and spiral growth of the planktonic foraminiferal test. The nature of the morphologic distribution of this Early Paleocene muricate plexus therefore is compared from world oceans, particularly between high and low latitudes. In light of this morphometric analysis, the position of named species in the morphospace investigated and the

inclusiveness, the temporal span of the genus now extends from the Early Pennsylvanian through the Early Permian. This study also widens the current geographic range of Sinocrinus, with specimens having been found across a wider span of the Eurasian continent.

Session 7-Poster 7: Saturday, 4:45 PM
Presenter: Weimin Si

EARLY PALEOCENE ORIGIN, PHYLGENY AND GEOGRAPHIC DISTRIBUTION OF MURICATE PLANKTONIC FORAMINIFERA

Si, Weimin, Earth and Planetary Sciences, Rutgers University, 610 Taylor Road, Wright-Riemann Laboratories, Piscataway, NJ 08854; Berggren, William A., Earth and Planetary Sciences, Rutgers University, 610 Taylor Road, Wright-Riemann Laboratories. Piscataway, NJ 08854

Early Paleocene oceans witnessed the first wave of rapid diversification of planktonic foraminifera in the aftermath of the Cretaceous/Paleogene mass extinction. Characterized by morphologic evolutionary novelties including murica covering the test and photosymbiotic relationship with algae, a taxonomically important group including Acarinina, Morozovella and Igorina diversified around Biochron P2 (61.2–60.0 Ma). The first representatives of these three genera, Ac. strabocella, M. praeangulata and I. pusilla, respectively, as well as their proposed lineal ancestors, Praemurica inconstans or Praemurica uncinata, form a morphologically similar and probably continuously distributed morpho-complex, herein called the early muricate plexus. Earlier paleogeographic investigations postulated a high latitude origin for the acarininds (strabocella) and subsequent ecologic diversification into low latitude habitats. However, this is difficult to reconcile with the fact that other root forms of the muricate plexus are exclusively low latitude dwellers. An alternative hypothesis views these morphologically similar populations as having evolved from Pr. inconstans in the following manner: 1) Pr. uncinata , Pr. spiralis , Ac. strabocella; 2) Pr. uncinata , I. pusilla; 3) Pr. uncinata , M. praangulata . M. angulata. Although a significant effort has been devoted to qualitatively evaluate the origin, phylogenetic relationships, as well as the evolutionary (anagenetic) trend of this muricate plexus, few works have focused on a quantitative study of the nature of morphologic variation in this group and its relationship with current taxonomy. The magnitude of morphologic variability and the scale of persistence of a named morphospecies, both stratigraphically and geographically, remain poorly known, preventing us from a clear understanding of how morphologic and ecologic novelties have arisen in this group and their significance for phylogenic reconstruction. In this study, to separate morphologic changes due to geographic variation from those controlled by changes that occurred isochronously in geographically distant populations of the lineage, two morphometric methods, outline analysis and landmark morphometrics, are applied to describe the chamber shape and spiral growth of the planktonic foraminiferal test. The nature of the morphologic distribution of this Early Paleocene muricate plexus therefore is compared from world oceans, particularly between high and low latitudes. In light of this morphometric analysis, the position of named species in the morphospace investigated and the
current phylogetic scenario(s) are examined.

Session 7-Poster 8: Saturday, 4:45 PM
Presenter: James Westgate

PRIMATE DIVERSITY AND ASSOCIATED MAMMALS IN A MICRO-MAMMAL FAUNA FROM THE UINTA C MEMBER OF THE UINTA FORMATION: EVIDENCE OF LATE MIDDLE EOCENE LOCAL CLIMATE STABILITY

Westgate, James, Earth and Space Sciences, Lamar University, Beaumont, TX 77710; Cope, Dana, Sociology and Anthropology, College of Charleston, Charleston, SC 29424; Townsend, Beth, Department of Anatomy, Midwestern University, Glendale, AZ 85308

Primate, associated mammal and reptile remains recovered from the WU-26 locality in the upper part of the late middle Eocene Uinta C member of the Uinta Formation in Uintah County, Utah indicate there may have been little climatic change during deposition of the Uinta B and C members of the Uinta Formation. Previous workers have reported that the omomyid primate Myotinius hopsoni was locally the sole living primate during deposition of Uinta C and concluded that the loss in primate diversity in the transition from Uinta B to C time was the result of major climatic change. We have recovered the following Omomiyid primates from the WU-26 quarry: Myotinius hopsoni, Omomys cf. O. carteri, a smaller Omomys sp., and cf. Trogolemur sp. This primate community having at least four species suggests there was no major climatic event during the Uinta B/C transition. Previous lack of recognition of the primate diversity during Uinta C time appears to be the result of the lack of micro-mammal fossil localities. This may be due in part to the change in depositional regimes and the transition from the Uinta B to the Uinta C Member of the Uinta Formation. At least 21 other mammalian species are associated with the WU-26 primates. Specimens primarily come from the micro-rodents Janius rhinophilus, Pauromyx sp., Pareumys sp. and Microparamys sp. Reptiles include the carettochelyid turtle Psuedanosteira pulcura, “Allognathosuchus” sp., and other crocodilians. Modern carettochelyids are restricted to the island tropics of the southwestern Pacific Ocean, while modern crocodilians range no farther poleward than the subtropics. The presence of these reptilian species suggests that the Uinta Basin was subtropical or warmer throughout deposition of the Uinta Formation.

Session 7-Poster 9: Saturday, 4:45 PM
Presenter: Emily D. Woodruff

SUPERTREE PERSPECTIVES ON THE PHYLOGENY OF FOSSIL AND EXTANT MAMMALS

Woodruff, Emily D., Department of Biology, University of Florida, Gainesville, FL 32611; Burleigh, J. Gordon, Department of Biology, University of Florida, Gainesville, FL 32611; Bloch, Jonathan L., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Large-scale phylogenetic studies have elucidated the relationships of extant mammals but the evolutionary placement of many fossil taxa within these trees is less clear. Combining extant and fossil taxa is particularly challenging given the difficulty of analyzing molecular and morphological data simultaneously. Additionally, phylogenetic studies that focus on fossil mammals are generally limited in taxonomic scope. Supertree methods provide one approach to combining disparate data from partially overlapping taxa into a single comprehensive phylogenetic hypothesis. Given the extensive number of previous studies of relationships among mammal taxa, it is now possible to infer the evolutionary relationships of all major clades of fossil and extant mammals using supertree methods. We investigate the evolutionary relationships of 580 representative taxa from all major mammalian clades including fossil and extant mammals using the matrix representation with parsimony (MRP) and the Robinson-Foulds (RF) supertree methods. MRP is the most widely used supertree method, but RF is a new method that directly seeks the supertree that includes the most clades found in the input trees. We compare the performance of MRP and RF methods and assess criteria for selecting source trees, re-analysis of source trees, and taxon overlap between different data sets. The supertrees are well resolved and successfully recovered the major mammalian clades Afrotheria, Euarchontoglires, Laurasiatheria, and Xenarthra. The position of fossil taxa within these clades is generally congruent with the source phylogenies. The supertrees presented here reveal a framework with which many other evolutionary questions may be addressed, in particular, documenting large-scale patterns of morphological change.

Session No. 8: Biostratigraphy, paleoecology, taphonomy, and extinction (poster session)
Saturday Afternoon, 4:45 PM to 5:45 PM

Session 8-Poster 10: Saturday, 4:45 PM
Presenter: William Brightly

OLFACTORY RATIO AS A POTENTIAL PROXY FOR BEHAVIOR IN THEROPODA

Brightly, William H., Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187; Lockwood, Rowan, Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187

Olfactory ratio is a measure of the relative size of the olfactory bulb to its corresponding cerebral hemisphere. This metric is frequently used as a proxy for the olfactory acuity in extant Aves and, because it can be reconstructed from the fossil record, it can be applied to non-avian theropods as well. Extant avian taxa show a remarkable diversity in olfactory lobe size and morphology; however, the significance of this diversity is unclear. Previous authors have correlated olfactory ratio with various ecological traits; however, all of these, except for event timing (parts of the day/night cycle during which individuals are active) have
been shown to be non-significant once body size is accounted for. For this study, mating system, pair bond length, and event timing were all investigated as potential predictor variables of olfactory ratio in extant birds. If these ecological variables are shown to be significant predictor variables in extant Aves, then olfactory ratio may prove useful for reconstructing behavior in extinct, non-avian theropods. A data set of 123 extant avian species, representing 66 families, was compiled from the literature, including data on olfactory ratio, body mass, mating system, pair bond length, and event timing. Mating system was categorized as polyandrous, monogamous, mostly monogamous (5%–15% polygyny), polygynous, cooperative, or promiscuous. Pair bonds were classified as either long-term (two or more consecutive breeding seasons) or short-term. Finally, species were classified as either diurnal or low light active (nocturnal or crepuscular at any point in their life history). Two phylogenetic trees compiled from the literature were used to control for the confounding variable of phylogenetic relatedness. Preliminary results using a linear model suggest that both pair-bond length and event timing are positively correlated with olfactory ratio when body mass is controlled for. However, preliminary analysis using a phylogenetic generalized least-squares approach suggests that neither of these variables is significantly correlated with olfactory ratio once phylogeny is taken into account. These results suggest that previously described correlations between olfactory ratio and ecological traits may have been the results of phylogenetic artifact.

Session 8-Poster 11: Saturday, 4:45 PM
Presenter: David Campbell

DATABASE POTENTIAL AND PITFALLS

Campbell, David C., Department of Natural Sciences, Gardner-Webb University, Boiling Springs, NC 28017

Rapid improvements in data processing and storage have enabled the creation of massive, collaborative, online databases. Several projects have created biological and paleontological databases, designed to make data readily accessible and analyzable. However, many projects have emphasized generation of a computing framework to the neglect of data quality and management. Databases are only as good as the data they contain, in addition to the need for appropriate data structures and management. One area of concern is the accuracy of the data. How can databases ensure correct usage of names? For example, organism names must be checked for problems such as Latin agreement, homonyms, and typographical errors. Names likely to give problems need to be flagged, such as wastebasket names, errors in commonly used references, or widely used but outdated classifications. Are the organisms commonly misidentified? Are there geographic, habitat, or temporal limits, for which extralimital reports should be suspect? All of these require review of the data by appropriate experts. Ironically, the large amounts of low-quality data in many databases mean that only experts can make good use of them because only they can judge what is reliable. However, the databases also facilitate access by users who don’t realize the limits of the data. Currently, databases publicize how many records they have; adding a metric of how well checked the records are could lead to better quality. Qualified data review is essential to produce a reliable data set, yet often the task is completely unfunded. Data compilation and entry is commonly left to volunteers or beginning students who won’t recognize existing errors and who are more likely to make new ones through unfamiliarity with the material. Another consideration is data access. Is the data access sufficiently flexible to allow a wide range of specialized uses? How much can the user customize the access to match the need? Keeping data up to date has difficulties. How are new citations tracked, especially if data are submitted before publication? Is the latest publication actually the most up to date in content? How can problems be identified? How are corrections received and transmitted between linked databases? Addressing these requires appropriate participation by workers in the relevant fields. What barriers to participation exist, and what might help address them?

Session 8-Poster 12: Saturday, 4:45 PM
Presenter: Tobias Grun

DRILLING PREDATION ON UPPER OLIGOCENE ECHINOIDS (ECHINOCYAMUS) FROM NORTHERN GERMANY

Grun, Tobias, Department of Geosciences, University of Tübingen, Sigwartstraße 10, D-72076, Tübingen, Germany; Nehlsick, James H., Department of Geosciences, University of Tübingen, Sigwartstraße 10, D-72076, Tübingen, Germany

Recent echinoids are known to be commonly hunted by numerous predators, including cassid gastropods, which produce drillholes. Numerous tests of the minute clypeasteroid echinoid Echinocyamus from the late Oligocene of Northern Germany have been studied with respect to morphology, size parameters, and drill holes. The echinoid tests originate from two different localities (Doberg and Astrup, both in North Rhine-Westphalia, Germany) and are generally well preserved, allowing the analysis of test size, drilling frequencies, and possible site- and size-selectivity of prey. The results from these localities are compared to each other as well as to similar studies on both recent (Red Sea, Mediterranean) and fossil Echinocyamus populations. Test length and width are highly correlated for both localities. Interpreted predation rates are roughly similar at both localities, although drillhole sizes differ. Predation rates are also compared between distinct size classes. The shape of the drillholes is highly influenced by the morphology of the echinoid skeleton (plate distribution, ambulacral pores, and spine tubercles), but is generally rounded in shape. The distribution of drillholes shows a high selectivity of the predator for the aboral side of the test, and the petalodium. In contrast, no preference for drillholes in the anterior or posterior parts of the echinoids was found. The drillholes are interpreted to originate from cassid snail predation, which is known to produce similar holes in recent echinoids.

Session 8-Poster 13: Saturday, 4:45 PM
Presenter: Claudia C. Johnson

BIVALVE MOLLUSK ASSEMBLAGE OF BED III,
OLDUVAI GORGE, TANZANIA

Johnson, Claudia C., Department of Geological Sciences, Indiana University, Bloomington, IN, 47405; Njau, Jackson K., Department of Geological Sciences, Indiana University, Bloomington, IN, 47405; Kauffman, Christopher E., Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, Australia; Kauffman, Erle G., Department of Geological Sciences, Indiana University, Bloomington, IN, 47405; Toth, Nicholas P., Department of Anthropology and Stone Age Institute, Indiana University, Bloomington, IN, 47405; Schick, Kathy, Department of Anthropology and Stone Age Institute, Indiana University, Bloomington, IN, 47405; Kearney, John, Department of Geological Sciences, Indiana University, Bloomington, IN, 47405

Olduvai Gorge is a rich paleoanthropological site documenting the evolution of stone tool-using hominins over the last two million years. The Olduvai Gorge site, located on the western flanks of the Gregory Rift in northern Tanzania, produced a wealth of paleoecological information due to the excellent preservation of fossils within a well-dated sedimentary context. Despite a rich history of paleoanthropological and archaeological studies throughout Olduvai Gorge, mollusk identifications and interpretations within a paleoecological context have been absent. Here we report bivalve mollusks that were localized within Bed III conglomerate channel deposits, well above the famous Chert Factory Site. The small channels that yielded the bivalves vary in thickness from centimeter- to decimeter-scale, and consist of gray conglomerates with fining-upward sequences. Channels are overlain by red, fine-grained conglomerates and sandstones on a recessive slope. Both fragmented and whole specimens of bivalves define a relatively small population. In total, thirteen equivalved, inequilateral, bivalved specimens and a number of single valves are represented in the collection. An average of whole valve lengths of 91.2 mm compares favorably with the greater than 100 mm size range of Chambardia. The fossils contain well-defined growth lines with a progression of strong inflation of ornamentation on the anterior end to weak inflation of ornamentation on the posterior. These specimens, along with numerous fragments, show edentulous hinge plates including a ligamental pit and posterior, sharply triangular sinus. In conjunction with a weak beak, not very pronounced or inflated, the morphology of these bivalves is consistent with Chambardia aff. C. wahlbergi. The large size of bivalved specimens and the matrix lithology suggest the bivalves were living in stream channels near their site of final deposition, whereas fragments and smaller shell pieces indicate transport and breakage. Distance to lake margins is as yet unknown. A thin layer of gray matrix cemented to the outside of all specimens, and inside of some, may represent an ash fall that adhered rounded to sub-rounded lithics to the shells. As Chambardia is one of the most widespread genera in modern Africa found in riverine environments stretching across the continent, further comparisons with Olduvai fossils may yield an important paleoecological assessment. Our present goal is to present a typological species comparison in this first detailed account of bivalve mollusks from Olduvai Gorge, with the further goal of reconstructing a high-resolution paleoenvironmental setting of Bed III (1 myr) and adaptation of Homo erectus in the Olduvai basin.

Session 8-Poster 14: Saturday, 4:45 PM
Presenter: Steven Porson
PARAPHyleTIC VERSUS NON-PARAPHyleTIC FAMILIES: IMPLICATIONS FOR PHYLOGENETIC SYSTEMATICS OF THE BIVALVIA (MOLLUSCA)

Porson, Steven, Geological Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599; Coachman Ct, Harrisburg, NC, 28075; Wesolowski, Catherine, Geological Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599 Carter, Joseph G., D Geological Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599

Although previous studies have analyzed Phanerozoic family-level bivalve diversity, none have addressed potential differences in diversity dynamics between paraphyletic and non-paraphyletic families. The paraphasic classification of the Bivalvia recently proposed for the Treatise on Invertebrate Paleontology provides an opportunity to make such comparisons. Based on standing diversity, paraphyletic families increased sharply from the Early Ordovician through Early Devonian, remained nearly stable during the Carboniferous and Permian, decreased sharply (30% extinction) at the Permian–Triassic boundary, rebounded to Carboniferous Permian levels by the beginning of the Late Triassic, further increased during the Late Triassic, remained more or less stable for the remainder of the Mesozoic, then declined sharply and permanently at the Cretaceous–Paleogene boundary (18% extinction). Non-paraphyletic families increased sharply during the early Ordovician, remained nearly stable throughout the remainder of the Paleozoic, decreased sharply (48% extinction) at the Permian–Triassic boundary, increased sharply during the Lower and Middle Triassic, increased gradually during the Jurassic and Early Cretaceous, declined sharply at the Cretaceous–Paleogene boundary (25% extinction), increased to just below Late Cretaceous levels during the lower Eocene, then increased to essentially modern levels (except for the Holocene 'pull of the Recent') by the early Miocene. Paraphyletic families reached their highest diversity in the late Jurassic, followed by general decline until the Paleocene, after which their standing diversity has remained essentially the same. This long episode of declining diversity of paraphyletic families indicates that new post-Jurassic families were derived from a declining number of paraphyletic families. An opposite trend is seen in the early Paleozoic, when new families were derived from an increasing number of paraphyletic families. Furthermore, the ratio of paraphyletic/non-paraphyletic families was very high from Silurian through Middle Triassic, decreased sharply after the Middle Triassic, then gradually decreased to the modern level, which is still characterized by a high proportion of paraphyletic families. This has implications for a potential phylogenetic (cladistic) classification of the entire Bivalvia, as well as extant-only Bivalvia, because such classifications do not permit paraphyletic groups.

Session 8-Poster 15: Saturday, 4:45 PM
Presenter: Elizabeth A. Reinthal
PATHOLOGY, TAPHONOMY, ENCRUSTATION, AND BIOEROSION OF AN ABUNDANT CRINOID IN THE
MIDDLE JURASSIC OF SOUTHERN ISRAEL

Reinthal, Elizabeth A., Geology, The College of Wooster, Wooster, OH 44691; Bosch, Stephanie, Geology, The College of Wooster, Wooster, OH 44691; Wilson, Mark A., Geology, The College of Wooster, Wooster, OH, 44691; Feldman, Howard R., Division of Paleontology (Invertebrates), American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024

Fragments of the articulate crinoid Apiocrinites negevensis are among the most common fossils in the Matmor Formation (Middle Jurassic) exposed in the Negev of southern Israel. This robust crinoid was a pioneer colonist in shallow-marine waters. During life, they were often infected with what appear to have been parasites that produced gall-like swellings in their columns. After death, they provided skeletal debris that served as ‘benthic islands’ for a diverse sclerobiont fauna in a classic example of taphonomic feedback and facilitated ecological succession. This paleoecosystem is of special significance because tropical marine communities from the Middle Jurassic are inadequately known. A large collection of crinoid fragments was collected from exposures of the Matmor Formation in Hamakhtesh Hagadol, southern Israel. For stratigraphic and paleoenvironmental consistency, only those fossils from the informal ‘subunit 51,’ a calcareous marl, were studied here. This subunit is in the Quenstedtoceras (Lamberticeras) lamberti Zone of the Upper Callovian. These sediments were deposited very close to the paleoequator in the Ethiopian Province of the Tethyan Faunal Realm. Other fossils in the subunit include rhynchonellid and terebratulid brachiopods, rhabdocidarid echinoids, scleractinian corals, calcisponges, gastropods, bivalves, nautiloids, and ammonites. Many of the crinoid pluricolumnals have swellings that indicate some type of infection during life. These gall-like protuberances often have shallow pits associated with them. This could mean that the crinoid either had a tissue growth reaction to an organism boring into its stem, or it had the reaction to an endoparasite that eventually bored its way out. This is an organism boring into its stem, or it had the reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an organism boring into its stem, or it had the reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bored its way out. This could mean that the crinoid either had a tissue growth reaction to an endoparasite that eventually bore...
THE ROLE OF VERY-ABUNDANT TAXA IN OVERPRINTING ECOLOGICAL SIGNALS IN FOSSIL ASSEMBLAGES

Slattery, Joshua S., School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620; Mondal, Subhransu, School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620; Harries, Peter J., School of Geosciences, University of South Florida, 4202 East Fowler Ave., NES 107, Tampa, FL 33620.

The relative abundances of different taxa have been used to infer ecological gradients in a range of both modern and ancient settings using a variety of multivariate statistical techniques, such as cluster analysis, non-metric multidimensional scaling (NMDS), and detrended correspondence analysis (DCA). The inferred ecological gradients derived from these statistical techniques are typically controlled by the relative abundances of different taxa within each respective assemblage, as abundances of taxa usually track environmental and ecological conditions. In the majority of ecological analyses, the most common or abundant taxa modulate the patterns produced by these various statistical techniques. The role of less abundant taxa in controlling these patterns is not well understood and necessitates further study. To examine this question, we examined how very-abundant genera (i.e., >25% abundance in pooled samples) control ecological signals from different fossil samples using both cluster analysis and DCA. Our data were derived from bulk samples collected from five separate shell-rich horizons separated by unconformities in the Pleistocene Bermont Formation exposed in the Longan Lakes Quarry, FL. Samples from this locality are characterized by diverse, mollusk-rich fossil assemblages with an abundance of the bivalve Chione (Mühlfeld, 1811) and/or the gastropod Cerithium (Born, 1778), which together typically represent >50% of the fauna. We compared cluster diagrams and DCA plots that utilized datasets that both included and excluded Chione and Cerithium abundance data. The DCA plots show distinct patterns before and after the exclusion of Chione and Cerithium. Prior to elimination of these genera, most taxa on the DCA plot show an interpretable cluster isolated from Chione and Cerithium. When they are removed, an ecologically interpretable ‘boomerang’ pattern for samples and taxa becomes visible in the plot. In the cluster analysis, the five samples show a distinct clustering pattern before and after the removal of Chione and Cerithium. When the most common taxa are removed from the dataset used for the cluster analysis, the faunal similarities and differences become more apparent and appear to correspond to depth related changes that are also apparent in the lithostratigraphy of the Longan Lakes section. These scenarios reveal how the overall ecological and environmental pattern can be overprinted by the most abundant components of a fossil assemblage.

Session 8-Poster 19: Saturday, 4:45 PM
Presenter: Theodorou Georgios

THE DEVELOPMENT OF ALLOMETRIC EQUATIONS FOR ESTIMATING THE DIMENSIONS OF THE ELEPHAS TILIENSIS SKELETAL ELEMENTS

Mitsopoulos, Vasiliki E., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Isidorou, Stelios K., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Vasilopoulos, Theodoros K., National Technical University of Athens, School of Mechanical Engineering, Mechanical Design and Control Systems Section, Zografou Campus, PO 15780, Athens, Greece; Theodorou, Evangelos G., National Technical University of Athens, School of Mechanical Engineering, Mechanical Design and Control Systems Section, Zografou Campus, PO 15780, Athens, Greece; Michailidis, Dimitrios G., National Technical University of Athens, School of Mechanical Engineering, Mechanical Design and Control Systems Section, Zografou Campus, PO 15780, Athens, Greece; Roussakis, Socrates J., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Roussakis, Socrates J., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Roussakis, Socrates J., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece.

Excavations in Charkadio cave at Tilos Island have been held...
for more than thirty years. Through 2012, excavations have unearthed more than 15,000 fossil bones of *Elephas tiliensis*. Our aim is to reconstruct a life-size model, according to the auspices of THALIS MSJ380135, based on morphology, biometry, and rapid prototyping technologies such as CT and laser scanner. The first biometrical and morphological results of the study of *E. tiliensis* suggested sexual dimorphism in adult individuals. This study evaluates how different measurements of individual skeletal elements are correlated to each other. The relative value of different measurements was evaluated and only highly correlated measurements have been included in our analysis. Statistical analysis methods and multivariate allometry have been utilized in order to create mathematical equations representing the correlation of different skeletal elements. The aforementioned equations have been estimated by using either the formula of simple allometry or the curve estimation produced by the calculation of the best-fit line describing the data. This procedure contributed to the estimation of missing measurements due to fragmentary material or specimens of different ontogenetic stage. The optimal selection for the current research has been made so as to minimize the errors between the observed values and the estimated values derived from the allometric patterns.

Session 8-Poster 20: Saturday, 4:45 PM
Presenter: Louis G. Zachos

**UPPER MISSISSIPPIAN (CHESTERIAN) ECHINODS FROM ALABAMA AND MISSISSIPPI**

Zachos, Louis G., Geology and Geological Engineering, University of Mississippi, University, MS 38677

Upper Mississippian (Chesterian) sedimentary rocks in the Pride Mountain Formation Hartsele Sandstone and Bangor Formation (in ascending order) are well-exposed in quarries, road cuts, and natural outcrops in portions of Colbert County, northwest Alabama, and Tishomingo County, northeast Mississippi. Echinoid remains, consisting of scattered to isolated plates, spines, and lanterns, are common although not abundant. Disarticulated palaeochinid remains (tentatively identified as *Melonechinus* sp.) are found in lowermost Pride Mountain Fm. sandy limestone associated with a diverse megafauna of well-preserved rugose corals, brachiopods, crinoids, and blastoids (*Pentremites* sp.). The sedimentary setting is interpreted as a shallowing-upward, nearshore shelf environment. Scattered plates and spines of archaeocidarid echinoids (tentatively identified as *Lepidocidaris* sp.) are found in thin storm-lag deposits rich in blastozoan debris and bryozoans in what is interpreted as a distal ramp environment of the Bangor Formation. Paleozoic echinoids are notoriously ill-preserved in general, but their association with other echinoderms remains permits direct comparison of taphonomic histories and paleoecologic interpretation.

**Session 8-Poster 21: Saturday, 4:45 PM**
Presenter: Kathryn Estes-Smargiassi

**A STRING OF SMALL KNOBS FROM THE UPPER TRIASSIC SHALES OF WESTERN EUROPE**

Estes-Smargiassi, Kathryn A., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Klompmaker, Adiël A., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

A string of small knobs was collected from the dark-colored Late Triassic (mid-Rhaetian) shales of the Eastern Netherlands, deposited in a near-coastal environment. The specimen was found in Quarry IV of the Winterswijk quarry complex, 180–200 cm below the Rhaetian-Oligocene contact. These Dutch Rhaetian shales are a part of the Sleek Formation, which is the lowermost unit of the Altana Group. The shales in this quarry contain bivalves (eight species, 689 specimens), ophiuroids (at least twenty individuals from a single species), and fish, as well as plant fossils including palynomorphs and one horsetail fragment, based on previous research. The specimen consists of a string of small knobs about 20 mm in length and 3.5 mm in width, with each knob of about 0.5 mm in diameter. The width of the string is not consistent throughout and the string is oriented parallel to the bedding plane. The knobs are present on both the top and the bottom of the string. This research will discuss possible hypotheses as to what this string of knobs may represent, including a string of eggs, larvae, or a fossil burrow.

**Session 9: New advances and applications in sclerochronology (poster session)**

Saturday Afternoon, 4:45 PM to 5:45 PM

**Session 9-Poster 22: Saturday, 4:45 PM**
Presenter: Justin McNabb

**ESTABLISHING THE LIFESPAN OF THE PLIOCENE BIVALVE ASTARTE CONCENTRICA USING SCLEROCHRONOLOGIC ANALYSIS**

McNabb, Justin J., Geological Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599; Surge, Donna, Geological Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599

The extant genus *Astarte* exhibits decreasing size through geologic time. It is an ideal candidate for studying changes in longevity through time because of its wide temporal and spatial distribution, ranging back to the Oligocene and today extending from the Arctic to the Caribbean. Our overall goal is to determine whether the observed change in size is accompanied with a change in longevity. To achieve this goal, we first established a methodology to identify annual increments in shell growth and estimate age using Pliocene shells from the Mid-Atlantic Coastal Plain, USA. Annual growth increments were identified using sclerochronologic analysis and ontogenetic changes were evaluated using von Bertalanffy growth equations. Previous studies have shown that modern species of *Astarte* live for about 20 years. Future work will determine if growth rates and longevity are similar throughout the genus, and whether changes in climate and/or water depth play a role in shell growth and longevity.
Session 9-Poster 23: Saturday, 4:45 PM
Presenter: Donna Surge

MARINE CLIMATE ARCHIVES ACROSS THE MEDIEVAL CLIMATE ANOMALY-LITTLE ICE AGE TRANSITION FROM VIKING AND MEDIEVAL AGE SHELLS, ORKNEY, SCOTLAND

Surge, Donna, Geological Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599; Barrett, James H., McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, UK.

Proxy records reconstructing marine climatic conditions across the transition between the Medieval Climate Anomaly (MCA; ~900–1350 AD) and Little Ice Age (LIA; ~1350–1850 AD) are strongly biased towards decadal to annual resolution and summer/growing seasons. Here we present new archives of seasonal variability in North Atlantic sea surface temperature (SST) from shells of the European limpet, Patella vulgata, which accumulated in Viking and medieval shell and fish middens at Quoygrew on Westray, Orkney. SST was reconstructed at submonthly resolution using oxygen isotope ratios preserved in shells from the 12th and mid-15th centuries (MCA and LIA, respectively). MCA shells recorded warmer summers and colder winters by ~2°C relative to the late 20th Century (1961–1990). Therefore, seasonality was higher during the MCA relative to the late 20th century. Without the benefit of seasonal resolution, SST averaged from shell time series would be weighted toward the fast-growing summer season, resulting in the conclusion that the early MCA was warmer than the late 20th century by ~1°C. This conclusion is broadly true for the summer season, but not true for the winter season. Higher seasonality and cooler winters during early medieval times may have resulted from a weakened North Atlantic Oscillation index. In contrast, the LIA shells show a more variable inter-annual pattern. Some years record cooler summers and winters relative to the MCA shells and late 20th century, whereas other years record warmer summers and cooler winters similar to the MCA shells. Our findings provide a new test for the accuracy of seasonal amplitudes resulting from paleoclimate model experiments.

Session 9-Poster 24: Saturday, 4:45 PM
Presenter: Lauren E. Graniero

USING NITROGEN ISOTOPES TO CHARACTERIZE NITRATE CYCLING IN COASTAL ENVIRONMENTS IN BOCAS DEL TORO ARCHIPELAGO, PANAMA

Graniero, Lauren E., Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; Grossman, Ethan L., Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; O’Dea, Aaron, Smithsonian Tropical Research Institute, Panama City, Panama; Rodriguez, Felix, Smithsonian Tropical Research Institute, Panama City, Panama.

Nitrogen isotope ratios ($^{15}$N/$^{14}$N) as recorded in tissues and shells of modern bivalves have the potential to serve as a proxy for natural and anthropogenic nitrate fluxes in coastal environments. Nitrogen isotope ratios vary in coastal environments as a result of local productivity and nitrate source. Local productivity affects how much nitrate is consumed versus how much remains in the water column in a specific environment. Coastal sources of nitrate vary widely and include marine nitrate, terrestrial nitrate, and anthropogenic nitrate from sewage and fertilizer. Carbon isotope ratios ($^{13}$C/$^{12}$C) can be used to derive the amount of terrestrial input into these ecosystems as well. In Chiriqui Lagoon, a restricted waterway influenced by freshwater input, nitrate concentrations tend to be high during the rainy season. In contrast, ocean-exposed environments such as Almirante Bay have significantly lower nitrate concentrations (D’Croz et al., 2005). Especially in the southeast Chiriqui Lagoon, rivers contribute a significant amount of nitrate to the coastal environment (D’Croz et al., 2005). Two common bivalve species, Isognomon alatus and Pinctada imbricata, were collected from eight sites in Bocas del Toro, Panama. Bodies were removed and analyzed for N isotopes, while shells were analyzed for C, O, and N isotopes. Preliminary data show that tissues from bivalves collected from sites closer to human development, such as the Smithsonian Tropical Research Institute facility, have higher $^{15}$N (4.2‰) and lower $^{13}$C (~18.3‰) values than sites more exposed to the open ocean, such as Escudo de Veraguas ($^{15}$N=3.1‰ and $^{13}$C=−16.3‰). Both the south Chiriqui Lagoon and Boca del Drago sites fall between these two end members with values of $^{15}$N=3.6‰ and $^{13}$C=−17.4‰ and $^{15}$N=3.9‰ and $^{13}$C=−18.0‰, respectively. Natural variation in $^{15}$N records found in sedimentary organic matter from cores in Almirante Bay range from ~0 to 3‰ (Hilbun, 2009), whereas anthropogenic impacts from sewage contamination introduces values that range from 10 to 20‰ (McClelland et al., 1997). Other studies suggest comparable pristine tropical environments have plant $^{15}$N values closer to 2–3‰ (Bowen and Valeila, 2008), equivalent to filter-feeder $^{15}$N values of 5–6‰ after accounting for trophic enrichment. Preliminary results suggest that none of these sites are significantly impacted by sewage input and that variation in N isotopes is more likely related to variations in productivity and source of nitrate between sites. Once these modern $^{15}$N values are well understood, this technique can be applied to other modern and past coastal environments to understand changes in nutrients in regions of the Caribbean and Pacific coasts after the closure of the Central American Isthmus.

Session 9-Poster 25: Saturday, 4:45 PM
Presenter: Aaron M. Martinez

TIME-AVERAGING IN CHESAPEAKE BAY MOLLUSKS: ESTIMATES BASED ON AMINO ACID RACEMIZATION OF HOLOCENE MULINIA

Martinez, Aaron M., Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187; Lockwood, Rowan, Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187.

Time-averaging is the mixing of non-contemporaneous organisms and sediment into a single deposit, resulting in a stratigraphic layer representing an extended period of time. Time-averaging directly limits the temporal resolution of the fossil record. If multiple generations of organisms that lived hundreds of years apart are preserved within the same
Session 9-Poster 26: Saturday, 4:45 PM
Presenter: Janet E. Burke

ASSESSING THE IMPACT OF TIME-AVERAGING ON A MIocene VERTEBRATE FAUNA FROM NORTHERN PAKISTAN

The Y311 locality is a highly fossiliferous Miocene vertebrate site in the Siwalik sequence of Pakistan. It has a magnetostratigraphic date of ~10 Ma and represents bone accumulation in ~5 meters of fluvial sediments deposited in a large-scale abandoned channel fill. Collections of over 4700 specimens by the Harvard-Geological Survey of Pakistan team include surface and excavated mammals, reptiles, birds, and fish. This collection and supporting contextual information were used to compare species diversity and taphonomic features in samples representing different depositional context and degrees of time-averaging. Two separate excavations, West-1+2 (346 specimens) and DS-4 (176 specimens), provide the highest available temporal resolution estimated at ~102–103 kyr each and were compared for taphonomic and taxonomic disparities. These excavated samples occur in different contexts within fluvial channel deposits, with DS-4 closer to the base of a channel complex and West 1+2 in the upper part of the same unit. The combined data from both excavations were then compared with the total Y311 sample, estimated to represent 104-105 kyr, to test for the impact of increased time-averaging on faunal diversity and ecological information. The two excavated samples do not differ significantly in body size distribution, mammal skeletal part representation, or faunal diversity, but there are significant differences in rounding, dissolution, weathering, and evidence of biological bone modification indicating greater fluvial processing in DS-4. The faunal remains in the excavations differ from the overall Y311 collection in body part representation and faunal diversity but not significantly in body size distribution. We also compared the overall Y311 fauna with analogue mammal communities in modern ecosystems to look for differences in community structure and gaps in the fossil record. The Y311 fauna has more large mammal taxa (>1 kg) than four modern sites and many fewer identified small mammals. The paucity of small mammals likely reflects taphonomic biases, but more species of large mammals is evidence for a real difference in community structure. In terms of the rank order distribution of mammal body sizes, the overall Y311 fauna is more similar to Kanhk Park in India, which has both open grasslands and woodlands, than to the closed-forest environments of southeast Asian national parks Gugung-Leuser, Kaziranga and Manas. Our findings indicate that even the shorter time-averaged excavation samples with variable taphonomic histories capture information on body-size distribution in the overall Y311 fauna, and the combined sample represents a paleocommunity with more large mammal species than present-day ecosystems in southeastern Asia.
The $\delta^{13}C$ of terrestrial C3-plant tissues has long been known to correlate with mean annual precipitation (MAP). Collagen and tooth enamel $\delta^{13}C$ values in herbivores have a known offset with respect to plant (diet) compositions, so carbon isotope measurements of fossils from C3 ecosystems can, in principle, recover MAP. Recent experiments, however, suggest that C3 plant $\delta^{13}C$ depends strongly on $p$CO$_2$ (the partial pressure of CO$_2$). If so, then a correction for past $p$CO$_2$ must be applied to fossil data before MAP can be determined or ecosystems interpreted from isotope data. This possibility was tested by: 1) re-regressing the global dataset of modern C3-plant $\delta^{13}C$ vs. MAP correcting for anthropogenic changes in $p$CO$_2$; and 2) recalculating MAP for fossil collagen and tooth enamel $\delta^{13}C$ based on the new, $p$CO$_2$-dependent calibration. In general, the revised equation implies corrections up to several per mil to $\delta^{13}C$ values, substantially reduces MAP during times with high $p$CO$_2$, and increases MAP during times with low $p$CO$_2$. Recalculated results contrast markedly with independent estimates of MAP and ecosystems. For example, the Last Glacial Maximum was generally dryer than today with open habitats. Whereas the original $p$CO$_2$-independent calibration returned average MAP $\sim$350 mm/yr (typical of semi-arid climates), the revised equation returns average MAP $\sim$2250 mm/yr (typical of rainforests). Conversely, generally wet and forested conditions are demonstrated for the mid-Miocene climatic optimum, late Paleocene and early Eocene. Whereas the original calibration returned an average MAP $\sim$1000 mm/yr, the revised equation returns $\sim$150 mm/yr (typical of desert scrubland). For the cool, high $p$CO$_2$ Oligocene, the revised equation returns negative MAP, implying higher corrected $\delta^{13}C$ values for C3 plants than are observed on Earth today. Few biases can explain the discrepancies between predictions of the revised calibration and geological observations. Diagenetic alteration of isotopes or dietary selection would have to somehow reduce $\delta^{13}C$ preferentially for fossils younger than $\sim$15 Ma and increase it for older fossils. This contrasts with repeated studies demonstrating isotopic resistance to diagenetic alteration and clear similarities in taphonomy, depositional environment and tooth chemistry throughout the Cenozoic. Dietary selection bias seems unlikely given conservative physiologies and similar feeding strategies among herbivorous groups. $p$CO$_2$ is either measured directly or multiple proxies return similar values. Rather, the fact that high vs. low $p$CO$_2$ calculations consistently give results that are too dry vs. too wet instead indicates that the $p$CO$_2$ correction itself is flawed and that one or more parameters remains uncontrolled within experiments.
region, most species are biased toward $C_3$ resources, and most are highly variable. Only one species so far exhibits a latitudinal gradient in $C_4$ consumption and only one has a diet dominated by $C_4$ resources. At the local scale, species that were live sampled at sites in NE Nebraska and SW Kansas exhibit variability like that observed at the regional scale. Despite the long-term increase in the abundance of $C_4$ grasses regionally, fossil rodents in Nebraska and Kansas both show patterns of variability like the modern regional and local datasets. Specialization and selective feeding by some species are likely confounding factors, and the relationship between rodent isotope ecology and local habitats may be more complicated than previously hoped.

Session 10-3: Sunday, 9:15 AM
Presenter: Sean Moran

PALEOECOLOGICAL INTERPRETATIONS OF THE EARLY MIocene EQUID, PARAHIPPUS LEONENSI S, FROM THE THOMAS FARM LOCALITY, GILCHRIST COUNTY, FLORIDA

Moran, Sean M., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

The Hemingfordian Thomas Farm locality in Gilchrist County, Florida, is one of the richest vertebrate fossil sites of the North American early Miocene. A large number of vertebrate fossils have been collected from Thomas Farm since the early 1930s, including three equid taxa. The most abundant of these, Parahippus leonensis, is often considered an incipient grazer in the browsing to grazing transition documented in Miocene horses. The high abundance of vertebrate fossils at Thomas Farm allows for a comprehensive, yet spatially constrained, study of paleoecology through carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) stable isotope analyses during a crucial period in equid evolution. Furthermore, the hypothesized rapid deposition of the site provides a temporally constrained window into terrestrial climatic conditions during the early Miocene in Florida, about 18 Ma. Enamel of approximately 50 lower molars of P. leonensis collected from the Thomas Farm site was sampled with a Foredom hand drill for carbon and oxygen isotopes. To ensure the preservation of ontogenic trends in the data, samples were taken from each of the three molar positions, which span the entire temporal range in enamel mineralization of the dentition, and from the apex and base of each tooth. The powdered enamel carbonate was treated overnight with $H_2O_2$ to remove organics, rinsed, and then treated with 0.1 M acetic acid to remove secondary carbonates. The samples were analyzed in the Department of Geological Sciences ICP-MS lab at the University of Florida for carbon and oxygen isotope values using the $H_2PO_4$ digestion method. The ratio of stable carbon isotopes is often employed as a dietary proxy in herbivorous mammals to evaluate the proportion of $C_3$ to $C_4$ vegetation incorporated into the organism’s diet and subsequently into the mineral structure of the enamel hydroxyapatite. Preliminary results of the $\delta^{13}C$ signal in P. leonensis show a distinct $C_3$ signal, interpreted to represent browsing, and a lower degree of dietary variation than was hypothesized based on previously analyzed samples, varying from $-13\%$ to $-9\%$ with a mean of $-11.0\%$ (vs. VPDB). Furthermore, an ontogenetic trend of increasing $\delta^{13}C$ values was observed based on samples from the various tooth positions. Stable oxygen isotope ratios have been shown to be an accurate proxy in the terrestrial realm for meteoric water intake by larger mammals. This signal is highly correlated with regional climate, specifically to temperature and amount of precipitation. Most of the variation in $\delta^{18}O$ occurs between 0% and 3%, with a mean of 1.1% (vs. VPDB). Results presented here illustrate a fairly equable, stable climate in Florida during the deposition of Thomas Farm. This data supports other studies that have shown P. leonensis did not exhibit seasonal birthing patterns.

Session 10-4: Sunday, 9:30 AM
Presenter: Julia Tejada

ECOLOGY OF MIocene AMAZONIAN MAMMALS BASED ON EVIDENCE FROM STABLE ISOTOPES

Tejada-Lara, Julia V., Department of Biology, University of Florida, Gainesville, FL 32611; MacFadden, Bruce J., Department of Geology, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Antoine, Pierre-Olivier, Institut de Sciences de l’Évolution, Place Eugène Bataillon, Université Montpellier 2, 34095 Montpellier, France; Flynn, John J., American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024; Salas-Gismondi, Rodolfo, Departamento de Paleontología de Vertebrados, Museo de Historia Natural-UNMSM, Av. Arenales 1256, Lima 14, Perú

Even though the Amazonian tropical rainforest is arguably the most important continental ecoregion on Earth, the origin and evolution of its great biodiversity is still poorly understood. The fossil record is crucial for deciphering the origin of environmental conditions that shaped Amazonia and the ecological patterns that existed before the establishment of its modern biota. But fossils from tropical South America (SA) are limited because of the paucity of known fossiliferous localities. In the specific case of Tertiary SA tropical mammals, ecological interpretations have been inferred from living-based ‘analogs’ or the relationship between macroniche structure and rainfall in modern tropical mammalian faunas. However, these interpretations might be rather inaccurate (and even inappropriate) if we consider the fact that most of SA Tertiary faunas lack of modern lineages or even extant ecological analogs. More reliable techniques have been performed (i.e., dental meso/microwear and stable isotopes), but they have been focused on faunas in the southern cone of the continent and/or Pleistocene material. Stable isotopes have additionally been restricted to enamel-bearing mammals, thus excluding an important component of SA mammalian assemblages, the xenarthrans. Here we present the results of isotopic analyses ($\delta^{13}C$, $\delta^{18}O$) of tooth enamel and orthodentine carbonate performed on three major clades of native herbivorous mammals (Astrapotheria, Toxodontia, and Phyllophaga) from the late middle Miocene of what is now the Peruvian Amazonia. Within Phyllophaga, members of Mylodontidae (Pseudopreotherium =Mylodontidae), Mylodontidae (e.g., Urumacotherium, cf. Nematherium), and “Hapalops-like forms” were analyzed. The study investigates canopy structure, niche partitioning, and seasonality following the Middle Miocene Climatic Optimum. Results obtained from both bulk and serial sampling indicate that: 1) the area was forested and bordered
on closed canopy; 2) there was resource partitioning among the groups; and 3) there is evidence of seasonal variation. Univariate statistics, ANOVA, and nonparametric Kruskal-Wallis tests indicate significant differences (p<0.05) in 813C mean values of a) toxodonts vs. astrapotheres, and b) both toxodonts and toxodons vs. Hapaloplois-like forms. Interestingly, there are also significant differences between the two ungulates vs. Pseudopreotherium, but not between toxodonts and mylodontids (cf. Nematherium and Urmacotherium). These differences indicate resource partitioning among mylodontoids which is consistent with the morphological differences of their dentitions. In addition, toxodonts and cf. Nematherium likely shared the same niches toxodonts and cf. Pseudopreotherium, but not between toxodonts and mylodontids (cf. Nematherium and Urmacotherium.) These differences indicate resource partitioning among mylodontoids which is consistent with the morphological differences of their dentitions. In addition, toxodonts and cf. Nematherium likely shared the same niches

Session 10-5: Sunday, 9:45 AM

**MULTI-PROXY ELEMENTAL AND ISOTOPIC ANALYSIS OF TOXODON SP. DENTAL ENAMEL: CLIMATE, DIET, GROWTH, AND MOBILITY**

Pestle, William J., Department of Anthropology, University of Miami, Merrick Hall 102E, Coral Gables, FL 33124; Hubbe, Alex, Departamento de Genética e Biologia Evolutiva, Instituto de Biociências-Universidade de São Paulo, São Paulo, Brazil; Pourmand, Ali, Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149; Arienzo, Monica, Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149; Swart, Peter, Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149; Sharifi, Arash, Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149; Peterson, Larry, Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149

The Pleistocene megaherbivore *Toxodon* sp. was described by Darwin as “perhaps one of the strangest animals ever discovered”. Among this taxon’s curious characteristics was its hypsodont (high-crowned) and hypselodont (ever-growing) dentition. Here, we present the results of high-resolution (spatio-temporal) analysis of trace elements, stable isotopes, and radiogenic isotopes in the dental enamel of a Late Pleistocene-Early Holocene *Toxodon* sp. specimen from Abismo Ponta de Flecha, Iporanga, São Paulo, Brazil. This study was undertaken with the hope of ascertaining enamel growth rate, diet (browse/graze), water source/intake, seasonal mobility, paleoclimate, and the effects, if any, of diagenesis on the elemental and isotopic composition of the sample in question. The multi-proxy, high-resolution approach we employed represents a novel means for the reconstruction of the life history of extinct fauna and past continental environments.

Session 10-6: Sunday, 10:30 AM

**HOW WELL DO MODELED STRONTIUM ISOTOPE RATIOS PREDICT BIOAVAILABLE STRONTIUM FOR MIGRATORY AND NON-MIGRATORY MAMMALS IN NORTH AMERICA?**

Crowley, Brooke E., Department of Geology and Department of Anthropology, University of Cincinnati, Cincinnati, OH 45221; Miller, Joshua H., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Strontium isotope ratios ($^{87}$Sr/$^{86}$Sr) offer a powerful geochemical tool for investigating the mobility and spatial relationships among organisms through time. As rocks weather, they release strontium into overlying soils and surface water. Strontium is then incorporated into plant and animal tissues. Because this uptake occurs with little fractionation, the Sr content of an organism’s tissues reflects local weathered strontium ratios at the time of tissue formation. Strontium isotopes can, therefore, be used to identify the relative mobility of species and populations. Modeled ‘isoscapes’ can be used to quickly assess whether or not an individual may be local, and if not, identify probable geographic origins. However, the density of empirical Sr data upon which models are built is geographically heterogeneous. Recent advances in continental-scale Sr models provide an opportunity to test broad patterns of how bones and teeth from migratory and non-migratory mammals compare to modeled Sr ratios from their sample locations. Here, we compile published biologically available strontium isotopic data for North America to assess how well measured empirical strontium isotope ratios for migratory and non-migratory mammals correspond to those predicted by newly developed models. We also establish the impact of local geologic complexity on these patterns. Geologic complexity at sample sites was assessed using a spatially explicit USGS geologic map of the contiguous United States and counting the number of rock types within 1° of the specimen. Using the difference (i.e., offset) between the measured Sr ratio of the specimen and the Sr ratio estimated by the model at the specimen’s sample site, we test the following two predictions: 1) migratory species have systematically greater offset in Sr isotope ratios compared to non-migratory species, and 2) geologically complex areas produce greater offset between modeled Sr ratios and empirical values. As predicted, we find that Sr ratios offsets are significantly larger for migratory species (at least in the geologically less complex regions where adequate sample sizes permit analysis). We also find that increased geologic complexity generally leads to increased offset between modeled and empirical Sr ratios. Results anomalous to these patterns from specific portions of the US (e.g., Appalachia and areas of high geologic complexity in the American West) indicate geographic regions that may benefit from additional empirical data and model refinement. We also find that offset for small-bodied (> 1 kg) non-migratory species can be uncharacteristically large and highly variable. This result suggests continental-scale models may be less useful for establishing Sr expectations for small-bodied species, and that accurate ecological assessment may still require detailed local Sr sampling. For species greater than 1 kg, available Sr models appear sufficient for assessing geographic mobility.

Session 10-7: Sunday, 10:45 AM
PALEOSEASONALITY RECORDS IN BRACHIOPOD SHELLS?

Presenter: Alberto Perez-Huerta

Perez-Huerta, Alberto, Geological Sciences, University of Alabama, Tuscaloosa, AL 35487; Aldridge, Anthony E., PO Box 19576, Woolston, Christchurch, New Zealand; Endo, Kazuyoshi, Department of Earth and Planetary Sciences, The University of Tokyo, Tokyo, Japan; Jeffries, Teresa E., Department of Earth Sciences, The Natural History Museum, London, UK

Fossil brachiopods have been extensively used in paleoclimate and paleoenvironmental studies, in particular for the Paleozoic, because of their high abundance, diversity, and widespread (paleo-) geographical distribution. In this context, shells are widely used in paleothermometry since modern shells can record seawater temperature via oxygen isotopes. However, brachiopods have been recently less favored than the use of other organisms with higher biostatigraphic potential (e.g., conodonts). The importance of brachiopod shells as archives of past environmental changes will increase significantly if the age of specimens could be determined accurately. Despite of numerous previous attempts, there is no clear methodology to achieve this objective. The recent application of determining spiral shell deviations for calculating specimen ages has provided promising results in modern taxa, which requires a further examination. Here, we evaluate the interpretation of spiral shell deviations throughout the ontogeny of the modern brachiopod species Laqueus rubellus collected from Sagami Bay, Japan, in combination with high-resolution biogeochemistry. The determination of spiral maxima and minima indicate that there is a different growth rate for ventral and dorsal valves, as well as for juvenile and adult specimens, and that the anterior shell regions provide better records of shell growth. The analysis of P/Ca shows a strong correlation between shell maxima and increase in phosphorous content, indicating periods of significant shell growth. Also, there is a strong correlation between P/Ca and Mg/Ca values for both valves. Applying Mg/Ca thermometry (Pérez-Huerta et al., 2008) around the maxima and minima at the anterior shell region for both valves, temperature values coincident with the maxima correspond to seawater temperatures instrumentally recorded in September-October. The combination of trace element proxies (P/Ca and Mg/Ca) with the determination of shell spiral deviations indicates that the maxima represent prominent periods of shell growth that occurs during the beginning of the autumn. By counting the maxima on dorsal valves of fully mature specimens, these specimens can record shell growth up to 6–7 years, which is confirmed by independent morphological and isotopic studies in the same brachiopod species. The integration of statistical measurements of shell morphologies with trace element chemistry represents an innovative methodology for specimen-age determinations in brachiopods. Furthermore, results in this study provide a better understanding of the use Mg/Ca paleo-thermometry, and using P/Ca as a shell growth and paleoproductivity proxy. Finally, the application of this approach to fossil brachiopods may open a new venue for paleoseasonality and paleoceanography studies.

Neocyclotus snails produce a calcified plate (operculum) that is attached to the foot of the gastropod, which closes over the aperture of the shell and serves as a protection mechanism from predators and to avoid dehydration. Opercula are seldom preserved in the archaeological record, and have been recovered from very few archaeological contexts. Excavations at the Archaic site of San Jacinto 1, Colombia (5,940 BP to 5,190 BP) have facilitated the recovery of 3,542 Neocyclotus opercula, a presence that has not been recorded previously in Colombia or the Neotropics. These calcified plates are made of calcareous layers, which halt growth during yearly dry seasons and could potentially be used as markers for seasonality of deposition. Evidence for processional forcing of Holocene climate in northern South America remains equivocal, and there appear to be more complex spatial patterns of climate evolution that are not consistent between available marine and terrestrial paleoclimate records. Analysis of amino acid racemization of the opercula of land snails recovered in archaeological sites are showing promising results in aminostratigraphy dating and as indicators of climatic cycles. Data obtained from opercula samples is superior to that of shells as they show less natural variability and preserve intra-crystalline proteins, possibly resulting from the greater stability of calcite. The particular characteristics in opercula makes these structures ideal for analysis of stable isotope variability of δ18O to infer low and high frequency climate variability as demonstrated in studies using gastropod shells conducted in Lake Valencia, Venezuela. The stable isotope analysis for δ18O of Neocyclotus opercula recovered in San Jacinto 1 could become the basis for reconstructing changes in the climate of northern Colombia during the middle Holocene and corroborate the paleoclimate projections established for Lake Valencia, and the interpretations for San Jacinto. In order to utilize the opercula samples for chemical analysis, it is also necessary to understand their deposition at the site to establish how these were collected, where and how they were utilized, and to be sure of their age and stratigraphy in order to determine functional descriptions from stable isotope analysis and amino acid racemization. A random sample of the San Jacinto 1 opercula will be analyzed to determine their: specific stratigraphic position, spatial attributes, taxonomic characteristics, morphometric characteristics, biochemical alterations, taphonomic alterations, biological alterations, and human modifications, if present. These analysis will allow us to infer their function at the site as well as to determine the conservation and quality of opercula samples, and if these can be utilized for a future stable isotope analysis and amino acid racemization analysis as determinants for Paleoclimate in northern Colombia during the middle Holocene period.
SESSION NO. 11: Form and function: Tracing the foundations of animal diversity, ecology, and functional morphology

Chairs: Mike Meyer and James Schiffbauer
Sunday Morning 8:00 AM to 11:45 AM

Session 10-9: Sunday, 11:15 AM
Presenter: Yurena Yanes

CARBON STABLE ISOPE COMPOSITION OF LAND SNAIL SHELLS AS A PALEOVEGETATION PROXY

Yanes, Yurena, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

The carbon isotopic composition (δ^{13}C) of land snail shells is frequently employed as a proxy for paleovegetation. This approach assumes that land snails ingest all plants available in the landscape in relation to their abundance, and that consumed plants are the only source of carbon that affect the δ^{13}C values of the shell. Even though some laboratory studies suggest that CaCO₃ from sediments has a negligible effect, field studies indicate that many snail species, especially those than inhabit carbonate-rich areas, have the potential to ingest and assimilate CaCO₃ which, in turn, affect the δ^{13}C values of the shell. Moreover, different species and individuals may experience differing metabolic rates that further complicate these relationships. In the present study, land snails from Lanzarote (Canary Islands) were live-collected from a CAM-C₃ plant habitat to evaluate if snails record reliably the relative proportion of plants with different photosynthetic pathway. Snails were collected from either CAM or C₃ plants for subsequent carbon isotope analysis of the shell and body tissue. Respective shell and body δ^{13}C values of snails collected from CAM plants averaged -8.5±1.7‰ and -22.8±1.6‰ (n=28), whereas specimens collected from C₃ plants averaged -10.1±0.7‰ and -24.9±1.1‰ (n=30). A published flux balance-mixing model suggests that analyzed specimens experienced comparable metabolic rates. A two-source mass balance equation indicates that, on average, snails included ~10% of CAM plant of their diet, in agreement with the relative abundance of CAM plant in the landscape. Nonetheless, contemporaneous specimens from the same habitat exhibited a highly variable diet, with a CAM plant intake ranging from ~41% to 0%. The present study illustrates that: 1) the studied snail species (Theba geminata) consumes CAM plants when they are available in the landscape; 2) the δ^{13}C values of snail shells reflect the relative proportion of plant types; 3) migration of snails between C₃ and CAM plants is a common phenomenon; and 4) numerous specimens should be analyzed to capture the large variability expected from snail diet in natural settings. Future laboratory studies should attempt to quantify the potential effects of δ^{13}C values of assimilated CaCO₃ into the land snail shell.

Session 11-1: Sunday, 8:00 AM
Presenter: Mike Meyer

VISCO-BIONTS? BIOMECHANICS AND EARLY LIFE

Meyer, Mike B., Geosciences and Natural Resources Department, Western Carolina University, Cullowhee, NC 28723

Form is an important facet in paleontology as commonly, we are left with little else to examine! Morphological studies have become more advanced with improvement of technological approaches for data collection; and increased emphases placed on understanding taphonomic processes have additionally aided our ability to dissect how fossil forms were preserved (or altered) in the rock record. Biomechanical studies have also become more prevalent, with researchers delving into the physics of fossil form and function. A growing number of investigations into early life are utilizing advanced methodologies to help unlock the secrets of some of the most exotic and alien forms in the fossil record, those of the Ediacaran biota and others in the Precambrian. Ediacara fossils in particular often exhibit enigmatic morphologies that challenge easy phylogenetic characterization and placement, thus straining categorization with, and relations to, extant taxa. By examining the biomechanical properties of some Ediacara fossils, it may be possible to at least postulate on potential phylogenetic affinities, which, while broad, could immensely increase our understanding of early ecosystem dynamics.

Session 11-2: Sunday, 8:15 AM
Presenter: Christine M. Solon

PALEOEKOLOGY OF RUGOCONITES AND TRIBRACHIDIUM: NEW DATA FROM THE EDIACARAN OF SOUTH AUSTRALIA

Solon, Christine M., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Droser, Mary L., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Gehling, James G., South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia; Dzaugis, Mary E., School of Oceanography, University of Rhode Island, Narragansett, RI 02882

The Ediacara Biota was Earth’s first experiment in the development of multicellular animal life. The organisms that made up this fauna were soft-bodied, and their fossils are abundant where they occur and can be found globally. Despite this, many aspects of this paleoecosystem remain enigmatic. Excavation of a succession of beds within the Flinders Ranges, South Australia, allows for more detailed study of the paleoecology of these organisms, ultimately helping to clarify the ecology and biology of these enigmatic fossils. To date, a total of 26 fossiliferous beds at have been excavated at Nilpena, South Australia. Rugoconites and Tribrichidium are two Ediacara genera that occur relatively commonly in the Ediacara Member of the Rawnsley Quartzite in South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia; Meyer, Mike B., Geosciences and Natural Resources Department, Western Carolina University, Cullowhee, NC 28723; Gehling, James G., South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia; Dzaugis, Mary E., School of Oceanography, University of Rhode Island, Narragansett, RI 02882
Australia. *Rugocontes* is defined by its round, rarely conical shape, and branching ridges radiating from its center to a well-defined outer rim. Furthermore, both described species, *R. enigmaticus* and *R. tenuirugosus*, occur at Nilpena, although *R. enigmaticus* is much more common. *Tribrachidium* is the classic tri-radial genus of the Ediacara Biota. Like *Rugocontes*, *Tribrachidium* is also round and conical in shape with a well-defined outer rim. Both genera are preserved in negative relief on the base of beds, and, unlike most other Ediacara taxa, both are found in three different facies, occurring most commonly in wave-base sand facies. Neither *Rugocontes* nor *Tribrachidium* exhibit spatial patterns within an excavated bed. However, across all beds, they exhibit a non-random distribution. *Rugocontes* occurs on ten of the excavated beds at Nilpena. Although typically only a few individuals occur on a bed, *Rugocontes* is the dominant genus of one bed and occurs in relatively large numbers on two others. Similarly, *Tribrachidium* occurs on nine of the excavated beds at Nilpena, dominating one of them and occurring in large numbers on two others. *Tribrachidium* occur in distinct size groupings (where size is measured as the diameter of an individual) on different beds. These groups have much smaller size ranges than the overall observed size range across all beds. Although our sample sizes are small, the size range of *Rugocontes* on the *Rugocontes*-dominated bed is nearly an order of magnitude smaller than the overall size range of all *Rugocontes* measured from South Australia. Additionally, the distributions of *Rugocontes* on the two beds where it is most common are significantly different from the overall distribution. The size distributions of *Tribrachidium* on the three beds where it is most common are also significantly different from the overall distribution and are nearly non-overlapping. These data suggest that there is spatial heterogeneity in terms of distinct cohorts.

Session 11-3: Sunday, 8:30 AM
Presenter: Erica Clites

**A CONSTRUCTIONAL LINK ACROSS THE CAMBRIAN BOUNDARY: THE EDIACARA TAXA CORONACOLLINA ACULA**

Clites, Erica C., University of California Museum of Paleontology, Berkeley, CA 94720; Droser, Mary L., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Gehling, James G., South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia.

The apparent lack of taxonomic continuity between the Precambrian and Cambrian fossil records has led to controversial and conflicting interpretations about the Ediacara biota and their place in the evolution of metazoan life on this planet. This has been further complicated by the absence of similar modes of construction between these faunas and the rarity of Precambrian skeletonized fossils. *Coronacollina acula* is an Ediacaran organism preserved in the Ediacara Member (Rawnsley Quartzite) of South Australia that represents the oldest multielement organism. *Coronacollina* consists of a truncated cone associated with spicules, up to 37 cm in length, diverging radially from the cone. The morphological consistency between articulated and disarticulated spicules suggests they were made of a rigid substance, such as opaline silica, or calcium carbonate. In life, the spicules likely provided structural support in a manner similar to the Cambrian demosponge, *Choa*. Although generally preserved flattened, *Choa* specimens from the Cambrian Fezouata Formation of Morocco exhibit raised central regions, perhaps representing soft tissue replaced by pyrite. The presence of Ediacaran sponge-grade organisms has been suggested by both biomarkers and other skeletonized forms such as *Palaeophragmodictya*, but *Coronacollina* solidifies this record. Constructed from a framework of rigid and brittle elements, *Coronacollina* reveals a constructional mode not recognized previously among members of the Ediacara biota. It provides a critical link across the Cambrian boundary and sheds light on the development of structural support in early sponges.

Session 11-4: Sunday, 8:45 AM
Presenter: Steven T. LoDuca

**YUKNESSIA FROM THE CAMBRIAN OF CHINA**

LoDuca, Steven T., Department of Geography and Geology, Eastern Michigan University, Ypsilanti, MI 48197; Wu, Mengyin, Department of Economics and Management, Guiyang College, Guiyang, 550005, China; Zhao, Yuanlong, College of Resource and Environment Engineering, Guizhou University, Guiyang, 550003, China; Xiao, Shuhai, Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Schiffbauer, James D., Department of Geological Sciences, University of Missouri, 101 Geology Building, Columbia, MO 65211

Charles Walcott erected *Yuknessia* in 1919 on the basis of Burgess Shale material, and assigned the taxon with some doubt to the green algae. Recently, however, scanning electron microscopic (SEM) study of the holotype and new specimens of the type species, *Y. simplex*, from British Columbia, as well as specimens assigned to this taxon from the Cambrian of Utah, revealed the presence of fusellar structure, indicating a benthic pterobranch affinity for this material. These findings call into question the phylogenetic affinity of other specimens currently assigned to *Yuknessia* from a number of Burgess Shale-type deposits, including several from China. Here, we report the results of an SEM-based study of *Yuknessia*-like material from the middle Cambrian Kaili Biota of Guizhou Province. SEM analyses of these simple, strap-like forms show a uniform surface devoid of fusellar structure and a composition dominated by carbon (kerogen). These findings are consistent with an algal affinity for this Chinese material, as proposed for these specimens in the original descriptions, but argue against assignment to *Yuknessia* as currently understood. Surficial examination suggests that the same is true for most other material assigned to *Yuknessia* from China, including specimens from the Chengjiang Biota. Simple strap-like forms from the Wheeler Formation of Utah, long regarded to be fragments of *Yuknessia* but recently shown to differ in terms of composition and microstructure, match the morphology and composition of the Chinese “*Yuknessia*.” Collectively, this material appears to be conspecific and to represent a previously undocumented taxon of Cambrian macroalga.

Session 11-5: Sunday, 9:00 AM
A NEW ORDOVICIAN EUPRYTERID FROM THE WILLIAM LAKE LAGERSTÄTTE, MANITOBA, CANADA—PHYLOGENETIC AND PALEOBIOLOGICAL IMPLICATIONS

Cuggy, Michael B., Department of Geological Sciences, University of Saskatchewan, 114 Science Place, Saskatoon SK S7N 5E2, Canada; Rudkin, David M., Department of Natural History (Palaeobiology), Royal Ontario Museum, 100 Queen’s Park, Toronto, ON M5S 2C6, Canada; Young, Graham A., Geology and Paleontology, The Manitoba Museum, 190 Rupert Avenue, Winnipeg, MB R3B 0N2, Canada

Upper Ordovician (Richmondian) dolomudstones of the William Lake Lagerstätte, central Manitoba, are yielding exceptionally preserved remains of a wide range of soft-bodied and weakly sclerotized organisms associated with a sparse shelly fauna. These sediments record a shallowing-upward depositional cycle under increasingly restricted and very low-energy conditions within a marginal marine environment. The fauna includes a variety of non-biomineralized arthropods, among them many specimens of a new eurypterid taxon. Occurrences of pre-Silurian eurypterids are extremely limited, with only six genera described worldwide. Their early evolutionary history is not well established, and any new material from this interval is potentially significant for clarifying basal palaeontology. Preliminary analysis of the available William Lake material reveals a species that does not easily fit into any of the established clades within the Eurypterida. It has a mixture of features typical of a number of different superfamilies, as well as unique characters not seen anywhere else in the Order. This indicates that the poorly known record of Ordovician eurypterids may be obscuring a more complicated early evolutionary history than previously inferred. Studies by others of eurypterid size-frequency distribution in the Upper Silurian of Ontario and the Welsh Borderlands suggested smaller individuals may have preferentially occupied shallower, more restricted 'nursery' settings where larvae and juveniles developed prior to moving into deeper water environments. Most eurypterid fossils at William Lake are relatively small and we interpret these as juvenile growth stages. The recent recovery of larger individuals at several horizons will allow us to test for a possible correlation between size and water depth through the shallowing-upward sequence, and examine other aspects of the 'mass-mate-spawn-moult' hypothesis.

Preliminary analysis of the available William Lake material reveals a species that does not easily fit into any of the established clades within the Eurypterida. It has a mixture of features typical of a number of different superfamilies, as well as unique characters not seen anywhere else in the Order. This indicates that the poorly known record of Ordovician eurypterids may be obscuring a more complicated early evolutionary history than previously inferred. Studies by others of eurypterid size-frequency distribution in the Upper Silurian of Ontario and the Welsh Borderlands suggested smaller individuals may have preferentially occupied shallower, more restricted 'nursery' settings where larvae and juveniles developed prior to moving into deeper water environments. Most eurypterid fossils at William Lake are relatively small and we interpret these as juvenile growth stages. The recent recovery of larger individuals at several horizons will allow us to test for a possible correlation between size and water depth through the shallowing-upward sequence, and examine other aspects of the 'mass-mate-spawn-moult' hypothesis.

Session 11-6: Sunday, 9:15 AM
Presenter: Michael Cuggy

AN INCLUSIVE GENERIC PHYLOGENY REVEALS CONSTRAINT AND CONVERGENCE IN THE GRAPTOLOIDEA

Bapst, David W., Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701; Mitchell, Charles E., Geology, University at Buffalo, Buffalo, NY 14260

Phylogeny-based analyses can be used to identify the frequency of convergence and the role of constraint in the gains and losses of morphological features, allowing us to understand the relative role of ecology and development in the evolution of these traits. However, phylogenetic analyses of fossil lineages often do not encompass all or even a majority of known taxa, with a tendency to include only species known from well-preserved material. This is particularly true in the Graptoloidea, a diverse group of early Paleozoic zooplankton, where many taxa with unique combinations of morphologies are incompletely known. To deal with this, we combined previous phylogenetic analyses, detailed morphological studies and taxonomic information, using a cladistic synapomorphy-guided protocol to assemble an honest summary that reflects the current understanding and uncertainty of graptoloid relationships. Our inclusive, informally constructed supertree encompasses 245 graptoloid genera, 117 of which were drawn from previous cladistic analyses. To analyze patterns of character evolution, we applied analyses that utilize only the branching topology (avoiding the need for time-scaling procedures) and account for the uncertainty in our phylogenetic summary. We identify a set of morphological innovations often considered notable in discussions of graptoloid colony form. We used randomized, parsimony-based algorithms to estimate the minimum number of unique gains for these morphological innovations. Preliminary analyses suggest these innovations were independently gained a high number of times across graptoloid evolutionary history, regardless of how we handle phylogenetic uncertainty. This suggests that these pronounced but convergent changes in colony architecture are highly evolvable. By resampling character change distributions in simulations, we can test whether changes in pairs of traits are significantly more or less coincident than expected (à la Wagner and Erwin, 2006), using the number of clades that share both characters as a summary statistic. We find evidence that several innovations are non-randomly distributed with respect to each other, suggesting that these traits evolved under related ecological or developmental constraints. The exceptional fossil record of graptoloid teratologies captures the ‘intrinsic’ morphological potential of character combinations beyond established populations, allowing us to distinguish instances where colony form was probably more constrained by ecological and functional factors than by developmental and constructional constraints.

Session 11-7: Sunday, 9:30 AM
Presenter: Timothy W. Lyons (Invited Keynote)

THE LONG ROAD TO ANIMAL LIFE: TWO BILLION YEARS OF EVOLVING OXYGEN IN THE ATMOSPHERE AND OCEAN AND ESCAPING THE ‘BORING BILLION’

Lyons, Timothy W., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Planavsky, Noah J., Department of Geology and Geophysics, Yale University, New Haven, CT 06511; Reinhard, Christopher, T. Department of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125

The first oxygenic photosynthesis and resulting accumulation of free oxygen in the atmosphere are arguably the biggest events in the history of life on Earth. Very recently, the classic organic biomarker record of 2.7-billion-year-old oxygenesis by cyanobacteria was challenged and
The position of sclerobions on biotic substrates has often been used to infer biologically meaningful information about the host organism and environment. However, there are examples in the literature where interpretations of the biology of the host, for example, the life orientation of fossil brachiopods, differ between studies. By using an independent, biomechanical test of brachiopod life orientation, we have developed a new method for more accurately assessing the biological significance of the position of sclerobions on brachiopod hosts. In a previous study by the authors, realistic models of atrypide brachiopods, placed in a flume to assess possible life orientations, found that a dorsibiconvex atrypide most likely lived reclining on its dorsal valve (anatomically speaking, independent of orientation), attached to the substrate via a pedicle, with about 5–6% of the brachiopod’s overall shell surface area resting against the substrate. This area, including the posterior-most portion of the dorsal valve and the tip of the umbo on the ventral valve, would have been unavailable for sclerobiont settlement while the brachiopod host was alive and is therefore referred to as the “dead zone.” The remaining portions of the dorsal and ventral valves are referred to as the “cryptic” (underside, about 58% of the overall surface area) and “exposed” (about 39% of the overall surface area) zones, respectively. Preliminary application of the above method was conducted on atrypides from the Firebag Member of the Waterways Formation (Givetian, Alberta, Canada). Of 369 mapped sclerobions, 38 were found to have encrusted the brachiopod post-mortem (within the dead zone). Using the surface area of each of the three zones to represent the proportion of expected encrustation per zone, 2x2 chi-square tests were conducted to determine if there was a preference for 1) a live versus dead host, or 2) the cryptic or exposed zone, assuming that each zone could be encrusted when available for sclerobiont settlement. Chi-square tests were conducted for all sclerobions, and separately for each major type of sclerobiont. Results indicate that while sclerobions from this formation do not show a strong preference for cryptic versus exposed zones, there appears to be a significant preference for the dead zone (p < 0.01), indicating that post-mortem encrustation occurs more than would be expected based on proportions of brachiopod surface area. By using models to test the plausible life orientations of brachiopods biomechanically, it is not only possible to determine how often brachiopods are encrusted post-mortem, but it is also easy to test the biological significance of sclerobiont settlement locations and preferences.

Session 11-8: Sunday, 10:30 AM
Presenter: Kristina M. Barclay

**OF MAPS AND MODELS: A NEW METHOD FOR DETERMINING THE BIOLOGICAL SIGNIFICANCE OF SCLEROBIONT POSITIONS ON BRACHIOPOD HOSTS**

Barclay, Kristina M., Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB T6G 2E3 Canada; Schneider, Chris L., Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB T6G 2E3 Canada; Leighton, Lindsey R., Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB T6G 2E3 Canada

Session 11-9: Sunday, 10:45 AM
Presenter: Diedrich Sievers

**THE PETALODIUM OF CLYPEASTEROID SAND DOLLARS: A GEOMETRIC MORPHOMETRIC DESCRIPTION OF SHAPE AND COMPARISON OF FOSSIL AND LIVING SPECIES.**

Sievers, Diedrich, Department of Geosciences, University of Tübingen, Sigwartstraße 10, D-72076, Tübingen, Germany; Nebelsick, James H., Department of Geosciences, University of Tübingen, Sigwartstraße 10, D-72076, Tübingen, Germany

In this investigation, landmark-based geometric
morphometric methods are used to better characterize the petalodium of fossil and living clypeasteroids. The analysis describes shape variation as well as explores the presence of directional and fluctuating asymmetries while comparing closely related fossil and recent sand dollar populations. Landmark-based geometric morphometric methods are based on configurations of homologous measuring points, consisting of x- and y-coordinates, that accurately describe and allow for the visualizations of both the shape itself as well as shape changes between populations. An exceptionally preserved population of Encope tamiamiensis (Mansfield, 1932) from the Pliocene Tamiami Formation of Charlotte County, Florida, allows for a detailed analysis of the petalodium shape and its morphological implications. These fossil sand dollars are compared with the living species: Encope michelini (L. Agassiz, 1841) which is found in high densities in shallow water habitats off the west coast of Florida. All specimens used in this study originate from the Florida Museum of Natural History, Gainesville, Florida. Landmark configurations were applied to digital high-resolutions pictures of specimens. After removing all information except for that of shape from the data set through a Procrustes fit, the remaining data is subjected to a statistical shape analysis. Principal component analysis shows distinct trends in shape variation between the species for the symmetric component. Results were less clear for the asymmetric component of shape variation indicating high conformity in petal and test shape. Canonical variate analysis shows clear shape differences between the species. Regression analysis show similar results for both species and shows high conformity between petal shape variations and increasing size. A Procrustes ANOVA shows highly significant influence of both Directional and Fluctuating Asymmetry in the both fossil and recent sand dollar populations. As expected, both species show similar results with respect to petalodium shape variations. Differences are seen in the relationship between petal length and size of the apical system as well as in petal orientation and size. These results are discussed with respect to ecology, ontogeny, and the shape of internal organs.

Session 11-10: Sunday, 11:00 AM
Presenter: Darrin Molinaro
GOING THE DISTANCE: THE INFLUENCE OF MORPHOLOGICAL VARIATION ON TAXON DURATION.

Molinaro, Darrin J., Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3 Canada
Leighton, Lindsey R., Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3 Canada

Current estimates indicate that today’s extinction rate is between 1000–10,000x that of the mean rate of extinction throughout Earth history. Similarly, the International Union for the Conservation of Nature, a global index of species, lists one in every three species as either threatened or at risk of extinction. Despite these alarming biodiversity statistics, our understanding of the factors that promote individual species survivorship remains relatively poor. One factor of particular interest is morphological variation, which is thought to represent a species’ ability to inhabit and utilize a wide variety of resources and environments, something which has been hypothesized as a buffer against extinction. No previous studies have examined the influence of morphological variation on species duration outside of the Cenozoic; this is problematic as it does not provide us with a general understanding of the factors that control species survivorship throughout the Phanerozoic. For example, if fossil species demonstrate that those with increased morphological variation display longer durations (stratigraphic ranges) than those with less morphological variation, it may be possible to use morphological variation in extant species to better determine their risk of extinction. In order to determine if morphological variation influences species duration (stratigraphic range), various brachiopod species (orders Atrypida, Spiriferida, Strophomenida) from the Middle Devonian Traverse group of Michigan, USA, were analyzed using both Bookstein shape coordinates and generalized Procrustes analyses. Morphological variance of individual species was calculated from multiple populations of each taxon from multiple stratigraphic intervals, to capture the full range of shape variation through time and space. Morphological variation of each species, at both the character and whole organism level, was then compared to the species’ stratigraphic range to determine if there is a relationship between morphological variation and species duration. Preliminary results for species of both Atrypida and Strophomenida suggest that morphological variation positively and significantly correlates with species duration. If this trend holds true for additional species, morphological variation is likely an important factor influencing species duration and survivorship. As such, morphological variation may be a useful indicator for identifying, monitoring, and conserving species at risk of extinction today.

Session 11-11: Sunday, 11:15 AM
Presenter: Stefan Bengtson (Invited Keynote)
EMBRYOS, EMBRYOIDS, CYSTS, AND PSEUDO-EMBRYOS IN THE FOSSIL RECORD

Bengtson, Stefan, Department of Palaeobiology, Swedish Museum of Natural History, Box 50007, SE-104 05 Stockholm, Sweden

Following the reports of early metazoan embryos in Cambrian phosphorites in the 1990s, a rich and rampant literature has grown up bearing on issues of animal development and evolution as borne out by the fossil record. The focus is on the early evolution of animal multicellularity, mainly because Proterozoic and Cambrian sedimentary environments provide good conditions for the fossilization of minute, non-mineralized organisms. Between Paleoproterozoic pseudo-embryos and Cambrian undubitable animals, there is a spectrum of embryo-like fossils that have been summoned as evidence for a a substantial Neoproterozoic diversification of metazoan clades and a consequential early establishment of developmental patterns. Recognizing that many of these fossils may represent cysts (resting and/or reproductive) or embryoids (aggregations of somatic cells) rather than true embryos (early developmental stages of multicellular organisms), a wider spectrum of possible interpretations is opened. Testing these, we may in the end gain important insights into the pathways to animal-type multicellularity.
MACROEVOLUTION AND MACROGENESIS:
EVOLUTION IN THE FAST LANE

Chatterjee, Sankar, Museum of Texas Tech University, 3301 4th Street, Lubbock, TX 79409

The mechanisms that might have triggered macroevolutionary events—the sudden and spectacular radiations of higher clades throughout the geologic record—remain elusive because of their historic origin. Such big leaps in macroevolution required enrichment and expansion of genetic pools. A synthesis in paleontology, genetics, molecular phylogeny, and developmental biology recognizes several genetic mechanisms that might be linked to macroevolutionary events. I hypothesize that macroevolution occurs via macrogenesis, a different set of genetic mechanisms than point mutation and vertical gene transfer (VGT) that furnish the heritable variation in microevolution. The macrogenesis agents include horizontal gene transfer (HGT), endosymbiosis, hybridization, and polyploidy, which are powerful facilitators of genome enrichment in living organisms. The mode of gene transfer in macrogenesis is bimodal, where both HGT and VGT are involved. HGT, endosymbiosis, and hybridization indicate high level of horizontal gene exchange across species boundary that violates the simple branching pattern of tree of life, but polyploidy does not; it follows the VGT pattern. Macrogenesis agents are well known among living organisms. HGT is the most prevalent mechanism of gene transfer among three domains of life—Bacteria, Archaea, and Eukarya. Eukaryotes gained several key organelles such as mitochondria and chloroplasts by serial endosymbiosis of aerobic and photosynthetic bacteria respectively. In vertebrate evolution, three rounds of gene duplication resulted in the origin of craniates, gnathostomes, and teleosts, respectively. Ancient polyploidy is linked to the origin of spermatophytes and angiosperms. Hybrid speciation is common in plants, but has been documented in a long list of animal species including insects, fish, amphibians, reptiles, birds, and mammals. Polyploidy is rampant in living angiosperms. Duplications or mutations of Hox genes may turn on complex cascades of developmental processes to give rise to macroevolutionary novelties in divergent phyla. Macrogenesis associated with newly acquired genes creates new body plans, morphological innovations, phenotypic diversity, and taxon richness in evolutionary fast lane. The pattern of macroevolution in the fossil record reveals a three-step process in ascending order of timeline, interspersed with intervals of million years. These steps include: 1) origin of a higher clade by macrogenesis; 2) an interim stabilizing process called phylogenetic fuse; and 3) rapid cladogenesis or evolutionary explosion. The pattern of macroevolution is quite distinct from the punctuated equilibrium, which operates on two stages—punctuation and stasis, when a single species splits into two. Macrogenesis appears to be an unrecognized but major evolutionary force and is more powerful than microevolution in creating biodiversity.
Species selection is a higher-level version of natural selection, where speciation and extinction rates covary with phenotypic or macroecological properties of species. Species selection acts on species’ properties without regard for how those properties are produced or how the species containing those properties are related. In contrast, the macroevolutionary response to selection depends on the structure of the properties’ phylogenetic variation among species in the clade and on how that variation is produced over species’ lifetimes. This means that the response to species selection is governed by both microevolutionary phyletic and phylogenetic change. For species selection to generate large-scale trends, both species selection and the macroevolutionary response to species selection must align in a concordant way. But the interaction between selection and the response to selection can be complex. For example, if species selection is strong but orthogonal to microevolutionary change, the resultant is an equilibrium non-trend, where the average trait values among species are stable over time. Non-trends are interesting because if selection or the response to selection are considered only in isolation, strong directional trends are expected. What matters for any given selection and response regime is the resultant vector produced by the vector of selection and the vector of response to selection. This framework lends itself to studying the evolution of macroecological trait distributions. Many macroecological traits often change over the lifetime of species and also show highly variable phylogenetic signal. For example, geographic range size is consistently associated with extinction selectivity, yet range size changes dramatically over the lifetimes of species as well as over phylogeny. What this framework provides is a means to understand how changes to macroecological distributions are made. How much change is due to selectivity or due to phyletic change? How do these inferred changes interact with each other to produce the total change in the distributions of macroecological traits? The answers to these questions show in what way macroevolution is more than microevolution scaled up over deep-time. Cladogenesis and extinction together add new levels evolutionary processes that make up the major features of macroevolution.

Session 12-5: Sunday, 9:00 AM
Presenter: Lauren C. Sallan

ECOLOGICALLY-DRIVEN PERSISTENT INCREASES IN EARLY VERTEBRATE BODY SIZE REVERSED BY ABIOTICALLY DRIVEN MASS EXTINCTION

Sallan, Lauren C., Ecology and Evolutionary Biology and Michigan Society of Fellows, University of Michigan, Ann Arbor, MI 48109; Galimberti, Andrew K., Biology, Kalamazoo College, Kalamazoo, MI 49006

Animal body size has a profound effect on all aspects of ecology and biodiversity, including extinction risk, prey choice, and generation times. However, the evidence for active, large-scale size trends, such as ‘Cope’s rule’ (long-term coordinated increases) and the ‘Lilliput effect’ (short-term reduction after mass extinction), in vertebrates is limited. It has been hypothesized that vertebrate size increases are abiotically driven, directly correlated with oxygen levels, and inversely with temperature, but this has

Session 12-4: Sunday, 8:45 AM
Presenter: Carl Simpson

SPECIES SELECTION AND EVOLVING TRAITS CAN AND DO INTERACT

Simpson, Carl, Department of Paleobiology, Department of Paleobiology, Smithsonian Institution, National Museum of Natural History, Washington, DC 20013

Species selection is a higher-level version of natural selection, where speciation and extinction rates covary with phenotypic or macroecological properties of species. Species selection acts on species’ properties without regard for how those properties are produced or how the species containing those properties are related. In contrast, the macroevolutionary response to selection depends on the structure of the properties’ phylogenetic variation among species in the clade and on how that variation is produced over species’ lifetimes. This means that the response to species selection is governed by both microevolutionary phyletic and phylogenetic change. For species selection to generate large-scale trends, both species selection and the macroevolutionary response to species selection must align in a concordant way. But the interaction between selection and the response to selection can be complex. For example, if species selection is strong but orthogonal to microevolutionary change, the resultant is an equilibrium non-trend, where the average trait values among species are stable over time. Non-trends are interesting because if selection or the response to selection are considered only in isolation, strong directional trends are expected. What matters for any given selection and response regime is the resultant vector produced by the vector of selection and the vector of response to selection. This framework lends itself to studying the evolution of macroecological trait distributions. Many macroecological traits often change over the lifetime of species and also show highly variable phylogenetic signal. For example, geographic range size is consistently associated with extinction selectivity, yet range size changes dramatically over the lifetimes of species as well as over phylogeny. What this framework provides is a means to understand how changes to macroecological distributions are made. How much change is due to selectivity or due to phyletic change? How do these inferred changes interact with each other to produce the total change in the distributions of macroecological traits? The answers to these questions show in what way macroevolution is more than microevolution scaled up over deep-time. Cladogenesis and extinction together add new levels evolutionary processes that make up the major features of macroevolution.

Session 12-3: Sunday, 8:30 AM
Presenter: Catalina Pimiento

RECONSTRUCTING THE EXTINCTION OF THE GIANT MEGALODON SHARK (CARCHAROCLES MEGALODON)

Pimiento, Catalina, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Balk, Meghan, Department of Biology, University of New Mexico, Albuquerque, NM 87131; Clements, Christopher, Department of Animal and Plant Sciences, University of Sheffield, Western Bank, Sheffield S10 2TN UK

Top predators play a key role in structuring the world’s ecosystems. Their extinction can trigger cascading effects through entire food webs and impact ecosystem structure and function. Examining the fossil record to understand extinctions of ancient top predators may provide insight for conservation of modern organisms. Potential mechanisms underlying the extinction of the shark Carcharocles megalodon, the largest marine predator to ever exist, remain largely unknown. Based on the fossil record, we know that it lived from the middle Miocene to the Pliocene, could reach up to 18 meters in length, and had a global distribution. In spite of this, the time of its extinction and its body size and geographic distribution patterns have never been examined before. Here, we present an estimate of the date of extinction of C. megalodon, and an assessment of changes in its body size and geographic distribution throughout geologic time, in order to understand the trajectory of its extinction. We use statistical methods to establish the most likely age of extinction, tooth measurements of various global collections to estimate body size, and occurrence data to calculate distribution range over time. The results from this study will provide insights into the extinction of one of the ocean’s largest top predators. Most importantly, they will allow greater predictive power in addressing declining populations of extant sharks and assist in targeting conservation efforts directed at mitigating large shark extinction risk.

Session 12-5: Sunday, 9:00 AM
Presenter: Lauren C. Sallan

ECOLOGICALLY-DRIVEN PERSISTENT INCREASES IN EARLY VERTEBRATE BODY SIZE REVERSED BY ABIOTICALLY DRIVEN MASS EXTINCTION

Sallan, Lauren C., Ecology and Evolutionary Biology and Michigan Society of Fellows, University of Michigan, Ann Arbor, MI 48109; Galimberti, Andrew K., Biology, Kalamazoo College, Kalamazoo, MI 49006

Animal body size has a profound effect on all aspects of ecology and biodiversity, including extinction risk, prey choice, and generation times. However, the evidence for active, large-scale size trends, such as ‘Cope’s rule’ (long-term coordinated increases) and the ‘Lilliput effect’ (short-term reduction after mass extinction), in vertebrates is limited. It has been hypothesized that vertebrate size increases are abiotically driven, directly correlated with oxygen levels, and inversely with temperature, but this has
been thrown into dispute. We analyzed a new database of over 1,100 Devonian–Mississippian (419–323 Mya) vertebrate body sizes to track change and the role of this trait during a critical interval in early fish and tetrapod evolution. Here we show that Cope’s rule was in force at all levels of Devonian fish diversity, involving jawed and jawless fishes, classes, ecosystems, and genera, but was unrelated to oxygen and temperature. This prolonged increase was abruptly stopped by the end-Devonian Hangenberg extinction, marked by loss of most previous size gains. Mississippian ecosystems more closely resembled the earliest Devonian, with bimodal distributions involving a small-sized/r-selected new majority of ray-finned and cartilaginous fishes (Actinopterygii and Chondrichthyes) and fewer larger-sized/K-selected ‘dead clades’ (e.g., *Gyracanthus*). The dominant ‘Lilliput’ fauna remained biased toward smaller sizes over the Mississippian, while large-bodied aquatic lineages became scarcer, suggesting high-level selection for small taxa. Likewise, the sizes of doomed Devonian agnathan lineages, static early on, dramatically increased alongside the numerical rise and increased ecological complexity of jawed vertebrates, continuing this trend even as their numbers subsequently declined. Limbed tetrapods follow slightly different trends than fishes, becoming smaller in the Devonian and larger in the Carboniferous as they diversify, suggesting that access to terrestrial ecosystems released them from aquatic selective pressures. Thus, long-term vertebrate size change appears to have proceeded under active selection driven by ecological interactions, with direction dependent on initial conditions. In both the Devonian and Mississippian, vertebrate size trends ramp up and continue long after the establishment of feeding morphologies, suggesting that dietary diversification precedes size changes at global scales.

Session 12-6: Sunday, 9:15 AM
Presenter: Matthew Powell

**INVERSE RELATIONSHIP BETWEEN MACROEVOLUTIONARY RATES AND GEOGRAPHIC RANGE SHIFTS OVER THE PHANEROZOIC ERA**

**Powell, Matthew G.**, Department of Geology, Juniata College, Huntingdon, PA 16652

Fossil latitudinal biodiversity gradients are poorly characterized relative to the present-day gradient. Here, I have used the Paleobiology Database to reconstruct sample-standardized, genus-level gradients for eight higher taxa and seventeen subtaxa over the Phanerozoic Eon—Mollusca (Bivalvia, Gastropoda, Cephalopoda), Brachiopoda (Rhynchonelliformea, Linguliformea), Arthropoda (Trilobita, Crustacea), Cnidaria (Scorpaenophyta, Rugosa, Tabulata), Porifera (Demospongea, Antho- and Hexacorallia, Scleractinia, Rugosa, Tabulata), Echinodermata (Pelmatozoa, Echinozoa), and Bryozoa (Stenolaemata, Gymnolaemata). The geographic patterns of genus diversity were generally highly correlated between individual taxa; all showed the same gradual, northward shift of peak biodiversity over Phanerozoic time. However, taxa differed in the amount of time in which their maximum biodiversity occurred in the tropics, ranging from a low of 38% (brachiopods) to a high of 70% (cnidarians). The geographic shifts in diversity over time documented here are either a fundamental feature of the biota or indicative of a massive sampling bias in fossil occurrence data which cannot be overcome by typical sampling-standardization methods. I also reconstructed latitudinal gradients of origination, extinction, and migration (invasion and extirpation) rates for the brachiopods as an example taxon, in order to examine how these factors varied to produce observed diversity. Overall, regional diversity was explained slightly more by invasion and extirpation than by in situ origination and extinction. Interestingly, origination and extinction rates (which declined over time) were inversely correlated with invasion and extirpation rates (which increased over time). This same relationship is evident geographically as well. Progressive increases in migration ability may have lowered origination and extinction rates because species that were better equipped to track a preferred habitat were less likely to evolve or become extinct in response to local environmental changes.

Session 12-7: Sunday, 9:30 AM
Presenter: S. Kathleen Lyons

**PATTERNS OF CO-OCURRENCE OF PLANT AND MAMMAL SPECIES ACROSS CRITICAL INTERVALS**

**Lyons, S. Kathleen**, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; **Gotelli, Nicholas J.**, Department of Biology, University of Vermont, Burlington, VT 05405; **Behrensmeier, Anna K.**, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; **Faith, J. Tyler**, Hominid Paleobiology Doctoral Program, Department of Anthropology, George Washington University Center for the Advanced Study of Hominid Paleobiology, Washington, DC 20052; **Atamangelo, Kathryn L.**, Ecology and Evolutionary Biology, Brown University Providence, RI 02906; **DiMichele, William A.**, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012 Washington, DC 20013; **Du, Andrew**, Hominid Paleobiology Doctoral Program, Department of Anthropology, George Washington University Center for the Advanced Study of Hominid Paleobiology, Washington, DC 20052; **Eronen, Jussi T.**, Department of Geosciences and Geography, University of Helsinki, Helsinki, 00014, Finland.

Understanding the structure, function, and dynamics of ecological communities is a central goal of ecology. Models of extant ecosystems hold that biodiversity is a buffer that helps stabilize ecosystem processes and services. When viewed over the entire Phanerozoic, modern levels of diversity and species richness are a relatively recent phenomenon in terrestrial communities. Many Mesozoic and younger communities are considerably less diverse than those of today, yet demonstrate patterns of species composition, dominance and diversity patterns, and architectures that parallel those of modern ecosystems. Here, we analyzed the strength of species associations in replicated samples of plant and mammal communities across several critical intervals, including the K/Pg, the PETM, and the Pleistocene-Holocene transition, using Pairs analysis. This program uses matrix
randomization and null model approaches to evaluate the non-independence of species pairs, which can be significantly aggregated or segregated, or not different from null expectations. We found striking differences in the species associations of plants and mammals across time: on average, 60% of the associated pairs of fossil plant taxa showed positive associations through evolutionary time, whereas only 30% of associated mammal species pairs exhibited such associations. However, only the Pleistocene–Holocene transition demonstrated differences in the strength of associations across an extinction event. Plants and mammals in North America exhibited a decrease in the percent of positive associations before and after this transition. For mammals, body size played an important role as small mammals drove the decrease in percent of positive associations; large-bodied mammals demonstrated an increase in positive associations before and after the extinction event. We evaluated these associations to determine the role of habitat and other environmental factors in shaping these associations. In general, habitat characteristics are important in explaining spatial patterns of species associations in both mammals and plants across time. This suggests that habitat requirements and similar responses of species to abiotic factors are driving patterns of community assembly across long time spans. Additional co-authors: Antoine Bercovici, Gary R. Graves, Nathan Jud, Conrad C. Labandeira, Cindy V. Looy, Brian McGill, David Patterson, Richard Potts, Brett Riddle, Rebecca C. Terry, Anikó Tóth, Amelia Villasenor, John J. Williams, Scott L. Wing.

Session 12-8: Sunday, 9:45 AM
Presenter: Seth Finnegan

USING BACKGROUND SELECTIVITY PATTERNS TO IDENTIFY THE ‘UNEXPECTED VICTIMS’ OF MASS EXTINCTION EVENTS: AN EXAMPLE USING LATE ORDOVICIAN–EARLY SILURIAN BRACHIOPODS

Finnegan, Seth, Department of Integrative Biology, University of California, Berkeley, Berkeley, CA 94720; Rasmussen, Christian Mac O., Natural History Museum of Denmark, University of Copenhagen, Østervoldgade 5-7, DK-1350 Copenhagen, Denmark; Harper, David A.T., Department of Earth Sciences, Durham University, Durham DH1 3LE UK

Selectivity patterns provide one of the most important types of evidence for deducing the processes that drove ancient extinction events. Determining which factors influenced extinction risk in a given interval can be complicated by nonlinear relationships between explanatory variables and extinction risk, by interactions among explanatory variables, and by multicollinearity of explanatory variables (e.g., geographic range size versus occupancy versus species richness). In addition, because extinction is never entirely random, pinpointing the unique selective signature of a given extinction event requires comparison with selectivity patterns in the ‘background’ intervals preceding and following it. Machine learning methods utilizing ensembles of classification trees can ameliorate the former issues, but lack a principled probabilistic framework for evaluating significance and comparing different intervals. We outline an approach to discerning selective signatures that involves training ensemble models of selectivity ‘rules’ for each interval under consideration, and then producing a matrix of model predictions in which every interval-specific model is used to predict the relative extinction risk of taxa in every other interval. This approach facilitates detailed comparison of selectivity patterns among different intervals and thus can help to determine which intervals may have experienced similar extinction regimes. When examining a mass extinction interval, it can be used to provide a baseline model of the expected distribution of extinction risk under a variety of background extinction regimes and thus to identify ‘unexpected victims’ that may provide insight into extinction drivers unique to that event. We apply this approach to examine Late Ordovician–early Silurian extinction patterns, using a comprehensive and taxonomically standardized global database recording the stratigraphic and paleogeographic distributions of ~560 rhynchonelliform brachiopod genera. The first (late Katian) pulse of the Late Ordovician mass extinction is characterized by higher-than-expected extinction rates among genera that had narrow latitudinal ranges and among genera that were restricted to deep (outer shelf) settings in the paleotropics. Increased extinction of genera with narrow latitudinal ranges is an expected consequence of interactions between thermal tolerance range and biogeographic barriers in a cooling climate, and this inference is supported by proxy evidence for rapid cooling at this time. Increased extinction of deep-water genera is more surprising because this selective pattern is opposite to that expected from oceanic cooling or falling sea level alone. Instead, we suggest that it may be related to oceanographic changes (e.g., in oxygenation or pH) accompanying the transition to an icehouse climate state.

Session 12-9: Sunday, 10:30 AM
Presenter: Felisa A. Smith

USING A ‘MACROSCOPE’ TO LOOK AT PATTERNS OF MAMMAL BODY SIZE IN THE FOSSIL RECORD

Smith, Felisa A., Department of Biology, University of New Mexico, Albuquerque, NM 87131; Lyons, S. Kathleen, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; Ernest, Morgan, Department of Biology, Utah State University, Logan, UT 84322

Macroecology is a big-picture, statistical approach to the study of ecology. By focusing on broadly occurring patterns and processes operating at large spatial and/or temporal scales, macroecologists aim to uncover general mechanisms operating at organism, population, and even ecosystem levels of organization. Macroecological approaches are often employed in paleontology; not only are many of the questions similar (e.g., understanding the factors limiting geographic ranges, the way that species assemble into communities, or understanding attributes that lead to higher extinction risk), but, the same types of data are typically used. When applied broadly across time, macroecology blurs into macroevolution. Here we employ a macroecological approach to examine patterns of mammalian body size over both time and space. We address the following macroecological/evolutionary questions: 1) How has
mammalian body mass changed over the evolutionary and geological history of the planet? 2) Can we identify intrinsic and/or extrinsic drivers or constraints that influence the evolutionary process? 3) Do mammalian orders achieve their maximum size at a consistent time after lineage origination? 4) How do productivity, lifestyle, and the allometric scaling of generation time interact to influence the evolutionary rate and trajectory of mammalian clades? 5) Are there commonalities in the way that mammals assemble into communities that are consistent across time and space? Our results highlight the intimate interplay between the macroecological and macroevolutionary dynamics underlying the generation and maintenance of morphological diversity.

Session 12-10: Sunday, 10:45 AM
Presenter: Simon A.F. Darroch
RESPONSE OF BETA DIVERSITY TO PULSES OF ORDOVICIAN–SILURIAN EXTINCTION AT NESTED SPATIAL SCALES

Darroch, Simon A.F., Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, CT 06511; Wagner, Peter J., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013

Fossil deposits that record the biogeographic fabric of extinctions are potentially invaluable to interpreting the consequences of present-day and future ecosystem collapse. In particular, beta (between-site) diversity describes turnover in species composition across a wide range of temporal and spatial scales, and underpins much of conservation theory and practice. Three questions that have yet to be rigorously examined using the fossil record, and yet have immediate application in informing conservation efforts, are: 1) What are the effects of extinction on beta (between-site) diversity? 2) To what extent are these effects scale-dependent? 3) Are these effects consistent across different mechanisms of extinction? We test these hypotheses by examining the changing contributions of alpha (local) and beta (between-site) diversity to overall changes in generic richness (gamma diversity) across both pulses of the Ordovician–Silurian mass extinction, using a large georeferenced database of brachiopod occurrences from the Paleobiology Database (PBDD). We also reconstruct geographic ranges for well-sampled brachiopod genera over this interval in order to assess the contributions of range-size expansion and contraction on changing patterns of beta diversity. We find: 1) the two pulses of extinction had opposite effects on alpha diversity—the first pulse resulted in increase, while the second pulse resulted in a dramatic decrease; 2) the two pulses of extinction had opposite effects on beta diversity—the first pulse produced a global decrease, while the second pulse resulted in a dramatic increase; 3) decrease in beta diversity in the Hirnantian is more apparent at regional (>500 km), rather than local scales; and 4) these patterns likely reflect a combination of extinction dynamics, dispersal ability, and eustatic sea-level rise and fall. In a conservation paleobiology context, these data suggest that the warming signs for mass extinction may be changes in community similarity (beta) at regional scales, rather than loss of richness in local assemblages (alpha).

Session 12-11: Sunday, 11:00 AM
Presenter: Lucy Chang
PATTERNS OF DIVERSIFICATION IN NOVEL ENVIRONMENTS: EXAMINING THE FOSSIL RECORD OF THE EARLY WESTERN INTERIOR SEAWAY

Chang, Lucy, University of California Museum of Paleontology, Berkeley, CA 94720

The formation of extensive shallow seas over the course of Earth’s history provides a valuable opportunity to examine the ecological and evolutionary responses of faunas to the opportunities associated with novel environments. These epeiric seas formed relatively rapidly in geologic time and differed physically from open marine habitats, with shallower depths and altered salinity, temperature, and circulation patterns. The buildup of diversity within these new habitats must result from one or more of the following processes: uninhibited dispersal of open-marine taxa, limited dispersal with ecological filtering of open-marine taxa, and one or more rounds of in-situ speciation. Indeed, some have suggested that epeiric seas may contain fundamentally different diversification processes than those in open ocean environments (Miller and Foote, 2009). However, previous studies have primarily approached the establishment of epeiric sea faunas qualitatively or using a within-seaway geographic focus, typically lacking quantitative comparison with their source faunas and their ecological properties. Thus, despite the extensive representation of epeiric seas in the fossil record, little has been done to characterize and quantify the sources of epeiric faunas. The focus for this study is the evolutionary and ecological drivers that established the fauna of the North American Cretaceous Western Interior Seaway. High sea levels and inland flooding during the Cretaceous resulted in globally distributed shallow seas, including the creation of a seaway stretching between the present-day Arctic Ocean and the Gulf of Mexico. Specifically, I focus on ammonites due to their fast rates of evolution, abundance, and typically high quality of preservation—features that allow for fine temporal and spatial control. Using an extensive taxonomic, geographic, and ecological dataset compiled from published literature on Aptian, Albian, and early Cenomanian ammonites of North America and from visits to key collections, I present patterns of ammonite diversity in the broader geographic context, comparing the Western Interior Seaway against the immediately adjacent open-ocean environments. Preliminary analyses using global occurrences suggest that many genera include both seaway endemics as well as open-ocean representatives. This will allow for multiple pairwise comparisons of the biology of the invaders with that of the non-invaders and, thus, the possibility of statistical power in the search for generalities on the forces that shaped the seaway fauna. These analyses also suggest greater variation in ammonite body size in the shallow sea endemics. Further comparisons will shed light on the latent potential of lineages to invade, function, and diversify in environmental conditions that they had not previously experienced.

Session 12-12: Sunday, 11:15 AM
Presenter: Jonathan Marcot

SEAWAY ENVIRONMENTS: EXAMINING THE FOSSIL PATTERNS OF DIVERSIFICATION IN NOVEL
PHYLOGENETIC TESTS OF CLIMATIC INFLUENCE ON UNGULATE BODY MASS EVOLUTION

Marcot, Jonathan D., Department of Animal Biology, University of Illinois, Urbana, IL 61801; Hellert, Spencer, Program in Ecology, Evolution, and Conservation Biology, University of Illinois, Urbana, IL 61801

Body mass is commonly used as a currency to examine the relationship between climate and biotic changes during the Cenozoic. Body mass is a particularly efficient summary of many ecologically relevant morphologic and life-history traits, and is relatively easily estimated from fossils. Broad trends toward increasing body mass throughout the Cenozoic are readily apparent in the North American ungulate fossil record; the maximum and mean body masses of several clades are known to increase, particularly during an interval spanning the late Paleogene and early Neogene. Revealing the drivers of these trends, and the precise mechanisms by which they drive body mass evolution requires more detailed quantitative analysis. In this study, we use phylogenetic comparative methods to estimate the rates of body mass evolution at several scales. Specifically, we ask whether evolutionary rates shift over time across all ungulates, and within individual ungulate lineages. We estimated the body masses of ungulate species using linear cheek teeth measurements. We compiled published measurements from the literature and supplemented these with novel data from museum specimens. We estimated body mass for each species using published regression equations. The final data set yielded body size estimates for more than 882 artiodactyl and perissodactyl species. We also assembled a species-level phylogeny for these species. Using these methods, we found a clade-wide shift in the rate of body size evolution in the late Paleogene. This shift affected several lineages simultaneously, including horses, camels, rhinoceroses, and ruminant artiodactyls. These independent trends are statistically confirmed by individual sub-clade analyses. These findings are consistent with abiotic factors driving body mass evolution within North American ungulates, as abiotic drivers are expected to place similar selective pressures on distantly related lineages (e.g., horses and camels).

Session 12-13: Sunday, 11:30 AM
Presenter: Philip M. Novack-Gottshall

REGRESSION AND CLASSIFICATION TREES ARE POWERFUL AND INTUITIVE ANALYTICAL METHODS FOR COMPLEX DATASETS IN PALEONTOLOGY

Novack-Gottshall, Philip M., Biological Sciences, Benedictine University, 5700 College Road, Lisle, IL 60532; Wang, Steve C., Mathematics and Statistics, Swarthmore College, 500 College Ave., Swarthmore, PA 19081; McClain, Craig R., National Evolutionary Synthesis Center, 2024 W. Main Street, Suite A200, Durham, NC 27705

Paleontological data have grown immensely in recent years. Although many analytical tools are available, datasets are often so large or complex (containing combinations of presence-absence, abundance, morphometric, and factorial variables), that they defy typical attempts at analysis. In recent decades, decision-tree-based methods have grown in popularity. These methods are well suited to discovering structure within large datasets, particularly when one wishes to determine which values of a variable are most predictive of some target variable (or outcome) of interest. The methods are equally well suited when the outcome variables are quantitative (regression methods) or categorical (classification methods). Such methods offer alternatives to logistic regression, and they have the advantage of handling interactions and categorical predictors in a natural and intuitive way. Thus, paleontological applications for these methods are diverse. Here we show how these methods work, and demonstrate their power through two case studies. The first uses trilobite environmental and geographic occurrences to identify which variables are most predictive of survivorship during the Late Ordovician mass extinction. Regression-tree analysis demonstrates that a wide paleolatitudinal range is the most important variable for survivorship. However, the tree also reveals important exceptions: trilobites inhabiting clastic substrates preferentially went extinct regardless of their large geographic range, and south-hemispheric endemics inhabiting deep-water carbonates also tended to survive, despite their narrow geographic ranges. Thus the tree allows us to identify both the most important classifier as well as when important exceptions exist. The second case demonstrates how tree methods can be used to enhance the power of more traditional statistical methods. The task involved identifying which statistical model (lognormal, loguniform, exponential, among others) best fit the body-size distribution for taxa within a local assemblage. Analyses using existing methods (maximum-likelihood, Kolmogorov-Smirnoff, and probability plot correlation coefficient) demonstrated that these methods have limited statistical power, even at moderate and ecologically often unattainable sample sizes. To overcome these limitations, we used a Monte-Carlo routine that 1) produced random samples (using actual sample statistics as parameters) from known distributions, 2) analyzed these ‘known’ samples using the standard model-fitting methods, and then 3) produced a regression tree to identify which statistical results were most accurate in predicting the original ‘known’ model. Compared to other methods, the regression-tree method resulted in a ~150–250% improvement in how often correct models were chosen. Taken together, tree methods offer a powerful exploratory method when paleontologists seek to analyze large and complex datasets.
Among the extinct ancestors of mammals, the Dicynodontia is a clade easily recognized by characteristic turtle-like beaks, toothless except for a pair of large tusks. Dicynodonts were an ecologically important group of herbivores with a distribution across the Permo-Triassic boundary. Evidence exists that some dicynodonts were burrowers; for example, *Dictodon* has been found fossilized in burrows. Two highly specialized genera, *Cistecephalus* and *Kavingasaurus*, have skeletal morphologies very similar to that of modern moles in that they have shortened but very robust humeri, with enlarged epicondyles and deltopectoral crests. These taxa have been presumed to be fossorial, possibly even entirely subterranean. Despite the description of dicynodonts as generally fossorial by many workers, this assumption has yet to be rigorously tested. Here we test for the presence of morphological indicators of burrowing behavior in dicynodonts using by quantitatively identified osteological correlates of fossoriality in extant mammals whose behavior is known. Understanding burrowing behavior in dicynodonts will give insight into the evolution of this unique group, as well as provide a model for examining the functional morphology of fossoriality in other vertebrate groups. We collected linear measurements on the forelimb and hindlimb skeletons of 45 Permian to Triassic dicynodonts and 157 extant mammals spanning 15 orders. Extant mammals were binned into three categories: fossorial, subterranean, or non-fossorial. Discriminant analysis and principal component analysis was utilized to classify these materials at the specific level. Linear measurements included: total dentary length, depth of dentary at p3, dentary depth at m1, height of p4, width of p4, length of m1, width of m1 talonid, diameter of m2, width of m2, and length of the mandibular toothrow (p2–m2). Values were initially obtained from modern *Mustela nigripes* (black-footed ferret) among these taxa expands the historic distribution of this now exclusively captive taxon further westward. Moreover, *Cynomys* spp., critical prey resource of contemporary black-footed ferrets, are markedly absent from this and other nearby Great Basin localities. In the preliminary description of SCBC mustelids, it was noted that specimens identified as *Mustela nigripes* (black-footed ferret) among these taxa expands the historic distribution of this now exclusively captive taxon further westward. Moreover, *Cynomys* spp., critical prey resource of contemporary black-footed ferrets, are markedly absent from this and other nearby Great Basin localities.
Session 13-3: Sunday, 8:30 AM
Presenter: Benjamin Atkinson

**CONSERVATION OSTEOMETRY: APPLYING PALEONTOLOGICAL AND ZOOARCHAEOLOGICAL TECHNIQUES TO EXPLORE THE IMPACTS OF GHOST TRAPS ON DIAMOND-BACKED TERRAPINS, MALACLEMYS TERRAPIN (TESTUDINES: EMMYDIDAE)**

Atkinson, Benjamin K., Department of Wildlife Ecology and Conservation, University of Florida, 110 Newins-Ziegler Hall, PO Box 110430, Gainesville, FL 32611

Diamond-backed terrapins are estuarine turtles that belong to the family Emydidae. The monotypic genus, *Malaclemys* is native to tidal salt marshes and mangrove habitats along the Atlantic and Gulf coasts of the United States. A curious, disjunct population is also established on Bermuda. Ghost traps include lost and abandoned blue crab (*Callinectes sapidus*) traps that passively capture diamond-backed terrapins. An estimated 25% of all crab traps become ghost traps, which can persist for years in coastal wetlands. Bycatch species die from anoxia, starvation, or predation within a trap. Any animal entering a ghost trap may become new bait until a trap is retrieved or disintegrates. I estimate the number of ghost traps in brackish sounds and intracoastal waterways using side-scan sonar, which allows detection of unseen traps hidden below turbid surfaces. I retrieve ghost traps using a hand-made snap line, or a gaff hook during spring low tides. I interpret salvaged skeletal elements from retrieved traps to estimate terrapin mortality. Minimum mortality rates and terrapin demographics can be inferred by applying paleontological techniques to disarticulated bones gleaned from ghost traps. Hyoplastra and hypoplastra (elements of the plastron, or lower turtle shell) are the bones most frequently retained in traps, due to their large, hooked nature. Both elements have proven reliable for allometry, enabling reconstruction of shell dimensions in life. Fontanels also facilitate determination of demographic class, due to the dramatic sexual dimorphism exhibited by diamond-backed terrapins. Mature females are nearly double the size of adult males. Bycatch reduction devices (BRDs) can be fitted to crab-trap entrance funnels to exclude large, adult female terrapins. I assess the percentage of terrapin mortalities potentially avoided via BRDs and identify locations of highest concern. By measuring several hundred complete skeletons in museum and university collections, I created a dataset for comparison to bones collected in the field. Regression models based on complete skeletons allow me to use isolated terrapin bones retrieved from traps to predict which populations may be most vulnerable to ghost traps. These techniques, coupled with geo-referencing mortality hotspots, are powerful tools for understanding bycatch impacts. To describe application of these previously unpaired techniques I coined the term “conservation osteology.”

---

Session 13-4: Sunday, 8:45 AM
Presenter: Nicholas A. Famoso

**ARE HYPSODONTY AND ENAMEL COMPLEXITY EVOLUTIONARY TRADE-OFFS OR COMPLEMENTS FOR UNGULATES?**

Famoso, Nicholas A., Department of Geological Sciences and Museum of Natural and Cultural History, University of Oregon, Eugene, OR 97403

Davis, Edward B., Department of Geological Sciences and Museum of Natural and Cultural History, University of Oregon, Eugene, OR 97403; Feranec, Robert S., Research and Collections, New York State Museum, Cultural Education Center, 222 Madison Avenue, Albany, NY 12230

The spread of grasslands and a generally cooling climate beginning in the Miocene led to an increasingly abrasive diet for ungulates. This increase in abrasiveness is a proposed driver for hypsodonty and increasing complexity of occlusal enamel bands. It is hypothesized that these characters work as complements during mastication, resisting the heavy dental wear typical of a diet high in abrasive ingesta. An alternative view is that these two characters are independent of each other and act as trade-offs, with animals evolving higher hypsodonty needing no increase in enamel-hand complexity and animals evolving complex enamel bands needing no increase in tooth crown height. To test these hypotheses, we examined the Occlusal Enamel Index (OEI) and Hypsodonty Index (HI) of 773 ungulate teeth; 636 artiodactyls and 137 perissodactyls. Because we are focusing on mesodont to hypsodont forms, our perissodactyl data are restricted to equines and include teeth from Hipparionini (n=53) and Equini (n=84). These two equine tribes are known to qualitatively and quantitatively have different strategies with respect to enamel complexity and hypsodonty. We ran three linear regressions with HI as the independent variable and OEI as the dependent variable; one for the order Artiodactyla and one for each tribe of equids. The analyses for Artiodactyla (R²=0.04) and Equini (R²=0.03) have negative slopes that lack statistical significance, while the analysis for Hipparionini (R²=0.08) has a positive slope also lacking significance. These results indicate strong independence between HI and OEI for the included animals. These characters are not linked, and in this simple linear regression show no signs of either complementary evolution or evolutionary trade-offs. However, this regression analysis does not account for the evolutionary relationships amongst these species, leaving the possibility that accounting for evolutionary relationships in these lineages of ungulates would reveal a structured pattern of complementarity or trade-off. The next step in our analysis will be a phylogenetic regression, built upon a consensus tree of the included species.
both niche model predictions of biotic response to future climate change and for using fossil data to reconstruct past environments, but historical tests of niche conservation are often limited by the quality of the fossil record, especially for deep-time divergences across large geographic areas. This is especially problematic for extant squamate reptiles (lizards, including snakes), because a taxonomically ambiguous fossil record consisting primarily of isolated mandibular and vertebral elements has not been sufficient to test numerous molecular divergence timing and predictive habitat distribution models. New discoveries of fossils of the extant boid snake genus *Charina* from the early Miocene Harrison and Arikaree Formations of Nebraska and Wyoming provide deep-time data on the historical relationship between distribution and environment in extant populations. Extant *Charina* is a uniquely cold-tolerant boid, primarily inhabiting grassland and forest environments up to 3000m altitude in California, the Pacific Northwest, Montana, Wyoming, and Utah. The taxon possesses a unique, diagnostic caudal vertebral morphology consisting of hypertrophied, bifid neural spines, tall pterapophyses, and fusion of distal vertebrae to form a caudal club that is employed for defense. Fossil precaudal vertebrae from the Paleogene and early Neogene have previously been assigned to the genus on the basis of general form similarity, but multiple clubs and caudal vertebrae from the Great Plains early Miocene represent the oldest apomorphy-based record for the clade. Atmospheric pCO2 and temperature estimates derived from local and global proxies coeval with the Great Plains Charina record allow comparison with modern climate parameters. Combining niche model results with distributions predicted from paleoclimates indicates a greater temperature range tolerance than demonstrated by either dataset, and that modern distributions are relicts of much wider ranges. Limits on modern distributions appear correlated with precipitation and may additionally depend on competitive exclusion by allopatric sister-taxon *Lichanura*. Fossil data combined with metabolic studies in *Charina* suggest that the current northern distribution is achieved through physiological adaptations for rapid body temperature elevation, a process that should facilitate range expansion, as opposed to shifts, during future warming.

Session 13-6: Sunday, 9:15 AM
Presenter: Jeff M. Martin

**RE-EVALUATION OF BISON REMAINS FROM THE GREATER GRAND CANYON REGION AND COLORADO PLATEAU: NATIVE OR NON-NATIVE**

Martin, Jeff M., Department of Geosciences, East Tennessee State University, 325 Treasure Lane, Box 70357, Johnson City, TN 37614; Mead, Jim L., Department of Geosciences, East Tennessee State University, 325 Treasure Lane, Box 70357, Johnson City, TN 37614; Walker, Lindsay J., CU Museum and Department of Geosciences, East Tennessee State University, 325 Treasure Lane, Box 70357, Johnson City, TN 37614; Nufio, Cesar R., CU Museum, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309; Leckey, Erin H., Department of Geological Sciences, 399 UCB, University of Colorado Boulder, Boulder, CO 80309; Smid, Dena M., CU Museum and Department of Geological Sciences, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309; Walker, Lindsay J., CU Museum, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309; Nufo, Cesar R., CU Museum, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309

_Bison* spp. (bison) fossils are scarce on the Colorado Plateau, especially within and adjacent to the greater Grand Canyon region. Because of the poor fossil record for the bison on the Colorado Plateau and in and Grand Canyon National Park, various resource managers have surreptitiously designated bison a non-native and human-introduced species to the greater Grand Canyon region. We would contend this argument should be equivalent to the introduction of the California condor (*Gymnogyps*) to the Grand Canyon, even though it has not been a member of the local community for over 10,000 years. The lack of evidence for bison seems to be a collection bias rather than a true lack of bison remains from the Colorado Plateau. Today, Grand Canyon National Park has a neighboring herd of 350 bison that have wandered and unwantedly entered onto National Park lands from neighboring Forest Service and State of Arizona lands. Our research illustrates that bison occupied a larger region of the Colorado Plateau than previously believed. Bison remains from archaeological sites dating to the Holocene were often inadequately identified by zooarchaeologists due to an inherent assumption that bison were not Holocene inhabitants of the region. Our reassessment and identification of these specimens suggests that bison did exist on the Colorado Plateau during not only the late Pleistocene but also the Holocene. Initial conclusions imply that bison are a native species to the greater Grand Canyon region and adjacent areas of the Colorado Plateau. Radiocarbon dates are being obtained on bison elements from select paleontological and archaeological sites across southern Colorado Plateau and Grand Canyon to further determine if the occupation of the region was throughout the varied climatic episodes during the Holocene, or if they were merely rare, sporadic, or episodic inhabitants. These dates will create a temporal framework for the distribution of the bison localities, which then enables the reconstruction and understanding of bison geographic dispersal through time. Finalized data may require resource managers to reconsider whether or not bison should be considered a native species to the Grand Canyon National Park and elsewhere on the Colorado Plateau.

Session 13-7: Sunday, 9:30 AM
Presenter: Dena M. Smith

**INSECT RESPONSE TO EOCENE-OLIGOCENE CLIMATE CHANGE IN COLORADO, USA**

Smid, Dena M., CU Museum and Department of Geological Sciences, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309; Leckey, Erin H., Department of Geological Sciences, 399 UCB, University of Colorado Boulder, Boulder, CO 80309; Walker, Lindsay J., CU Museum, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309; Nufo, Cesar R., CU Museum, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309

Exceptionally preserved fossil insects from the middle Eocene Green River Formation (~49 Ma), the late Eocene Florissant Formation (~34 Ma), the early Oligocene Pitch Pinnacle Formation (~33 Ma) and the late Oligocene Creede Formation (~26 Ma) are being studied to determine the ecological and evolutionary responses of insects to dramatic climate change. During the approximately 23 million year time interval examined in this study, regional temperatures are estimated to have decreased by approximately 15.5°C, while marine temperatures are estimated to have declined by approximately 10°C. In modern ecosystems, a shift of this magnitude would be expected to result in significant shifts in species distributions and phenology, but how the continuation of such climate change will effect organisms in
the long term are unknown. The approach of this project is to understand the impacts of climate change over geologic timescales to address how communities have responded to past changes in the earth’s climate. Presented here are preliminary data for Coleoptera and Diptera from the Green River and Florissant formations. Insects are well-represented, abundant, and diverse (species richness and ecological breadth) in all of the study localities. Occurrence, relative abundance, and ecological data were compiled from both historical collections and newly collected materials. Taxonomic composition, richness and abundance distributions have been found to shift during this interval of the Eocene-Oligocene cooling event, and already apparent is the important role of life history characteristics in determining which groups had the strongest response to environmental change. Future efforts will incorporate data from the Oligocene insect assemblages and finer-scale analyses within the Green River Formation, allowing for a greater understanding of how the rate at which climate change occurs can influence insect turnover (extinction and origination).

Session 13-8: Sunday, 9:45 AM
Presenter: Rebecca C. Terry

HOLOCENE BASELINES INDICATE ECOSYSTEM-LEVEL RESTRUCTURING OF MODERN GREAT BASIN SMALL MAMMAL COMMUNITIES DUE TO ANTHROPOGENIC HABITAT TRANSFORMATION

Terry, Rebecca C., Zoology, 3029 Cordley Hall, Corvallis, OR 97331; Rowe, Rebecca J., Natural Resources and the Environment, University of New Hampshire, Durham, NH 03824; Rickart, Eric A., Natural History Museum of Utah, 301 Wakara Way, Salt Lake City, UT 84108

Efforts to understand the ecological impacts of environmental change have primarily focused on the species level, leaving little known about how aggregate ecosystem-level properties respond. It is typically assumed that these higher-level properties are more robust due to compensatory dynamics of the underlying species. However, our prior historical resurvey work with Great Basin small mammals has revealed a marked decline in biomass and energy use over the past century in the Ruby Mountains. To place these modern dynamics within a deeper temporal framework, we examined the Holocene dynamics of biomass and energy flux of the small mammal community at Homestead Cave across two important environmental transitions from cooler/moister to warmer/drier conditions: the early to middle Holocene, and the late Holocene to modern. Across the early to middle Holocene transition, we find that the total sample-standardized biomass of the community remains stable, but that a dramatic turnover occurs in the body-size classes responsible for most energy flux: species in the largest and smallest classes decline, while the middle size classes increase. Further, the proportion of biomass represented by mesic habitat specialists declines across this transition, while xeric habitat specialists become dominant. Nevertheless, the proportional division of biomass among dietary functional groups remains relatively constant due to the rise of a medium-sized xeric-adapted herbivorous kangaroo rat, Dipodomys microrops. This distribution of biomass and energy flux remains stable through the middle and late Holocene, though a slow and steady rise in the proportion of biomass represented by habitat generalists is apparent. The transition to the modern is marked by dramatic shifts away from Holocene baseline conditions. The overall biomass of the community falls markedly due to a shift towards smaller size classes in both individual and species body-size distributions. The substantial loss of energy flux from the middle size classes is thus not compensated by larger individuals as in the early Holocene, but is instead offset by a sharp rise in the energy flux of the smallest size class. A steep decline in the biomass represented by herbivores is offset by a strong rise in omnivores, and a moderate rise in granivores. At the species level, these dynamics are primarily driven by the rise of the deer mouse (Peromyscus maniculatus) and harvest mouse (Reithrodontomys megalotis), and loss of Heteromyids. The modern small-mammal community at Homestead Cave therefore represents a shifted baseline of ecosystem-level properties at the millennial scale. These trends mirror those detected at the century scale in the Ruby Mountains. Our study indicates that modern conditions likely reflect a response to transformation of habitats due to human activities rather than the direct impacts of climate change.

Session 13-9: Sunday, 10:30 AM
Presenter: Brian Lee Beatty

ONTOGENY MEETS PALEOECOLOGY: TAKING ADVANTAGE OF THE UNIQUE DENTAL ERUPTION OF MANATEES (TRICHICHDIAE) TO ESTIMATE EXPOSURE TO ABRASIVES DURING FEEDING IN THE PLEISTOCENE OF FLORIDA TO PRESENT

Beatty, Brian L., NYIT College of Osteopathic Medicine, Old Westbury, NY 11568

The study of dental wear has proven to be a fruitful, non-destructive means to better understand modern and fossil terrestrial mammal ecology. Sireniaan diet, though often oversimplified, varies between environments, between species, and between populations. Though manatee dental eruption is unique for mammals in providing a continuous source of new molariform teeth, their dental eruption rates and tooth-row lengths standardize once they reach maturity. This makes the observed state of wear of the entire tooth row a good measure of the abrasives encountered during feeding for the period of time in which those teeth have been in use. Qualitative variables of tooth wear (patterns of exposure of dentine), as well as quantitative measures of the total area of the worn surfaces of teeth (functional occlusal surface area, FOSA) were used to inform of the relative exposure to abrasives during feeding for 66 modern manatee specimens to determine what modern ecological variables were associated with which dental wear patterns. Most modern manatees, including Antillean manatees from Chetumal Bay, Mexico (T. m. manatus), have similar dental wear patterns, which can be directly linked to the mineralogy of the substrate from which they feed, which commonly tend to be carbonate sands. Florida manatees (T. m. latirostris) have a significantly greater degree of wear, presumably because of their recent incursion to silicilastic-sediment-dominated environments in Florida during the Pleistocene. Some qualitative similarities exist between wear patterns of T. m. latirostris and T. inunguis, presumably because of this similar environmental variable. Selected specimens of Pleistocene
manatee subspecies, including *T. m. bakerorum*, were examined to determine whether this exposure to dietary abrasives in the present is comparable to prehistoric populations. *T. m. bakerorum* from the Pleistocene of Florida have similar wear patterns to those of modern Florida manatees, and therefore may have already been exposed to the same abrasives during feeding. Current West African manatee populations are closely related to Florida manatees, and are at severe risk of extinction. The few samples of modern West African manatees (*T. senegalensis*) indicate they are exposed to less abrasive environments, but samples are severely lacking (especially from lacustrine environments). The divergence date of *T. senegalensis*, and *T. manatus* subspecies occurred during the Plio-Pleistocene, and a greater sampling of fossil samples of *Trichechus* and *Ribodon* from Florida, the Caribbean, and South America are needed to understand how the distributions of these populations may have been affected by changing climate through time.

Session 13-10: Sunday, 10:45 AM
Presenter: Richard B. Aronson

**CLIMATE, BIOLOGICAL INVASION, AND MODERNIZATION OF BENTHIC COMMUNITIES IN ANTARCTICA**

Aronson, Richard B., Department of Biological Sciences, Florida Institute of Technology, 150 W. University Blvd. Melbourne, FL 32901; **Vos, Stephanie C.**, Department of Biological Sciences, Florida Institute of Technology, 150 W. University Blvd. Melbourne, FL 32901; **Thatje, Sven**, Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton Waterfront Campus, European Way, Southampton SO14 3ZH, UK; **McClintock, James B.**, Department of Biology1720 2nd Avenue South, CH 464, Birmingham, AL 35294-1170 **Smith, Kathryn E.**, Department of Biological Sciences, Florida Institute of Technology, 150 W. University Blvd. Melbourne, FL 32901

Benthic communities on the continental shelf of Antarctica have been devoid of durophagous, or skeleton-breaking, predation for most of the last 40 million years. In response, the benthic shelf-fauna has evolved a retrograde community structure. Epifaunal, suspension-feeding invertebrates are more prominent in living communities on soft substrates of the Antarctic shelf than in comparable habitats elsewhere. The principal predators are slow-moving invertebrates of a Paleozoic functional grade, such as asteroids (seastars), nemerteans (ribbon worms), and pycnogonids (sea spiders), and there is even a serolid isopod that is arguably a trilobite analogue. Durophagous king crabs (*Anomura: Lithodidae*) in the Antarctic shelf are more prominent in living communities on soft substrates of the Antarctic shelf than in comparable habitats elsewhere. The principal predators are slow-moving invertebrates of a Paleozoic functional grade, such as asteroids (seastars), nemerteans (ribbon worms), and pycnogonids (sea spiders), and there is even a serolid isopod that is arguably a trilobite analogue. Durophagous king crabs (*Anomura: Lithodidae*) in the deep sea off of the western Antarctic Peninsula (WAP) currently appear to be expanding their bathymetric range up the continental slope. If they invade the Antarctic shelf, they could devastate the vulnerable, endemic invertebrate fauna and drastically restructure benthic food webs. Photo-transects on the shelf and shelf off Marguerite Bay, WAP, imaged by the towed camera-vehicle SeaSled in 2010, revealed a large, viable population of the king crab *Paralomis birsteini* at 830.2265 m depth. The bathymetric distributions of the crabs and their likely ophiuroid prey were largely non-overlapping. The study area was resurveyed in 2013. There appear to be no ecological or environmental barriers to *Paralomis* expanding to shelf habitats, apart from sea temperatures over the shallow portions of the shelf that are slightly too cold for the crabs to survive. Climate change is rapidly relaxing that constraint.

Session 13-11: Sunday, 11:00 AM
Presenter: Sahale Casebolt

**SHAPE CHANGE IN A CARIBBEAN MIocene Bivalve AND IMPLICATIONS FOR CONSERVATION AND MODERN ECOSYSTEM MANAGEMENT**

Casebolt, Sahale N., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; **Hendy, Austin J.W.**, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; **Kowalewski, Michal**, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

The bivalve *Anadara dariensis* was widespread throughout the Caribbean and eastern Pacific during the middle-late Miocene, but is now extinct. Its widespread geographic range and abundance in the fossil record make it an ideal candidate for exploring natural morphological variation in a bivalve species in the absence of anthropogenic effects. Using geometric morphometrics and focusing on landmarks around the umbo, dentition, and muscle scars, we analyzed shape change among hundreds of specimens of this species from a range of Caribbean and eastern Pacific fossil localities, including those of the Gatun Formation of Panama. The results suggest that the majority of the variation in shape among *Anadara dariensis* specimens is related to the enlargement of the posterior muscle scar. Some localities are characterized by larger muscle scars, while others are characterized by smaller muscle scars, with a general trend of muscle-scar size decreasing through time. This project contributes to our understanding of the temporal and spatial distribution of morphological variation among populations of a species of bivalve. Understanding this variation can be an important component of assessing the impact of anthropogenic factors on change in modern bivalves, which are increasingly being used as indicators of marine ecosystem health and productivity.

Session 13-12: Sunday, 11:15 AM
Presenter: Max Christie

**TAXONOMIC AND ECOLOGICAL CHANGES ACROSS THE Plio-Pleistocene EXTINCTION AND RECOVERY: DIFFERENT MECHANISMS IN THE CARIBBEAN AND NORTH AMERICA?**

Christie, Max, Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; **Patzkowsky, Mark E.**, Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802

The Plio-Pleistocene extinction occurred roughly at 2.0 Ma, and resulted in the extinction of nearly 70% of mollusks in
the western Atlantic. However, the recovery was asymmetric across a biogeographic boundary at Cape Hatteras, North Carolina (at approximately 35°N). Modern diversity has rebounded south of this boundary, but diversity north of this boundary has remained depauperate. Previous work has linked the extinction event to decreased productivity caused by new ocean circulation patterns in the Atlantic after the closing of the Isthmus of Panama. Most of the work on this event has focused on sites in Florida and the Caribbean; this study attempts to determine how taxonomic and ecological diversity changed in North America from New Jersey to Florida. We use fossil data from the Paleobiology Database and modern data from the Global Biodiversity Information Facility from sites located from approximately 25°N to 40°N. We use Huisman-Olf-Fresco (HOF) models to create genus response curves to latitude, and ecological lifestyles (similar to Bambachian guilds) to determine how ecological communities change from the Pliocene to the Modern, and across the biogeographic boundary at Cape Hatteras. HOF models were chosen because, unlike purely Gaussian response curves, HOF models evaluate different curve shapes, from straight lines to skewed distributions, using a maximum likelihood method. The establishment of a biogeographic boundary would likely result in a skewed response from taxa near that boundary. For example, the occurrence of taxa would increase to an optimum smoothly, then rapidly decrease across the boundary. This corresponds to the ‘type V’ HOF model. When ‘type V’ are considered, progressively more skewed relationships are seen near 35°N from the Pliocene to the modern. When considering lifestyle occurrences, there is very little change from the Pliocene to the Modern. Most lifestyles have remarkably similar occurrences both from the Pliocene to the Modern and across the biogeographic boundary at Cape Hatteras. This is especially true of suspension-feeding bivalves and carnivorous gastropods, which previous work showed decreased in abundance after the Pliocene in the Caribbean. This suggests that unlike the Caribbean, where decreased productivity is thought to drive faunal change across the Pliocene and Pleistocene, North American faunal change may have been driven by another mechanism, possibly temperature. This seems likely because when only taxa that survive from the Pliocene to modern are considered, ecological lifestyle occurrences mirror the whole fauna pattern, but the relative occurrence of the surviving genera decreases by 10% north of Cape Hatteras during the modern. These results may indicate that the closing of the Isthmus of Panama could have caused two different extinction mechanisms in two different parts of the world.

Session No. 14: The Cretaceous-Paleogene Gondwanan expressway

Chairs: Maria A. Gandolfo and Elizabeth J. Hermsen

Sunday Morning 8:30 AM to 11:45 AM

Session 14-1: Sunday, 8:30 AM

Presenter: Maria A. Gandolfo (Invited Keynote)

WHY ARE CENOZOIC PALEOFLORAS FUNDAMENTAL FOR UNDERSTANDING MODERN PLANT DISTRIBUTIONS?

Gandolfo, Maria A., 410 Mann Library Building, Department of Plant Biology, Cornell University, Ithaca, NY, 14853; Hermsen, Elizabeth J., Department of Environmental and Plant Biology, Ohio University, Porter Hall 315, Athens OH 45701; Zamaloa, Maria C., Departamento de Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Intendente Guiraldes 2620, C1428EHA Buenos Aires, Argentina

The Southern Hemisphere has highly diverse floras and faunas, but its biotic evolution is poorly known relative to that of the Northern Hemisphere. To expand our understanding of the modern biogeography of the Southern Hemisphere, it is important to take into account the origin, evolution, and diversification of taxa as well as to consider the events that affected their past and present distributions. The fossil record provides the only tangible evidence about past distributions of taxa, and is therefore essential to deciphering their biogeographic histories. It is well known that, while the disintegration of Gondwanaland started during the Mesozoic, the Cenozoic was a period of considerable geologic activity that affected the climate of Antarctica, Australasia (Australia, Tasmania, New Guinea, New Zealand, and associated islands), and South America in general. These changes directly affected the distribution and migration of both flora and fauna. Clearly, after the breakup of Gondwana, direct dispersal of warm-temperate and subtropical taxa among the land masses was probably impossible. However,
some cold-tolerant taxa could have migrated between South America and Australasia via Antarctica at this time. Traditionally, the more accepted model of the evolution of the Patagonian and Antarctic floras postulates the presence of three well-defined geofloras or vegetational associations (the Cretaceous Neotropical Paleoflora, Paleocene/Eocene Mixed Paleoflora, and the Late Oligocene Antarctic Paleoflora). Although this succession is widely accepted for Patagonia, new investigations being carried out and are offering novel data that allow us to reconsider this model. In this contribution, we analyze data gathered from palynology and megafossils in the light of the new evidence, and we present examples of how changes in the climate are reflected in the paleofloras and, ultimately, in modern floras as well. Our understanding of the floristic composition of modern floras in combination with a better comprehension of ancient distribution patterns provides data for those researchers interested in the relationships of climate, flora, and historical biogeography.

Session 14-2: Sunday, 9:00 AM
Presenter: Anthony J. Martin

THE GREAT CRETACEOUS WALK: AN ICHNOLOGICAL SURVEY OF LOWER CRETACEOUS STRATA IN VICTORIA, AUSTRALIA AND IMPLICATIONS FOR GONDWANAN PALEONTOLOGY

Martin, Anthony J., Department of Environmental Studies, Emory University, 400 Dowman Dr., Math and Science Center E510, Atlanta, GA 30322; Rich, Thomas H., Museum Victoria, Melbourne, VIC, Australia; Vickers-Rich, Patricia, School of Geosciences, Monash University, Clayton, VIC, Australia; Hall, Michael, School of Geosciences, Monash University, Clayton, VIC, Australia; Kool, Lesley, School of Geosciences, Monash University, Clayton, VIC, Australia; Trusler, Peter, School of Geosciences, Monash University, Clayton, VIC, Australia

Body fossils of plants, invertebrates, and vertebrates in the Wonthaggi and Eumeralla Formations (Aptian–Albian) of Victoria, Australia provide a remarkable glimpse of Gondwanan freshwater and terrestrial biotas from a circumpolar setting during the Early Cretaceous. These fossil assemblages also inform us about the role played by Australia in the origin and dispersal of some clades to other parts of Gondwana (e.g., parastacid crayfish), or having served as a refuge for clades that were extinct elsewhere (e.g., temnospondyls). Until recently, the paleontological record for this part of Australia lacked an ichnological component. We addressed this former deficiency with a comprehensive survey of trace fossils in Wonthaggi-Eumeralla strata that began in 2006, with the bulk of field reconnaissance—dubbed “The Great Cretaceous Walk”—done in 2010, and analyses of those field results done since. Although plant trace fossils have not yet been recognized from Wonthaggi-Eumeralla facies, invertebrate trace fossils are locally abundant, whereas vertebrate traces are apparently rare. Invertebrate trace fossils include small-diameter vertical burrows (Arenicolitides), meniscate burrows (Anconichnus, Taeniidium), and larger burrow networks (Thalassinoides, Cambroygma). Vertebrate trace fossils are represented by dinosaur (ornithopod and theropod) tracks, bird tracks, possible dinosaur burrows, and other burrows that may be attributable to lungfish and turtles. Unfortunately, most Wonthaggi-Eumeralla strata are devoid of trace fossils, a likely consequence of torrential flow and high depositional rates resulting from freshwater run-off during polar springs. Hence, the majority of trace fossils were probably made seasonally (spring–summer) in fluvial channel-margin, overbank, and floodplain facies. Nonetheless, trace fossils found thus far have given us many important insights on faunal presence. Examples include the oldest-known Gondwanan crayfish (detected through their burrows), the largest assemblage of polar dinosaur tracks in the Southern Hemisphere, and the only known Early Cretaceous bird tracks from Gondwana, which are in the Eumeralla Formation; these augment the oldest known Gondwanan bird bone (furcula) from the Wonthaggi Formation. As a result, these trace fossils further broaden our paleontological perspective of Gondwanan faunas during the Early Cretaceous. Moreover, the Wonthaggi-Eumeralla trace fossil assemblage lends insights on adaptation and behavioural behavoirs of Early Cretaceous Gondwana faunas in circumpolar environments.

Session 14-3: Sunday, 9:15 AM
Presenter: Alexis Rojas

CRETACEOUS LINGULIDAE BRACHIOPODS OF THE TROPICAL AMERICA

Rojas, Alexis, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Luque, Javier, Smithsonian Tropical Research Institute, Panama City, Panama; Gómez-Cruz, Arley, Ciencias Geológicas, Universidad de Caldas, Manizales, Colombia; Moreno-Sánchez, Mario, Ciencias Geológicas, Universidad de Caldas, Manizales, Colombia

Cretaceous lingulid brachiopods are usually included within the genus Lingularia. However, the genus-level assignment of those brachiopods is challenging because of the apparent morphological stasis within the group and scarcity of diagnostic morphological features. Although lingulid brachiopods have been recorded across the Cretaceous System of the Tropical America, their morphology, systematics, and spatiotemporal distribution have not been documented adequately. Only one taxon has been fully described in the northern South America (i.e., Lingularia noitis Holmer and Bengston 2009). A number of field surveys in Colombia during the last few years carried out by the Universidad de Caldas, Colombian Geological Service, and Smithsonian Tropical Research Institute uncovered multiple occurrences of those brachiopods, ranging from Valanginian to Santonian in age. A preliminary analysis of well-preserved lingulides from Upper Cretaceous suggests strong affinities with the Brazilian form. In fact, the new material lets us confirm previous speculations by Holmer and Bengston (2009) about its internal morphology (i.e., presence of a double and asymmetric dorsal umbonal muscle scar). High variability in shell dimensions as indicated by a width-to-length ratio (W/L) ranging from 0.42 to 0.71 (n=23) is also observed. The W/L ratio of the shells from a single locality overlaps with a number of taxa within the family. In addition, a comparison between lingulides grouped by stage shows non-significant differences in those ratios (F=0.7,
The isolated islands of modern New Zealand and New Caledonia comprise the terrestrial remnants of the ancient continent of Zealandia and have highly endemic floras that include representatives, and sometimes the sole remaining examples of, many ancient plant families (e.g., Amborellaceae). These include many elements derived from Gondwana, although it can be challenging to disentangle the different histories of arrival, radiation, and extinction for various plant groups. Zealandia has played an integral role in the evolution of Southern Hemisphere biotas and until the Late Cretaceous, there was a free exchange of plants and animals between Zealandia, Australia, Antarctica, and South America. After ~83 Ma, the terrestrial landmass of Zealandia, occupying an area about half the size of Australia, drifted slowly north and east into the southwest Pacific carrying its Gondwana-derived biota. As it drifted, Zealandia gradually subsided, achieving minimum land area and maximum isolation towards the end of the Paleogene (Late Oligocene). During this period, the climate of Zealandia was mainly subtropical: New Caledonia has remained warm, but over the past 10 million years, the climate of New Zealand has cooled to temperate. Key plant groups carried on Zealandia included tree ferns, such as Cyatheaceae and Dicksoniaceae, forest understory ferns including Gleicheniaceae, Hymenophyllaceae, and Osmundaceae, genera within Araucariaceae and Cupressaceae, and many Podocarpaceae genera. Some, which had a long history in Australia and South America (and Antarctica until ice eradicated the vegetation), have disappeared from these regions, but remain diverse in Zealandia. High diversity and endemicism exists in angiosperm families with known Gondwanan affinities, including Chloranthaceae, Cunoniaceae, Myrtaceae, Nothofagaceae, Picrodendraceae, Proteaceae, Strasburgeriaceae, and Winteraceae. Some genera or entire families have their center of diversity in Zealandia, and whereas in Australia and South America some Gondwanan taxa may have been driven to extinction by competition with plants from the Northern Hemisphere, Zealandia retained its isolation and thereby its Gondwanan affinities.

Session 14-5: Sunday, 9:45 AM
Presenter: Elizabeth J. Hermesen

BEYOND THE GONDWANAN EXPRESSWAY: PATAGONIAN-NORTHERN HEMISPHERE CONNECTIONS

Hermesen, Elizabeth J., Department of Environmental and Plant Biology, Ohio University, Porter Hall 315, Athens, OH 45701; Gandolfo, María A., Department of Plant Biology, Cornell University, 412 Mann Library Building, Ithaca, NY 14853; Wilf, Peter, Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; Cúneo, N. Rubén, CONICET-Museo Paleontológico Egidio Feruglio, Trelew, Chubut, Argentina

Beginning in the early twentieth century and continuing to the present day, the ancient biotic interchange that occurred among Antarctica, Australia, and South America has been the subject of many studies. Notable recent research has emphasized similarities between the Paleogene floras of southern Patagonia and the living floras of the Australasian region. Less explored are certain other potential biogeographic links, including connections to Northern Hemisphere floras. Given the composition of modern and ancient floras as well as tectonic models, it has been assumed that the biota of Patagonia was isolated from the biota of North America (and thus the Northern Hemisphere) until relatively recently in geologic time. Current research on Late Cretaceous and Paleogene fossil floras of Patagonia, however, highlights the occurrence of fossils representing taxa that have micro- and macrofossil records and/or modern distributions centered in the Northern Hemisphere. In this presentation, we will describe recent findings from the floras of the Late Cretaceous La Colonia Formation and the Paleogene Baibian Beds, as well as the exceptionally diverse early Eocene Laguna del Hunco flora. Northern elements include members of Marsileaceae (water ferns), Juglandaceae (walnuts and relatives), and Potamogetonaceae (pondweeds), as well as putative Castanopsis (Asian oaks) and Physalis (groundcherry) fossils. Fossils representing aquatic or semi-aquatic plants (Marsileaceae and Potamogetonaceae) are thought to represent groups that were likely widespread in
the past, probably occurring in suitable habitats to which they were dispersed by vertebrates. The putative Castanopsis, known from the Laguna del Hunco flora, is an interesting case, as this northern taxon occurs with Southern Hemisphere conifers in ancient Patagonia as well as modern New Guinea and southeast Asia, suggesting perhaps that this is a long-established association that may have developed in the Southern Hemisphere. Finally, the occurrence of some northern elements, such as unnamed fruits of Juglandaceae, has no clear explanation at the present time.

Session 14-6: Sunday, 10:30 AM
Presenter: Michael Donovan
FIRST COMPARISON OF LATEST CRETACEOUS AND EARLY PALEOGENE INSECT DAMAGE IN THE SOUTHERN HEMISPHERE SUPPORTS A PATAGONIAN BIODIVERSITY REFUGIUM
Donovan, Michael P., Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; Iglesias, Ari, Instituto de Investigaciones en Biodiversidad y Medioambiente INIBIOMA-CONICET, Universidad Nacional del COMAHUE, San Carlos de Bariloche, Argentina; Wilf, Peter, Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; Cüneo, Rubén, Paleobotany, Museo Paleontológico Egidio Feruglio, Trelew, Argentina; Labandeira, Conrad C., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013

In the western USA, insect feeding-damage diversity on fossil leaves decreased significantly across the Cretaceous–Paleogene (K–Pg) boundary as a result of the Chicxulub impact. However, little is known about plant-insect associations across this interval in the Southern Hemisphere. We present preliminary results comparing insect damage on latest Cretaceous with early Paleocene fossil floras from coastal deposits in Chubut Province, Patagonia, Argentina; the first such study done outside the western USA. We compared ~1000 leaf fossils from two sites in the latest Maastrichtian Lefipán Formation in northwestern Chubut to ~2000 leaf fossils from two sites in the Danian Salamanca Formation (C28N), located ~360 km to the southeast (~50° S paleolatitude). Insect damage on both the Cretaceous and Paleocene floras is more diverse than North American analogs and includes many new associations. Examples of new fossil damage types from the Lefipán Formation are spheroidal galls on primary veins surrounded by a wide rim of thickened woody tissue, and ellipsoidal to spheroidal galls composed of carbonized material with striated surfaces. Most early Paleocene plant localities from the western USA are associated with low plant and damage-type diversity and a homogenous, generalized composition across sites. In contrast, the Paleocene Salamanca floras are associated with high damage type diversity. Examples of new damage types include concentric rings of piercing and sucking marks, small holes surrounded by dark, blotched reaction tissue, and mines and two gall types on the oldest known Agathis. These preliminary results suggest that extinction of insect herbivores at the K–Pg boundary was less severe or recovery was more rapid in southern South America compared to previously studied North American analogs. High early Paleocene damage diversity, combined with earlier work demonstrating minimal overall pollen extinction across the K–Pg boundary in the Lefipán Formation, supports an emerging hypothesis that southern latitudes were buffered from the global environmental disaster after the end-Cretaceous impact. This buffering provided a refugium for associational diversity, as well as the survival of a long list of nominally Mesozoic plant and vertebrate clades.

Session 14-7: Sunday, 10:45 AM
Presenter: Camila Martinez
NEOTROPICAL CRETACEOUS-PALEOGENE FOSSIL MACROFLORAS AND ITS AFFINITIES WITH TEMPERATE AMERICA
Martinez, Camila, Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853; Jaramillo, Carlos, Smithsonian Tropical Research Institute, Unit 0948, APO AA 34002, Balboa, Ancon, 0843-03092, Panama; Crepet, William, Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853

Based on the configuration of the continents during the Cretaceous–Paleogene period, tropical America plays an essential role in understanding the biogeographic dynamics of the Southern Hemisphere biota. Additionally, its being the most species-rich biome today, with approximately thirty percent of the known flowering plant genera and species on Earth, supports the importance of including tropical fossil floras in these kind of studies. Three fossil macrofloras from the Cretaceous–Paleogene of Colombia (Guaduas, Cerrejón, and Bogotá Formations) are described and compared with temperate floras from North and South America, aiming at a better understanding of the origin of its diversity and biogeographic events. Climatic conditions related with latitude gradients are relevant when considering the diversity assemblages and migrations. In plants, the gradient of diversity associated with latitude is seen at the species, generic, and familial level. In this study, the comparisons between floras are done at the family level. Preliminary analyses of leaf physiognomy of the Maastrichtian Guaduas Flora suggest a warm and wet paleoclimate. Similarly, the Paleogene Cerrejón and Bogotá floras present high similarities with today’s tropical rainforest diversity and climate. Preliminary analyses show that tropical floras are significantly different to Argentinian contemporaneous floras, showing that climate conditions set deterministic biogeographic limits. Including tropical fossil macrofloras are then fundamental to understand the dynamics and the evolution of the South Hemisphere biota.

Session 14-8: Sunday, 11:00 AM
Presenter: Peter Wilf
PLANTS AND THEIR DATES TELL THE ANIMALS' WEST SIDE STORY (EARLY PALEOGENE OF PATAGONIA, ARGENTINA, WEST GONDWANA)
Wilf, Peter, Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; Barreda, Viviana D., Division Paleobotanica, Museo Argentino de Ciencias Naturales “Bernardino
Rivadavia”–CONICET, Buenos Aires, Argentina; Clyde, William C., Earth Sciences, University of New Hampshire, Durham, NH 03824; Cuneo, Nestor R., Museo Paleontologico Egidio Feruglio–CONICET, Trelew, Chubut, Argentina; Gandolfo, Maria A., Department of Plant Biology, Cornell University, 412 Mann Library Building, Ithaca, NY 14853; Hermsen, Elizabeth J., Department of Environmental and Plant Biology, Ohio University, Porter Hall 315, Athens OH 45701; Iglesias, Ari, Division Paleontologia, Universidad Nacional del Comahue, INIBIOMA–CONICET, San Carlos de Bariloche, Rio Negro, Argentina

We synthesize recent advances from integrated paleobotany and geochronology that have high relevance for understanding Patagonia’s important early Paleogene vertebrate faunas. Palynofloral data from the Lefipán Formation (Chubut) show a rapid recovery of coastal ecosystems across the Cretaceous–Paleogene boundary, supporting faunal data that show a large number of surviving vertebrate groups. The correspondingly rich coastal-forest macrofloras from the upper Salamanca Formation (Chubut) can now be assigned to C28n (64.67–63.49 Ma), and the laterally exposed Peligran vertebrates, which include a monotreme, are presumably nearly coeval. The overlying Peñas Coloradas Formation has a tuff with a U-Pb age of 61.984 +/- 0.041 Ma, which dates the formation’s macrofloras and provides a working age for its “Caradocia” zone vertebrates. From the Eocene, the Pampa de Jones site (Neuquén) and its plants and ontogenetic series of pipid frogs have an Ar-Ar date of 54.56 +/-0.45 Ma. The early Eocene Laguna del Hunco (LH, Chubut) and early middle Eocene Río Pichileufú (RP, Río Negro) sites feature outstandingly diverse and well-preserved plants, frogs, and fish in volcanic fossil-lake beds, bracketing in time the nearby Paso del Sapo mammalian faunas (~49–47 Ma), which have several Antarctic links. The fossiliferous section at LH is constrained by two paleomagnetic reversals and three Ar-Ar dated tuffs. The most precise age, on sanidine, is 52.22 +/-0.22 Ma, the time of the Early Eocene Climatic Optimum and the maximum presumed potential for trans-Antarctic linkage to Australia. At RP, the fossil horizons are closely associated with three Ar-Ar dated tuffs with a combined age of 47.74 +/-0.05 Ma, placing the biota at the earliest phases of Antarctic separation. The LH and RP florals are both outstanding for having large numbers of plant genera that are extant and often in association at great distance in Australasia and/or southeast Asia, but that are extinct in South America today.

Several of the taxa indicate dispersal or pollination syndromes with vertebrates. Strikingly similar modern assemblages can be found in lower montane rainforests of the Australian subtropics and wet tropics, New Guinea, and Borneo. Many of the plant genera also have fossil records from the Paleogene of southern Australia, showing that they were part of a vast, now fragmented and relocated trans-Antarctic rainforest biome. The RP flora is already lacking several of the trans-Antarctic elements found in the older LH florals. South American Paleogene mammals were classically considered “isolated,” and Australian faunas lack sufficient resolution to make firm comparisons. However, the trans-Antarctic history of Eocene rainforest plants strongly suggests a non-isolated model for the mammals, when also considering Antarctic links of the Paso del Sapo mammals and the many non-mammalian fossil vertebrates from Patagonia that have Australasian affinities.

Session 14-9: Sunday, 11:15 AM
Presenter: Carlos Jaramillo

DYNAMICS OF THE NEOTROPICAL RAINFOREST DURING GLOBAL WARMING EVENTS

Jaramillo, Carlos, Smithsonian Tropical Research Institute, Panama, Panama; Cardenas, Andres, Smithsonian Tropical Research Institute, Panama, Panama

There is concern over the future of the tropical rainforest (TRF) in the face of global warming. Will TRFs collapse or expand? The fossil record can inform us about that. Our compilation of 5,998 tropical empirical estimates of temperature over the past 120 Ma indicates that tropics have warmed as much as 7°C during both the mid-Cretaceous and the Paleogene. We analyzed the paleobotanical record of South America during the Paleogene and found that the TRF did not expand toward temperate latitudes of South America during global warm events, even though temperatures were appropriate for doing so. We suggest that the strong isolation of the tropical biome is related to the distribution of the Trapezian biome. Rather, a novel biome, adapted to temperate latitudes with warm winters, developed south of the tropical zone. The TRF did not collapse during past warmings, on the contrary, its diversity increased. The increase in temperature seems to be a major driver in promoting diversity. In contrast, global cooling reduced the area occupied by TRF, being replaced by a rapid expansion of savanna biome. Giving the strong correlation of diversity versus area, it would be expected that a large loss of diversity of TRF occurred over the past few million years, a drop in diversity yet to be recognized both in the fossil record and in DNA studies. Our study suggests that other factors rather than temperature, such as extreme fragmentation of TRFs, could increase extinction rates.

Session 14-10: Sunday, 11:30 AM
Presenter: Lisa Merkhofer

SIZING UP THE LEAVES OF AN EOCENE PATAGONIAN PALEARAINFOREST AND ITS AUSTRALIAN ANALOGS

Merkhofer, Lisa M., Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA 16802

Leaf size is a valuable indicator of environmental conditions. When measured from fossils, leaf size is commonly used to help infer paleoenvironments, and in studies of living florals, leaf size is one of the traits classically used to define rainforest type. Although no ancient forest provides an identical modern analog, the Laguna del Hunco (LH) paleoflora from early Eocene Patagonia, Argentina, possesses remarkable similarities to well-studied, extant subtropical rainforests in eastern Australia, in terms of leaf size, floristic composition, and diversity. Here, I use a new method of ecosystem reconstruction that makes both floristic and leaf size comparisons between fossils and modern plant communities. I apply this technique to LH to find possible modern analog rainforests within eastern Australia and test previous paleoecological inferences that have been determined from well-characterized members of the paleoflora. Fossil leaf sizes were measured directly or
estimated from incomplete leaves using three methods: the Cain and Castro formula, where size = 2/3*leaf width*leaf length, the Raunkiaer-Webb size categories, and a new technique applicable to more fragmented leaves using global scaling relationships between 2° vein density and leaf area (Sack et al. 2012). By evaluating each method on intact fossil leaves, I found that the Cain and Castro formula produced size estimates closest to actual values, and both the Raunkiaer-Webb categories and 2° vein scaling resulted in estimates of comparable, but lower accuracy. This made it possible to choose the most accurate method based on specimen completeness, producing measurements with known confidence levels for a robust characterization of assemblage-wide and taxon-specific leaf size. Preliminary comparisons to modern samples showed that the subtropical rainforests of northern New South Wales (NSW) share high floristic similarity with LH at the family and genus level. Although all modern samples had larger mean leaf sizes than that determined for LH, NSW leaf sizes were the most similar to the paleoflora, suggesting that rainforests from this region are the best analogs. My findings corroborate previous interpretations of LH paleoclimate, and may provide an additional line of support for the hypothesis that LH is most similar to simple-notophyll vine forests in montane environments. Reconstructing the LH paleorainforest refines our understanding of the now-extinct, mid_latitude rainforest biome during times of the highest sustained global temperatures of the Cenozoic. This new application of leaf size in paleoecology can be applied to other fossil floras that have numerous close living relatives, allowing paleoecological interpretations to be based on a whole fossil assemblage rather than only those species with known taxonomy.
The internet has become the primary source for many Americans to access information about science topics. In addition to more traditional websites, social media (e.g., blogs, podcasts, Twitter, Facebook) offer a way for paleontologists to engage directly with the public. Studies have shown, however, that the way people interpret and interact with online content is not straightforward, but involves a complex process reflective of the user’s personal interests and values as well as the visible reactions of other users. It is also unclear whether automatic search engine algorithms are actually limiting the content that users see. For paleontology to more effectively make use of the web and social media for outreach, we must first understand the visibility of our discipline in these venues. What do people find when they search the web for information on paleontology? What gaps exist in web coverage of our discipline? Who is “speaking” for the profession? To address these questions, I have conducted analyses of Google searches, paleontology-related blogs, and Twitter posts. Google searches using different search terms produce different results. For example, search results for “paleontology” are dominated by museums and parks, while results for “paleobiology” are primarily academic in nature. The search term “ancient life,” on the other hand, is much more likely to bring up recent news reports on fossil finds.

Using the Google Trends tool, I compared search volumes for “paleontology,” “astronomy,” and “zoology” over the past ten years. Astronomy volumes are much higher than the other two fields, and all three follow an academic year cycle (lower volumes in summer months), suggesting that students and teachers are the primary consumers of science-related web content. Search volumes for “fossil collecting,” “birdwatching,” and “birdwatching” reveal a much smaller web presence for paleontology as compared to these other popular science-related hobbies. In a Google search for blogs about paleontology, almost half the resulting sites were inactive (i.e., no posts in the last six months), reflective of a movement away from the blogosphere to other social media.

For paleontology to more effectively make use of the web and social media for outreach, we must first understand the visibility of our discipline in these venues. What do people find when they search the web for information on paleontology? What gaps exist in web coverage of our discipline? Who is “speaking” for the profession? To address these questions, I have conducted analyses of Google searches, paleontology-related blogs, and Twitter posts. Google searches using different search terms produce different results. For example, search results for “paleontology” are dominated by museums and parks, while results for “paleobiology” are primarily academic in nature. The search term “ancient life,” on the other hand, is much more likely to bring up recent news reports on fossil finds.

Using the Google Trends tool, I compared search volumes for “paleontology,” “astronomy,” and “zoology” over the past ten years. Astronomy volumes are much higher than the other two fields, and all three follow an academic year cycle (lower volumes in summer months), suggesting that students and teachers are the primary consumers of science-related web content. Search volumes for “fossil collecting,” “birdwatching,” and “birdwatching” reveal a much smaller web presence for paleontology as compared to these other popular science-related hobbies. In a Google search for blogs about paleontology, almost half the resulting sites were inactive (i.e., no posts in the last six months), reflective of a movement away from the blogosphere to other social media. The majority of blogs were written by professional paleontologists or university students, rather than professional science writers. Blog authors were also overwhelmingly white and male. Finally, a survey of two professional science writers. Blog authors were also

enthusiasts, and professional science writers. These data can help us understand how paleontology reaches the public through the web and social media. They also serve as a starting point for us to discuss our goals for public outreach and the most effective ways to achieve them.

Science cafes are informal gatherings of the interested public for the consumption of science-related presentations made by local experts and enthusiasts, followed by lively discussion. Science cafes typically meet monthly at a restaurant, tavern, or coffeehouse; they are locally organized, and have recently expanded to 49 states and 14 foreign countries. There are many aspects of the Science Cafe format that make it ideal as an avenue for paleontological outreach to the general public. The audience is self-selected and interested in what you have to say. Participants have the opportunity to consume food and beverages during the presentation, which improves their mood and promotes good feelings about your presentation. The informal setting reduces inhibitions towards asking questions; you can expect the subsequent question and answer session to be more vibrant than that which follows a typical college lecture or departmental colloquium. I had the privilege of presenting to Science Café Orlando during the summer of 2011, and it might have been the most gratifying two hours of my educational career. Science Café Orlando presentations are held in the main dining and bar area of a tapas restaurant. Perhaps counterintuitively, the clinking and clanging of dishes and glassware in the background largely seemed to add to the quality of the experience. As a speaker, I was forced to project and convey passion for the subject. The audience had to listen actively rather than passively assimilating the message. Many scientific subjects can, and have been, successfully conveyed through the Science Café format, but this venue is especially well suited to paleontology, with its potential for stunning visual imagery, hands-on specimens, and the keen level of interest it enjoys with a substantial segment of the population. As funding for paleontological research tightens, it is not sufficient for scientists to spend their whole careers in conversation with only their peers, students, journal editors, and grant review boards. The future level of public funding for paleontology might depend on reminding nonscientists that scientific
knowledge is not only responsible for the amazing growth of technology around them but is an end in its own right.

Session 15-3: Sunday, 2:00 PM
Presenter: Montana Hodges

"FOSSIL STORIES" RADIO SHOW: STIMULATING PUBLIC INTEREST IN PALEONTOLOGY VIA THE RADIO MEDIUM

Hodges, Montana S., University of Montana Paleontology Center, 32 Campus Drive, Missoula, MT 59812; Fanning, Ray, University of Montana Paleontology Center, 32 Campus Drive, Missoula, MT 59812; Stanley, George, University of Montana Paleontology Center, 32 Campus Drive, Missoula, MT 59812

Education and public outreach are important in the mission of the University of Montana. It was our intention to contribute to the education/outreach mission by creating a radio project for general public audiences. This project was funded by a Paleontological Society Outreach and Education grant that helped to produce a series of short radio segments targeted at elementary-age children. Each episode transports the listener to remote fossil sites where a story of science unfolds around discoveries. The characters include a scientist, “Fossil Man,” a budding female scientist, “Paleokid,” and her dog, “Bones.” These characters all interact to stimulate scientific interest and entertain young audiences by posing hypotheses and discovering the answers. The topics deal with various fossils and the geology at Montana field sites. The two-minute radio segments are a product of the University of Montana Paleontology Center (UMPC), which focuses on research and public exhibits of fossils in the Rocky Mountain West, and the Department of Radio-Television, an outstanding professional unit of the School of Journalism, where the twelve episodes were produced. The work elements of this project included: 1) researching the topics and writing the scripts, 2) recruiting voice talent, 3) recording the audio for the scripts and editing sound recordings, 4) securing sound effects and music rights, 5) editing those elements into 12 different episodes, 6) mixing and exporting the final episodes and 7) releasing the episodes for airing via public radio. Audiocasts may further reach listeners and achieve a wider audience.

Session 15-4: Sunday, 2:15 PM
Presenter: Nigel Hughes

THE "MONISHA AND THE STONE FOREST" CHILDREN’S BOOK PROJECT: PALEONTOLOGICAL EDUCATIONAL OUTREACH IN BENGALI LANGUAGE IN INDIA AND BANGLADESH

Hughes, Nigel C., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Bhattacharya, Dipen, Mathematics and Physical Sciences, Moreno Valley College, Riverside Community College District, CA 92551

Fieldwork offers opportunities and responsibilities for educational outreach in countries hosting the research. The Geological Society of India’s mission to provide geologically themed books in regional languages for children provided me with inspiration to write a book about petrified wood, a material common in the Indian state of West Bengal and in Bangladesh. The book, Monishar Pathorer Bon (Monisha and the Stone Forest), tells of an eleven-year-old village girl’s successful attempts to find a natural explanation for this material. This 100-page illustrated story was translated into Bengali by Dipen Bhattacharya, illustrated by Smt. Rati Basu, and was published by Monfakira Press in Kolkata. Thanks to sponsorship from the Paleontological Society, the Palaeontological Association, and the Geological Society of London, and the local assistance of the Pratichi Trust, our team was able to produce 5000 copies of the book in Bengali and 1000 in English. Over 4000 Bengali copies were distributed freely to children and libraries through a variety of means: teachers unions, educational workshops, programs arranged by the American Centers in both Kolkata (with Dr. Debalhuti Mukherjee of the Geological Survey of India) and in Dhaka, Bangladesh, with BRAC (the largest private educational organization in Bangladesh). Also, two female students of Bengali origin from the University Honors Program at UC Riverside, one Muslim, one Hindu, joined Hughes in conducting educational programs in 16 different rural institutions including schools, student-education centers, and madrassas over a two-week period in summer 2012. A follow-up study in July 2013 by a local female student, Payel Ghosh, assessed the impact of the book. Results showed that it stimulated several particularly motivated students, who participated in field trips and continue to interact. Some students were motivated to look for petrified wood on their own. The interest of teachers is key to integrating our visit and the book with the daily curriculum. In general, students related well to the ancient animals presented in the story, and remembered their differences from living counterparts. Understanding of the process of fossilization was less well developed, despite this being a major theme of the book. This may reflect limited exposure to science-based thinking, as the “dekho, bhabo, aber dekho” approach (look, think, look again) approach was apparently new to all students. We found that the most effective way to present the book was an extended discussion in which each chapter was read to the class, and then a series of prompting questions asked of the students. This engaged much lively discussion, following which students were presented with copies of the book that they could then share with others. A video on the project is at: http://www.youtube.com/watch?v=ggw0RCj2oHo with a Facebook discussion group page entitled “Monishar Pathorer Bon.”

Session 15-5: Sunday, 2:30 PM
Presenter: Stephen R. Durham

VIRTUAL FIELDWORK EXPERIENCES (VFES) TO BRIDGE THE GAP BETWEEN CLASSROOM AND FIELD-BASED PALEONTOLOGY EDUCATION

Duggan-Haas, Don, Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850; Durham, Stephen R., Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853; Wall, Alexander F., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850; Kissel, Richard A., Peabody Museum of Natural History, Yale University, P.O. Box 208118, New Haven, CT 06520; Ross, Robert M.
Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850

Fieldwork is central paleontological research; ideally middle or high school classes could visit the same site repeatedly during different parts of the curriculum, observing fossils and geological context, and would travel across the country to make observations not available locally. Even ambitious teachers at well-funded schools, however, often find it difficult to get into the field more than a few times in a year, and generally very locally. Moreover, good paleontological sites are not always locally accessible, and many classes never leave the classroom at all. How do we bridge the gap between classroom and real-world paleontological experiences? Through a variety of new forms of technology, the possibility to facilitate virtual visits to field sites on a regular basis in a way that involves visual exploration and analysis in real-time has become readily available even on a modest budget. Through Enhanced Earth System Teaching through Regional and Local (ReaL) Earth Inquiry, a professional development (PD) and curriculum materials development project funded by the National Science Foundation (NSF DRL 0733303), we have been developing methods—"virtual fieldwork experiences" (VFEs)—with teachers at workshops across the U.S. VFEs are not intended to replace actual field visits, but to supplement and complement them; the goal is for teachers and their students to create one or more VFEs in their own areas, but also use experiences created by other teachers and by researchers, and potentially to tap into streaming videoconferences with researchers in the field. We are experimenting with a variety of forms of VFEs: 1) One of us (Durham) took zoomable images of two field sites in North Myrtle Beach, South Carolina, showing exposure of the Late Pleistocene Canepatch Formation. One can zoom out to see the whole outcrop (about 10 m laterally x 4 m high) or zoom in to see the orientation of individual mollusk shells. 2) At a locality in Pompey, New York, one of us (Wall) created a zoomable image of a 30 m stratigraphic section in the Skaneateles Formation (Hamilton Group) in upstate New York. The VFE supports Fossil Finders, a citizen science project in which 5th to 9th grade teachers and students collect marine paleoecological data associated with a shallowing upward sequence. 3) At sites around Denver, Colorado, we experimented with videoconferencing live from the GSA Ancient Denvers field trip, showing footprints in the Dakota Formation (Cretaceous) and stromatolites in the Lykins Formation (Triassic); teachers create a VFE for classroom use. 4) For the well-visited Taughannock State Park near Ithaca, New York, a gorge exposing Middle–Late Devonian strata forms the basis of a trip documented through a variety of media (images, video, maps), all connected to a Google Earth kmz file. One goal is to create a network of VFEs for sites nationally, with accompanying specimens and data. See virtualfieldwork.org for more information.

Session 15-6: Sunday, 3:15 PM
Presenter: David L. Meyer

TRAMMEL FOSSIL PARK, SHARONVILLE, OHIO: A UNIQUE RESOURCE FOR FIELD-BASED EDUCATION IN PALEONTOLOGY

Meyer, David L., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Since 2003, Trammel Fossil Park on the northern outskirts of Cincinnati has provided access to some of the most fossil-rich strata in North America, the Late Ordovician Cincinnati Series. Developer R. L. Trammel donated 10 acres of an excavated and partly wooded hillside for the purpose of developing a park for geological education. The site exposes approximately 20 m in the Maysvillian Stage, including four formations (Fairview Ls., Miamitown Sh., Bellevue Ls., and Corryville Sh.) Paleoenvironments represented are shallow to deep marine subtidal. Although the park is not staffed, an interpretive kiosk with colored panels explains the significance of the site, its geologic age, paleogeographic position, lithology, stratigraphy, and illustrated fossil content of each of the formations. Formational contacts are marked on the outcrop by signage keyed to the kiosk. Of particular interest is an exposed mollusk-brachiopod shell pavement about 3x3 m with well-preserved epibiotic edrioasteroid echinoderms, a 'snapshot' of the benthic paleocommunity at the instant of obruption by muds. Plexiglas panels secured by a locked cable protect the bed from weathering and vandalism, but can be removed for display upon special arrangement. Representative smaller fossiliferous beds from each of the other formations are planned for future development as in-place displays. Collecting of hand-specimens is permitted at the park. Brachiopods, bryozoans, mollusks, trilobites, echinoderms, and trace fossils are the most common fossils. Regular visitors to the park include families with children, K–12 and college classes, scout groups, amateur fossil collectors, professional field trips, and researchers. There is parking space for cars and buses, as well as a portable toilet and hand-washing facility. The site is free of roadcut hazards and has moderate slopes, but is not specially designed for handicapped access. Development of the park was funded by the City of Sharonville and the park is maintained by the Sharonville recreation department. Architect Ted Johansen of Cincinnati designed the facilities, with the advice of University of Cincinnati faculty and architecture students; members of the Dry Dredgers Association of Amateur Paleontologists provided photographs for the signs as well as materials and labor for the covered pavement. Directions to the park can be found at http://www.sharonville.org/fossilpark.aspx.

Session 15-7: Sunday, 3:30 PM
Presenter: Katherine Lewandowski

TRIAL AND ERROR: DEVELOPING CURRICULUM FOR PUBLIC OUTREACH

Lewandowski, Katherine J., Geology-Geography, Eastern Illinois University, Charleston, IL 61920; Jaques, Charlie A., Geology-Geography, Eastern Illinois University, Charleston, IL 61920; O'Malley, Christina E., Stivers School for the Arts, 1313 E. Fifth Street, Dayton, OH 45402; Hollis, Kathy, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; McCarron, Heather K., Deepwater Explorations, Chevron North America Exploration and Production, Houston, TX; Judge, Shelley A., Geology, Wooster College, 1189 Beall Ave., Wooster, OH 44691
As academics and industry professionals developing public outreach curriculum, we have learned some important lessons over the last few years. As a group, we have extensive experience developing lessons and units for use with teachers or in the secondary and college/university classroom. However, the evolving nature of educational pedagogy in the K–12 realm demands that we—as scientists—continue to learn and devise new strategies for public outreach. As a result of being awarded one of the Paleontological Society's Outreach and Education Grants in 2010, a group of us developed a three-day workshop to be held at Eastern Illinois University for professional development credit. It was designed as a workshop for secondary teachers on paleontological topics. It was designed for a group of 10–15 teachers; ultimately, we had seven participants. New curriculum was developed that could be used in secondary classrooms on topics we mapped to Illinois State and National Science Standards. Inquiry–based activities were developed from primary source materials. We wanted to approach the material from the perspective of science as a human endeavor and to help students to explore the nature of science. The three days consisted of one day of content instruction in the form of mini-lectures, discussions, and hand-on inquiry activities, one day of visiting the Illinois State Museum to explore the role of collections in scientific research, and finally, a day in the field to experience geology and paleontology first-hand. One of our targets in developing curriculum for public outreach has been to foster global citizenship. To that end we have developed units in issues-based science with the goal of producing integrated learning. Developing a unit where students learn about something close to home to understand their own environment, then they learn about similar issues in places further from home, worked to that end. Lessons were developed on invasive species of Illinois, as well as those of Madagascar. These types of comparisons help students to explore what is similar and different about these regions. In creating programs for both students and teachers, we have spent most of our time worrying about the content and the instructional strategies. This is important; however, generating enough interest in the program to get participants to sign up is essential. Of course, the strategies used to generate interest are going to differ depending on the target audience and location. We will discuss strategies for engaging the diverse sectors of the public.

Session 15-8: Sunday, 3:45 PM  
Presenter: Katherine V. Bulinski

THE MUSEUMS AND FOSSILS INSTITUTE: USING MUSEUMS, CLASSROOM, AND FIELD EXPERIENCES FOR A K–12 PROFESSIONAL DEVELOPMENT WORKSHOP

Bulinski, Katherine V., School of Environmental Studies, Bellarmine College, 2001 Newburg Rd, Louisville KY 40205
Goldstein, Alan, Falls of the Ohio State Park Interpretive Center, 201 West Riverside Dr., Clarksville, IN 47129

Earth science and evolution are essential components of K–12 education standards around the country, yet many K–12 teachers lack formal training in these areas, particularly with respect to paleontology. In 2011, The Falls of the Ohio State Park Interpretive Center launched “The Museums and Fossils Institute,” a three-day biennial initiative for paleontology teacher training supported by an Education Outreach Award from the Paleontological Society. The purpose of this workshop is to provide educators with the paleontological knowledge, resources, and field experiences to more effectively create curriculum and organize paleontology-themed field trips for their own students. This workshop involves three primary components: 1) classroom instruction, 2) field experiences, and 3) visits to museums. The classroom instruction provides background about the processes of fossilization, proper approaches to teaching evolution, using fossils for teaching about paleoecology, and how to identify fossils. Teachers are able to build upon prior knowledge of paleontology and discuss in small groups how to most effectively incorporate these topics in their classrooms. Special attention is given to discussing best practices for teaching evolution across the curriculum, including what is and is not appropriate for public school science classes. Since this workshop is conducted in the highly fossiliferous tri-state region of Indiana, Kentucky, and Ohio, the second component of the workshop is to take the participants into the field for additional instruction and to allow them to collect specimens for building or enhancing their own teaching collections. The third component involves visiting three different local museum centers in the region: The Indiana State Museum, The Cincinnati Museum of Natural History, and The Falls of the Ohio State Park Interpretive Center. Each museum visit involves working with an education coordinator so that the participants learn about the kinds of resources available for paleontology education and outreach in the region. We expect that teachers participating in the Museums and Fossils Institute will return to their home institutions with a clearer idea of how to convey paleontological and evolutionary concepts in their classes. We also encourage the educators to build visits to museums with paleontology exhibits and local fossil collecting trips into their curricula. We anticipate that in future years, similar professional development workshops can be piloted in other regions of the country, especially where evolution and paleontological education needs to be strengthened.

Session 15-9: Sunday, 4:00 PM  
Presenter: Lauren B. DeBey

TEACHERS, DINOSAURS, AND DIRT: IMMERSIVE PROFESSIONAL DEVELOPMENT AND THE DIG FIELD SCHOOL

DeBey, Lauren B., Department of Biology, University of Washington, Box 351800, Seattle, WA 98195; Wilson, Gregory P., Department of Biology, University of Washington, Box 351800, Seattle, WA 98195; Kehl, Winifred, University of Washington, Seattle, WA 98195

The Discoveries in Geosciences (DIG) Field School is a free, 4-day immersive experience for K–12 teachers through the University of Washington and Burke Museum that takes place at an active field research site. Despite the fact that our program offers a dirty, sweaty, exhausting, and at times overwhelming experience, nearly all of our teachers say they’d do it again—why? Montana’s Hell Creek is an ideal outdoor classroom: famous for its dinosaur fossils, and the area bustles with activity from visiting scientists, giving participants an authentic research experience. In the field,
Session 15-10: Sunday, 4:15 PM

Presenter: Danita Brandt

FROM PRINCIPLES TO PRACTICE: OPTIMIZING THE LAB/FIELD EXPERIENCE FOR EARTH SCIENCE TEACHERS: AN EXAMPLE FROM THE MICHIGAN BASIN

Brandt, Danita S., Department of Geological Science, Michigan State University, 288 Farm Lane, Room 206 NS, East Lansing, MI 48824

What is the minimum background in geological principles required for a novice to be able to apply the concepts in the field? This was the organizing question in planning a two-week summer course for in-service teachers who had little or no background in Earth Science. The course was designed to fit into the existing two-week format with a week of class/lab work followed by a week-long field excursion. The regional geology set the logistical framework for the course—a geologic transect of the Michigan Basin. The instructional goal was to develop the skills to interpret the geologic history of Michigan from its geological materials and the two-dimensional representation of the distribution of those materials in time and space (bedrock and surficial geology maps). The class/lab portion included an overview of rocks and minerals, with an emphasis on the histories encoded by texture and composition (two days); plate tectonics, with emphasis on how plate tectonics explains the origin of contents and the distribution of rock types (one day); sediment and sedimentary rock textures as indication of depositional environment and the environmental significance of fossils (one day); and stratigraphic principles, the use of fossils in constructing a geologic map, and interpretation of geologic and surficial deposits maps (one day). The field excursion traced Michigan’s geologic history from the youngest bedrock exposed in the state—Pennsylvania-age coal strata exposed near campus—back through time to the Archean gneisses of the western Upper Peninsula. Teachers participated in the map interpretation as they traced the geographic and geologic journey across the state (and produced their own field trip guidebook as their class project), and facility in interpreting the history recorded in rocks in terms of the conditions/environments under which they formed. The guidebooks were evaluated on the students’ ability to interpret their field observations (fossils, rock types, textures) in terms of the geologic processes/paleoenvironment/plate tectonic setting they represent. The time investment for this instructional model was slightly more than the traditional class/lab-only format used in previous years; the new model required two additional days for travel over the weekend between the two weeks. Transportation in a university vehicle was covered by endowed funds. Lodging was also covered. Participants were responsible for their meals, as they are for all on-campus summer courses. Food and lodging expenses were minimized by camping several nights and by arranging cooperative meals. In short, participants got the benefit of field experience without the potential impediment of incurring significant additional costs or time commitment.

Session 15-11: Sunday, 4:30 PM

Presenter: Danita Brandt

FATE OF PALEONTOLOGY TEACHING/RESEARCH COLLECTIONS: A ‘BIG 10’ PERSPECTIVE

Brandt, Danita S., Department of Geological Science, Michigan State University, 288 Farm Lane, Room 206 NS, East Lansing, MI 48824; Smrecak, Trisha A., Department of Geological Science, Michigan State University, 288 Farm Lane, Room 206 NS, East Lansing, MI 48824

Programmatic cutbacks due to shrinking economic resources have resulted in downsizing or elimination of invertebrate paleontology programs at several R-1 (research-intensive) ‘Big 10’ universities. As faculty in specimen-based paleontology research retire, paleontology teaching and research collections are left to an uncertain future. In a time of economic contraction, space is money, and university administrators increasingly call for accountability on the use of department space using the metric of number of students served by teaching labs or the amount of indirect costs (overhead) generated in support of research labs. The days of dedicated paleontology (or structure, or mineralogy, or sed/strat) teaching labs are numbered for institutions that do not...
not have directed resources (e.g., endowments) in support of collections. In 2000, the Paleontological Society published guidelines for deaccessioning invertebrate paleontology collections. In practice, these considerations are a luxury in a climate in which there is little or no financial support for the considerable task of deaccessioning. Fourteen years on, it is time for our professional societies to address the issue of the disposition of threatened collections and to provide for a workable response. Such a response might include establishing funds for expenses related to the curation, shipping, and re-housing of specimens; maintaining a current list of institutions that are capable of accepting specimens; and soliciting and publicizing suggestions for alternative distribution of specimens to teachers, science museums, and other educational institutions.

---

**Session No. 11 (continued):** Form and function: Tracing the foundations of animal diversity, ecology, and functional morphology

**Chairs:** Mike Meyer and James Schiffbauer

**Sunday Afternoon 1:30 PM to 4:30 PM**

Session 11-12: Sunday, 1:30 PM

Presenter: Andrew K. Rindsberg

**J-, U-, AND W-SHAPED BURROWS: HOW GROWTH AFFECTS FORM AND FUNCTION IN ICHNOLOGY**

Rindsberg, Andrew K., Department of Biological and Environmental Sciences, Station 7, The University of West Alabama, Livingston, AL 35405

The names given to trace fossils depend ultimately on morphology: morphology, to be sure, as interpreted by ichnologists, ideally based on our understanding of tracemaker behavior. But the morphology of traces changes during the lifetime of a tracemaker. Change through time adds complications to ichnotaxonomy, and new opportunities for understanding the behavior of organisms. U-shaped dwelling traces demonstrate this well. A U-shaped burrow may begin as an I-shaped burrow that is progressively altered into a J and then a U. A morphologist focusing on the overall form might place these burrows in three ichnogenera, but if other morphologic features of the burrows were present, such as a characteristic pattern of striation, then one might be justified in unifying them under one name. As the inhabitant grows, several strategies are available to enlarge its dwelling. The U-burrow may be extended by shifting the burrow, creating a characteristic spreite, as in Diplocraterion. The living polychaete Chaetopterus variopedatus cuts an opening in the parchmentlike lining of its U-burrow and digs a new branch, changing a U to a W with one of the old branches walled off. Arenicolites carbonarius represents similar behavior in the Carboniferous of the United Kingdom. The U-burrow may be abandoned altogether and a new one excavated, perhaps leaving a series of Arenicolites of increasing size and depth. Similarly, a shallow U-burrow may be extended into a zigzag pattern, as in the case of Arenicolites longistriatus and Treptichnus apsorum (Pennsylvanian, Alabama, USA), with most of the structure in disuse at any one time. In addition to raising interesting ichnotaxonomic questions, such structures pose interesting behavioral questions. For example, most U-shaped burrows are probably ventilated by their inhabitants, a process called bioirrigation. The ventilation of narrow burrows encounters greater resistance by friction along the walls than does the ventilation of thick burrows; this might be reflected in wider diageneric zones around the larger burrows. Similarly, U-burrows beginning as J-burrows must be irrigated, but surely not in the same way. And how do modifications such as the right-angle turns of “Bifungites” and the helical coils of Notomastus burrows affect water circulation? Such problems challenge neoichnologists to investigate the bioirrigation of burrows at different stages during the lives of the tracemakers. When such burrows must be named, should we include all traces related by growth together? One might say yes in the case of clearly gradational forms, or in forms related by significant morphologic features other than overall form. In cases where simple forms may be associated with more than one complex form, it may be better to take a more strictly morphologic approach, leaving the interpretation for later discussion. The effort to understand these burrows in new ways should lead to greater understanding, even of long-studied forms.

---

Session 11-13: Sunday, 1:45 PM

Presenter: Andrew Hawkins

**PHOSPHATIZATION OF VERMIFORM FOSSILS FROM THE WINNESHIEK LAGERSTÄTTE, WINNESHIEK SHALE, NORTHEAST IOWA**

Hawkins, Andrew D., Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Xiao, Shuhai, Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Liu, Huaibao P., Geological and Water Survey, Iowa Department of Natural Resources, 109 Trowbridge Hall, Iowa City, IA 52242; Briggs, Derek E.G., Geology and Geophysics and Peabody Museum of Natural History, Yale University, 210 Whitney Avenue, New Haven, CT 06520

The Winneshiek Lagerstätte in the Middle Ordovician Winneshiek Shale of northeast Iowa is preserved in a meteorite impact crater, the Decorah Impact Structure, and hosts a diverse and exceptionally well preserved fauna, including examples of soft tissue preservation. Structures of unknown biogenic affinity, referred to as vermiform fossils, make up a significant percentage of the biota. Vermiform specimens exhibit a range of morphologies and have been suggested to represent trace fossils (e.g., coprolites), cololites, or possibly soft-tissue preservation of wormlike organisms. Despite their potential importance, the taphonomic processes responsible for the preservation of vermiform fossils are poorly understood. We analyzed these vermiform fossils from the Winneshiek Shale using BSEM
and EDS in order to constrain the taphonomic processes responsible for their preservation. Elemental mapping and point analysis of thin sections of vermiciform fossils reveal that they are composed primarily of calcium phosphate with lesser amounts of zinc sulfide. The primarily calcium phosphate composition of vermiciform fossils suggests that microbially induced phosphatization during decay was the main taphonomic process involved in vermiciform preservation. Spherical microstructures approximately 1–4 μm in size are visible under BSE inspection, and resemble structures interpreted in the literature as phosphatized bacteria: we argue for this interpretation here. The wrinkled external morphologies of many of these vermiciform fossils and the important role played by microbially induced phosphatization are consistent with a cololite interpretation, although coprolites are also present, and phosphatized organisms may yet be discovered.

Session 11-14: Sunday, 2:00 PM
Presenter: Emily Greenfest-Allen

ECOMORPHOLOGY AND RECURRENCE: A COMPARATIVE APPROACH TO UNDERSTANDING FISH COMMUNITY DYNAMICS IN THE BEAR GULCH BAY

Greenfest-Allen, Emily, Institute for Biomedical Informatics, University of Pennsylvania, Philadelphia, PA, 19104; Lund, Richard, Carnegie Museum of Natural History, 4400 Forbes Ave, Pittsburgh, PA 15213; Grogan, Eileen, Department of Biology, St. Joseph's University, Philadelphia, PA 19131

The fish fauna of the 318 million-year-old marine Bear Gulch Bay (Upper Mississippian, Montana, USA) provides a unique opportunity to evaluate factors affecting assembly of Paleozoic fish communities. The deposit preserves the geographical margins, horizontal spatial variability, and vertical historical span of a shallow tropical bay that communicated with an epicontinental sea during the Mississippian. The deposit preserves the bay in its entirety across its estimated 1000 years of existence. Quarrying of this deposit over >40 years of field seasons has yielded >150 species of fish and nearly 6000 specimens, many with exceptional preservation. Thus, the Bear Gulch provides a rare virtual snapshot of a Paleozoic fossil fish community. Strikingly different relationships to habitat variations exist for the osteichthyan and the chondrichthyan, which are more sensitive to local environmental patchiness. Alpha diversity was high in all bay habitats, even those supporting depauperate faunas. Beta-diversity between adjacent habitats was low, but sufficient to differentiate upper from lower bay assemblages. This characteristic pattern of high alpha diversity coupled with low beta diversity may reflect a trade-off between the pressures of coexistence at local and regional scales. Here we present a comparative systems approach that integrates distributional and ecomorphological information to characterize local and regional components of the Bear Gulch bay fish community. To evaluate the trade-off between local pressures (e.g., competitive ability, predation, sensitivity to abiotic factors, stress tolerances) and regional pressures (e.g., colonization ability, degree of habitat specialization) affecting coexistence, we distinguish two types of communities: local assemblages and regional communities, or groups of organisms that recur across the landscape, implying some level of integration among its members that allows the community to act as a coherent ecological unit. We identify recurrent groups of fish by assembling a network of potential interactions, using rarified abundance profiles and counts of presence/absence to accommodate both common and ecologically rare taxa, respectively. Nodes within the interaction network, each representing an individual taxon, were then clustered using a measure of topological overlap, revealing nine recurrent groups. These potential regional fish communities all exhibited long-term temporal and spatial stability for the bay’s duration. Mapping of broad ecomorphological characteristics to component taxa reveals that each community varied in its ecological complexity, supporting a variety of fish occupying disparate realized niches. As communities partitioned the bay fauna according to habitat preferences, patterns of succession reflecting differences in competitive ability within ecormorph complexes emerged.

Session 11-15: Sunday, 2:15 PM
Presenter: Shuhai Xiao (Invited Keynote)

PRELIMINARY REPORT OF NEW EDIACARA FOSSILS FROM BITUMINOUS LIMESTONE OF THE DENGYING FORMATION IN SOUTH CHINA

Xiao, Shuhai, Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Chen, Zhe, LPS and LESP, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, 210008, China; Zhou, Chuanning, LPS and LESP, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, 210008, China; Wang, Wei, LPS and LESP, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, 210008, China; Guan, Chengguo, LPS and LESP, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, 210008, China; Hua, Hong, State Key Laboratory of Continental Dynamics and Department of Geology, Northwest University, Xi’an 710069, China; Yuan, Xunlai, LPS and LESP, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, 210008, China

Most Ediacara fossils are preserved as casts and molds in late Ediacaran sandstones and siltstones, although rare examples are known from carbonates and shales. The taphonomic similarities and differences between these different taphonomic windows offer critical insights into the environmental distribution and paleoecology of Ediacara organisms on the eve of the Cambrian explosion. We report the occurrence of *Hiemalora, Pteridinium, Rangea, Charniodiscus*, and an annulated tubular form from subtidal, bituminous limestone of the Shibantan Member of the Dengying Formation (551–541 Ma) in the Yangtze Gorges area of South China. The new discovery significantly expands the ecological range of *Charniodiscus, Pteridinium, and Rangea*, previously known only from siliciclastic successions, and further supports that these Ediacara fossils are marine organisms rather than terrestrial lichens or microbial colonies as proposed in a recent reinterpretation. The annulated tubular fossil is reconstructed as an erect epibenthic organism with uniserial arranged modular units, highlighting the importance of modular construction among...
Ediacara organisms. The Shibantan fossils are closely associated with abundant bilaterian burrows, suggesting that they could tolerate moderate levels of bioturbation.

Session 11-16: Sunday, 3:15 PM
Presenter: Leanne G. Hancock

SULFIDE AND METHANE DRIVERS OF ECOSYSTEM DYNAMICS IN COLD-SEEP SETTINGS: A NOVEL GEOCHEMICAL PROXY APPROACH TO CONSTRAINING THEIR CYCLING AND AVAILABILITY

Hancock, Leanne G., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Lyons, Timothy W., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Gill, Benjamin C., Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Shapiro, Russell S., Geological and Environmental Sciences, California State University, Chico, Physical Science, Room 217, Chico, CA 95929; Bates, Steven M., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521

The distribution of chemosymbiotic macrofaunal assemblages in cold-seep settings is largely controlled by the availability of sulfide, which is produced by bacterial sulfate reduction within the sediment. In both modern and ancient seeps, sulfate and methane are closely linked, making cold-seep settings ideal natural labs for studying the coupled methane-sulfur cycles and their geochemical fingerprints. Key factors include the fluxes of both methane and hydrogen sulfide through these systems and their internal cycling. Many seep studies examine sulfur in pyrite, but pyrite formation is typically limited by the availability of reactive iron in these settings and thus may only capture the earliest diagenetic processes. A better way of tracking sulfur and its role in modulating methane and sulfide production and consumption may be by following the pathways of dissolved sulfate and their isotopic expressions using a proxy known as carbonate-associated sulfate or CAS. This tracer is well known for its utility in tracking seawater isotopic compositions, but it can also be used to constrain conditions associated with diagenetic carbonate precipitation. This study focuses on the Tepee Buttes in Colorado—a Cretaceous system of methane seeps that is marked by complex carbonate paragenesis—with the goal of tracing sulfate, carbon, and oxygen isotopes to unravel ancient methane cycling and its relationship to sulfate metabolic pathways and the overprinting of later diagenetic processes. Many thiotrophic chemosymbiotic-bearing macrofauna are present at this site, including Nymphalucina clams and inoceramid bivalves. Preliminary data suggest that pairing concentration and isotopic measurements of CAS may be useful for tracking spatiotemporal variation in rates of microbial sulfate reduction as coupled to anaerobic methane oxidation. These rates in both ancient and modern settings vary spatially and temporally and may be major drivers of macro- and microfaunal ecosystem dynamics by controlling the essential availability of both sulfide and methane. We hope to illuminate relative patterns of sulfate reduction and sulfide oxidation, thus providing a crucial backdrop for interpreting thiotrophic and methanotrophic symbiosis in the macrofaunal assemblages found in these important modern and ancient settings.

Session 11-17: Sunday, 3:30 PM
Presenter: Sandra J. Carlson

PHYLOGENY AND ONTOGENY: HOW DO TEREBRATULIDINE SHORT LOOPS COMPARE WITH RHYNCHONELLIDE CRURA?

Carlson, Sandra J., Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616; Roopnarine, Peter D., Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA, 94118; Schreiber, Holly A., Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616

Within the crown clade of articulated brachiopods (Nearticulata), a generally peramorphic evolutionary transformation from crura to short loops to long loops has been hypothesized, based largely on the stratigraphic first appearance of groups possessing successively more ‘complex’ mineralized lophophore supports. This morphcline has been supported recently by separate phylogenetic analyses of morphology and molecular sequence data, but the ontogenetic transformations necessary to interpret this morphcline in a heterochronic framework have been lacking or incomplete. Our goal in this study is to use three-dimensional geometric morphometric techniques and multivariate statistical analyses of 3D images generated from microCT scans to evaluate patterns of size and shape changes in crura and short loops, relative to body size, over ontogeny and phylogeny. So far, we have quantified morphological variation among adults of 10 species of the 19 genera of Recent Rhynchonellida, and ontogenetic series from three of those species, as well as adults from 11 species of Recent Terebratulida (with short loops), and ontogenetic series from four of those species. Numerous terebratulidine species mineralize lophophore spicules, in addition to short loops, that can interlock and further support the lophophore throughout its complex geometry; microCT scans produce images, otherwise unattainable, of 3D spicule configuration as well as loop shape, and enable lophophore geometry and function to be evaluated in even the smallest individuals without breaking the interlocking articulation between valves. Furthermore, the adults investigated vary in body size by more than an order of magnitude; dramatic body-size changes are apparent between sister taxa and across clades, and over ontogeny in larger species. Because body size is a useful predictor of many ecological and reproductive characteristics of organisms, and because crura and loops play an important role functionally in positioning the lophophore in the mantle cavity of brachiopods, establishing the range of morphological variation among juveniles and adults, of differing body size, across a phylogenetic hypothesis can facilitate the interpretation of morphology in a multidimensional evolutionary and ecological context. These analyses will allow us to compare morphological results within and among rhynchonellides and terebratulidines in terms of ontogeny, phylogeny, body size, function, and ecology, and thus allow us to test hypotheses of peramorphism and the role that heterochrony may have played in the evolution of articulated brachiopods. Comparing these results among extant brachiopods initially
will establish a range of specific hypotheses that can then be tested with data from the fossil record of their close relatives.

Session 11-18: Sunday, 3:45 PM
Presenter: Roy E. Plotnick

A RADICLE SOLUTION: MORPHOLOGY AND BIOMECHANICS OF THE EUCA LYPTOCRINITES ROOT SYSTEM

Plotnick, Roy E., Department of Earth and Environmental Sciences, University of Illinois at Chicago, 845 Taylor St., Chicago, IL 60607; Honeycutt, Chris M.E., Laboratory Sciences Jefferson CC, Watertown, NY 13601; Zinga, Anna, Department of Earth and Environmental Sciences, University of Illinois at Chicago, 845 Taylor St., Chicago, IL 60607;

Eucalyptocrinites is one the most common and familiar Paleozoic crinoids. This genus ranges from the Llandoverian–Emian, has a worldwide distribution, and is locally abundant. Eucalyptocrinites is particularly common in the Llandoverian and Wenlockian; for the latter epoch, it has more occurrences in the Paleobiology Database than any other crinoid genus. Most specimens are isolated cups; complete specimens of the large and distinctive tegmen are rare. Even less common are complete specimens; less than five are known. In contrast, American museums have hundreds of specimens of Eucalyptocrinites holdfasts from the Waldron Shale of Indiana and Kentucky. These distinctive structures resemble plant roots; Brett (1981) classified it as a dendritic radicular holdfast (dendritic radix). Photos were taken of Eucalyptocrinites holdfasts in the collections of the Field Museum, the Museum of Comparative Zoology, the National Museum of Natural History, and the Cincinnati Museum Center. These images were then analyzed using ImageJ. The root system is comprised of links (branches) that meet at nodes. We measured the X-Y coordinates of the nodes, the distances of the nodes from the stem, the angles between branches, branch length, and branch width. Rose diagrams show clearly that the root systems are not isotropic, but have preferred orientations. Three-fold symmetry is fairly common. Branch angles are highly variable, but cluster around 40°. Branch lengths are relatively constant, but branch thickness decreases away from the stalk. The branching pattern can be readily modeled as a self-similar (‘fractal’) structure. Several specimens labeled as Eucalyptocrinites show a distinct five-fold symmetry without branching and may represent a different taxon. The ‘roots’ of Eucalyptocrinites and other crinoids have long been compared with the root systems of plants. Although there are superficial visual similarities, there are fundamental differences. The most important is that plant roots can perform multiple primary functions, including resource acquisition, storage, and transport, as well as anchorage. These multiple functional constraints on plant roots strongly contrast with pelmatozoan holdfasts, where the major functional constraint is that it provides anchorage. The Eucalyptocrinites root system, along with the probably stiff dististele, most likely functioned as a rigid plate that resisted rotational forces due to currents acting on the heavy tegmen. Upstream radicles experienced tension, whereas downstream roots were compressed. Any radicles perpendicular to prevailing currents would have been under torsion and thus play little role in stability. This force distribution may explain the observed anisotropies in root morphology.

Session 11-19: Sunday, 4:00 PM
Presenter: Jean-Bernard Caron (Invited Keynote)

PRIMITIVE FISHES FROM THE MIDDLE CAMBRIAN OF LAURENTIA

Caron, Jean-Bernard, Department of Natural History (Palaeobiology), Royal Ontario Museum, 100 Queen’s Park, Toronto, Ontario M5S 2C6, Canada; Conway Morris, Simon, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ UK

Vertebrates evolved during the Cambrian explosion, but our understanding of the early diversity and evolutionary history of this group is hampered by the general lack of fossilized remains, in particular from Burgess Shale-type deposits. The lower (Stage 3) Cambrian Chengjiang biota has yielded the oldest known agnathans in the fossil record. These fossils have provided our only significant clues concerning the morphology of the earliest fish so far. Metaspriggina walcotti from the middle Cambrian (Stage 5) Burgess Shale is the only other putative vertebrate known outside of China, but until recently, the two known specimens were too fragmentary to provide critical new information. The discovery of dozens of new Metaspriggina specimens from the Burgess Shale, in particular from the new Marble Canyon locality in Kootenay National Park, British Columbia, significantly improves our knowledge of early vertebrate morphology and evolution. In addition to W-shaped muscles, the new Metaspriggina material preserves complex auditory and olfactory systems, as well as a series of dorso-ventrally differentiated branchial arches. The disposition of these arches may be informative as to the origin of jaws. Albeit with some morphological variations—Metaspriggina, for example, lacks fins—Metaspriggina is similar to Haikouichthys from the Chengjiang biota, suggesting a potentially close phyletic relationship. Metaspriggina was cosmopolitan around Laurentia during lower-middle Cambrian times (upper stage 3 to lower Drumian), and occurs in several Burgess Shale-type deposits (i.e., the Duchesnay Unit in British Columbia, Parker Slate Formation in Vermont, and Kinzers Formation in Pennsylvania). These occurrences demonstrate that early vertebrates were more widespread than previously thought, but remained generally cryptic members of normal Cambrian communities. Continuing fieldwork activities, in particular around the newly discovered Burgess Shale locality in Kootenay National Park, should yield many new discoveries of primitive vertebrates in the future.
Session No. 12 (continued): From macroecology to macroevolution: the ecological context of extinction and origination

Chairs: Seth Finnegan and Carl Simpson

Sunday Afternoon 1:30 PM to 2:45 PM

Session 12-14: Sunday, 1:30 PM
Presenter: Jessica A. Oswald

BIOGEOGRAPHY AND EXTINCTION OF NEW WORLD PASSERINES: EVIDENCE FROM PLEISTOCENE FOSSILS

Oswald, Jessica A., Department of Biology, University of Florida, Gainesville, FL 32611; Steadman, David W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

In the Americas, climate change from the last glacial-to-interglacial transition and overhunting by humans ~12,000 years ago have been implicated in the extinction of as many as 50 genera of large mammals (megafauna). The megafaunal extinctions undoubtedly triggered trophic cascades with broad-ranging implications for New World plant and animal communities. We are just beginning to understand how the distribution and diversity of songbirds (Passeriformes) were affected. Based on our fossil identifications, it seems that songbirds suffered substantial extinction and range contraction at the end of the Pleistocene. This pattern is most evident in the family Icteridae (blackbirds), exemplified by the extinct species *Euphagus magnirostris* first discovered in California and identified by us at two South American fossil sites > 5,000 km away. While the precise causes of extinction may not be directly measurable, it is clear that passerine birds, even ones that had very large ranges, were affected by similar factors that led to the demise of so many other species once dominant during the Pleistocene. Songbird diversity was even higher in the Neotropics in the geologically recent past than it is today.

Session 12-15: Sunday, 1:45 PM
Presenter: William J. Foster

FUNCTIONAL DIVERSITY OF MARINE ECOSYSTEMS FOLLOWING THE LATE PERMIAN MASS EXTINCTION EVENT

Foster, William J., School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA UK; Twitchett, Richard J., School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA UK

The Late Permian extinction event was the largest biotic crisis of the Phanerozoic, with up to 74% of benthic marine invertebrate genera becoming extinct. Understanding biodiversity changes through the Permian–Triassic interval requires more than just taxonomic richness data, however, especially when trying to investigate the impact of changing environments on biota. Paleoenvironmental data used for investigating biodiversity changes through this interval include: alpha diversity, tiering, taxonomic dominance, and biosedimentary fabrics (e.g., ichnofabric index), with each providing a different perspective on the extinction and recovery. In this study, we used two large, vetted genus-level databases of occurrences and range-through data for marine benthic invertebrates, compiled from the literature and supplemented by the Paleobiology Database. Each genus was assigned a score for its motility, feeding, and tiering using established methodologies. Changes in the functional diversity of the benthic fauna were assessed both temporally, through the Late Permian to Middle Triassic interval, and in different paleolatitudes, oceanic settings, and depositional environments. Despite the magnitude of the extinction event, only one mode of life was completely eliminated globally. Using occurrence data alone overestimates the extinction magnitude and loss of functional diversity due to sampling biases and the Lazarus effect. At local and regional scales, functional diversity was dramatically reduced in tropical ecosystems, but those at higher latitudes suffered less change, at least initially. Reef ecosystems and basinal settings were largely vacated across the boundary, but inner shelf settings were less severely affected. These differences further highlight the complexity of ecosystem response to the Late Permian extinction crisis and through the recovery period. The data also serve to highlight where gaps in knowledge of certain depositional settings or regions are biasing our understanding of key intervals in the recovery, such as around the Oleneian/Anisian boundary.

Session 12-16: Sunday, 2:00 PM
Presenter: Hannes Loeser

PERSISTENCE OF EARLY CRETACEOUS CORAL TO EXTANT

Loeser, Hannes, Hermosillo, Sonora, Mexico; Hernández Morales, Héctor, Mexico City, Distrito Federal, Mexico

This talk presents two examples of coral genera (Hexacorallia and Octocorallia) that have persisted from the Hauverivian into the Modern. The genus *Stephanocoloena* was originally described as an extant coral of the Caribbean and the Western Atlantic and was found to occur from the Oligocene on. The occurrences from the Cretaceous of Europe and Asia turned out to belong to other genera. While the genus existed since the Early Cretaceous, its distribution has been limited to the same region where it lives presently—the Caribbean and Western Atlantic. This phenomenon was found during a systematic study of collections and field work: there are several indications from the Aptian to the Cenomanian of Texas (USA), the Aptian and Albian of Sonora (Mexico), the Santonian of the Netherlands Antilles, and the Maastrichtian and Eocene of Peru. Up to the present, the genus has never been found in other areas and there are
no known records from the Central Tethys or from Asia. The
genus, which originated in the Hauterivian of CentralAmerica, never extended its paleobiogeographic distribution
to the east or west. With the opening of the Western Interior
Seaway during the Cenomanian, the sedimentation type
changed in North and Central America from carbonates to
siliciclastics, and the sea-water temperature and salinity
decreased. These changes inhibited coral growth in shallow
marine environments and did not allow further expansion of
the genus, which probably survived in South America and
was distributed to the North again when the Western Interior
Seaway closed during the Campanian. During this time, the
Atlantic Ocean was too wide to allow the genus to migrate
across to distant coasts and it persisted in the eastern waters
of the American continent. The analysis revealed also that the
genus has four extant species and not only one as reported by
the literature. Systematic comparison of type material proved
that the Cretaceous occocorallian genera Polytremacis and
Parapolytremacis are junior synonyms of the extant coral
genus Heliopora. This genus has its first occurrence in the
Hauterivian of the Paris Basin (France). Species diversity
increased until the Late Cretaceous with a worldwide
distribution. The genus shows its highest morphological and
taxonomical diversification between the Cenomanian and
Early Campanian. From the Late Campanian on, diversity
has constantly decreased resulting in only one extant species.
The reasons for the decrease of diversity are difficult to
explain. Today, the coral is restricted to very shallow marine
environments in the tropical zone. The lower sea level and
lower sea water temperatures from the Cretaceous onwards
may have limited the distribution of Heliopora. Since the
dispersal range at least of the extant Heliopora larvae is
known to be low, the closure of the Tethys and the formation
of natural barriers due to the fall in sea level may have
limited much its distribution.

Session 12-17: Sunday, 2:15 PM
Presenter: Jonathan Todd

ESTIMATING SPECIES DURATIONS AND
TURNOVER IN A HYPERDIVERSE NEOGENE
GASTROPOD RADIATION - AN INSIGHT INTO
PATTERNS OF CENOZOIC BIODIVERSITY

Todd, Jonathan A., Department of Earth Sciences, Natural
History Museum, London, UK; Johnson, Kenneth G.,
Department of Earth Sciences, Natural History Museum,
London, UK

The molecular revolution and modern large-scale marine
sampling programs have revolutionized our knowledge of
extant marine diversity. We now know that the magnitude of
species diversity is many times higher than previously
estimated, particularly in the tropics where clades of
morphologically very similar (so-called cryptic) species
abound, and these species are largely found in allopatry.
Unfortunately, so far these insights have had little impact on
Cenozoic invertebrate paleodiversity and taxonomic studies.
Here we present a reexamination of species diversity and
turnover in an extreme case, the hyperdiverse snail Polystira.
This highlights both 1) the importance of paleontology to the
study of adaptive radiations, and 2) the significant challenges
paleontologists face in developing and using realistic rather
than traditional treatments of paleodiversity. The venomous
carnivorous snail Polystira (Neogastropoda: Conoidea)
comprises the largest marine mollusk species radiation in the
Neotropics with perhaps 120 living species and a rich
Neogene fossil record. Here we analyze its patterns of
species richness, origination, and extinction over the past 12
Myr in a small part of its range—the SW Caribbean. Taxic
analysis of 3344 specimens and 112 species shows species
richness and sampling intensity to co-vary over this interval.
Richness is lowest in the Late Miocene, then rises and
remains approximately constant until the Recent, when it
rises sharply. No large peaks in fossil origination rates occur,
though extinction may peak between 2–1 Ma. Well-sampled
extinct species had median durations of 0.8–1.75 Myr.
However, the large majority of species are rare, confined to
one or a few horizons, and have recorded durations of <1
Myr. Polystira shows the fastest species origination rates
recorded among marine gastropods, combined with short
species durations; 94% of living species evolved within the
past 1.6 Myr. This contrasts with apparently longer durations
and slower speculation rates in the famously hyperdiverse
conoidean Conus, but that pattern requires re-study. We
conclude that 1) the fossil record of Polystira may be as well
or even better sampled than the living Caribbean representatives; 2) geographically and temporally short-
ranged species dominate the clade; and 3) estimating ranges
and species diversity will remain challenging due to the long
tail of rarity, typical of tropical marine mollusks today.

Session 12-18: Sunday, 2:30 PM
Presenter: Yuri Kimura

DIFFERENTIAL DENTAL ADAPTATIONS TO
DIETARY CHANGE IN MICE AND RAT LINEAGES
IN THE LATE MIOCENE OF PAKISTAN

Kimura, Yuri, Roy M. Huffington Department of Earth
Sciences, Southern Methodist University, 3225 Daniel Ave.,
Dallas, TX 75275

Evolutionary biologists consider sympatric speciation as one
process in the origin of sister species. However, the
completion of sympatric speciation and progressive
adaptations after the speciation event are difficult to observe
in the timespan of typical empirical studies. Abundant teeth
of murine rodents from the late Miocene of northern Pakistan
represent a fine-scale record of two evolutionary lineages
that diverged from an ancestral species in the region. A
previous analysis of carbon isotopes in molar enamel
demonstrated that the murine rodents experienced a
remarkable C3-C4 dietary shift, corresponding to vegetation
change in the ecosystem. Thus, murine samples from the
region provide a great opportunity to assess adaptive
diversification of dental morphology in sister clades that
appeared through in-situ evolution and diverged in diet. In
this study, I examine morphology of the upper first molar in
two sympatric clades of murine rodents (Karnimata and
Progonomys clades) by 2D geometric morphometric analysis
of tooth outline, morphometric distance of dental characters,
and topographic quantification of 3D tooth models. In the
geometric morphometric analysis, tooth outlines of the two
clades are similar early after sympatric speciation, but
deviate from each other with reduction of overlap area
through time, closely following a phylogenetic hypothesis
proposed in previous studies. Change of tooth outline in the
Karnimata clade is more strongly associated with reduction in spacing between anteroposteriorly positioned cusps and transverse arrangement of cusps. These characters are related to increasing chewing efficiency in a shift to a propalinal direction of mastication in murine rodents. However, in both clades, 3D topographic analysis shows that more derived (and younger) species have average slopes of cusps directed more anteriorly than more basal (and older) species. These results indicate that while both clades adapted to varying amounts of C4 grasses to their diets, selection pressure forcing dental adaptations was differentially greater in the Karnimata clade. In addition, the morphological analyses of this study with carbon isotope data for these two clades fit well with theoretical models of sympatric speciation, suggesting that interspecific resource competition was a probable cause of the sympatric speciation of these murine rodents.

**Session No. 13 (continued): Conservation paleobiology: Ecosystem, community, and species response to environmental change**

**Chairs:** Carrie L. Tyler, Sahale N. Casebolt, and Rebecca Terry

Sunday Afternoon 1:30 PM to 4:45 PM

Session 13-14: Sunday, 1:30 PM
Presenter: Michael Savarese

**STRATEGIES FOR CONNECTING CONSERVATION PALEOBIOLOGICAL RESEARCH TO MANAGEMENT: EXAMPLES FROM GREATER EVERGLADES’ RESTORATION OF SOUTHWEST FLORIDA**

Savarese, Michael, Marine and Ecological Sciences, Florida Gulf Coast University, Ft. Myers, FL 33965; Lytton, Gary, Rookery National Estuarine Research Reserve, 300 Tower Rd., Naples, Florida 34113

Much of the research accomplished by paleontologists can be categorized as conservation paleobiology. Unfortunately, these works often go unrealized or under-appreciated because the environmental professionals best positioned to use those results are disengaged from the scientific process or are completely unaware of the work. Commonly, a research program with management implications is undertaken without briefing the relevant agencies in advance and without their input with respect to research objectives and design. Academics typically work within or among their academic institutions with a predestined pathway toward peer-review publication in scholarly journals. Those papers often go unread by agency professionals, and universities at times of promotion rarely value technical reports. Partnership and collaboration with agencies is essential. Agency professionals have very specific environmental management objectives and priorities, often influenced by resource limitations. Academic scientists should adapt their research programs to accommodate agency research needs and priorities, and be willing to adopt research designs that best achieve agency objectives, even if those agencies are unable to financially support the effort. Often agencies can support research through in-kind match for field and laboratory work, or with research staff assistance. When partnerships are strong, RFPs from state and local governmental agencies can be customized for specific talents found among academics. University scientists and agency professionals in Southwest Florida have developed an appreciation of conservation paleobiology and a culture of cooperation. Effective steps for generating such a productive relationship include: 1) developing and actively participating in “management collaboratives,” working groups composed of agency professionals, university scientists, and NGO professionals with stewardship commitments to their region’s management and restoration needs; 2) attending and presenting conservation paleobiological work at environmental science and restoration conferences; 3) inviting agency professionals to market and solicit their environmental science priorities and then engaging agency representatives as co-investigators in those studies; and 4) reserving time for professional service for those same agencies and NGOs. Universities can incentivize conservation paleobiological research by valuing technical reports as community-engaged scholarship, particularly if the work results in a management decision or practice that helps the environment. Greater Everglades’ restoration efforts have benefitted greatly from conservation paleobiological approaches because of these team-building efforts. A number of examples will be presented.

Session 13-15: Sunday, 1:45 PM
Presenter: Patricia H. Kelley

**FIVE YEAR STUDY USING LIVE-DEAD ANALYSIS OF MOLLUSK ASSEMBLAGES TO ASSESS ANTHROPOGENIC IMPACT ON A NORTH CAROLINA TIDAL FLAT**

Korpanty, Chelsea A., Department of Geography and Geology, University of North Carolina Wilmington, Wilmington, NC 28403; Kelley, Patricia H., Department of Geography and Geology, University of North Carolina Wilmington, Wilmington, NC 28403; Dietl, Gregory P., Paleontological Research Institute, Ithaca, NY 14850; Visaggi, Christy C., Department of Geosciences, Georgia State University, P.O. Box 4105, Atlanta, GA 30302; Parnell, Bradley A., Robeson Community College, 5160 Fayetteville Rd, P.O. Box 1420, Lumberton, NC 28360

We conducted a five-year study of molluscan assemblages from an anthropogenically disturbed tidal flat in North Carolina using live-dead analysis; such studies detect anthropogenic impact by comparing taxonomic composition of the living community to that of the death assemblage. Anthropogenically stressed environments should yield low fidelity (discordance) between living and death assemblages because the time-averaged death assemblage lags behind its living counterpart in responding to environmental change.
Following Kidwell, we hypothesized that anthropogenic impacts should yield discordance between live and dead assemblages sampled at the same time, and that fidelity will be greater between concurrent living and dead assemblages than between living communities sampled in successive years. An intertidal shelly, muddy-sand flat near Masonboro Sound, Wilmington, NC, was sampled in summers 2008–2012, initially as part of a Research Experiences for Undergraduates program. The site was impacted by dredging of the Intracoastal Waterway (since the 1930s) and, more recently, by residential eutrophication and shellfishing. We collected 16 bulk samples each year from the upper 20 cm of sediment over a 200m² area. We used Holland’s Analytical Rarefaction to compare richness of live and dead assemblages. Spearman’s rank correlation coefficient (\(\rho\)) was used to compare rank-order abundance of genera in the living and death assemblages; we also compared death assemblages between years as well as live assemblages between years. Jaccard-Chao taxonomic similarity indices were calculated between live and dead assemblages and plotted against Spearman’s \(\rho\). Five years of sampling yielded 633 live and >20,000 dead bivalve individuals, and 64 live and ~3000 dead gastropods. Rarefaction indicated the death assemblage is enriched compared to the living assemblage in most cases. Contrary to prediction, all yearly analyses for bivalves showed concordance between live and dead assemblages, as did a live-dead analysis combining samples across all five years (\(\rho = 0.7877\)). Spearman’s correlation was also highly significant when gastropod assemblages were combined across five years (\(\rho = 0.5860\)), but samples from 2008, 2009, and 2012 showed live-dead gastropod discordance. Plots of Jaccard-Chao values vs. Spearman’s \(\rho\) place all yearly results within the “pristine” quadrant of the graph, except for the 2008 gastropod assemblage (which contained one live gastropod). Rank correlations are significant for the bivalve and gastropod death assemblages in pairwise comparisons of each collecting year. However, as predicted, most between-year comparisons of live assemblages were nonsignificant for bivalves (rarity of live gastropods precluded live-live comparisons). Live-dead concordance may result from equilibration of the dead assemblage to a post-perturbation state or occur because most taxa are rare in the dead assemblage and absent from the live assemblage.

Session 13-16: Sunday, 2:00 PM
Presenter: Leshno Yael

FIDELITY OF LIVE-DEAD MOLLUSCAN ASSEMBLAGES IN THE ISRAELI MEDITERRANEAN SHELF AS A PROXY FOR ECOSYSTEM MODIFICATION

Leshno, Yael, Department of Geological and Environmental Sciences, Ben Gurion University of the Negev, Beer Sheva, 84105, Israel; Edelman-Furstenberg, Yael, Geological Survey of Israel, Jerusalem, 95501, Israel; Benjamini, Chaim, Department of Geological and Environmental Sciences, Ben Gurion University of the Negev, Beer Sheva, 84105, Israel

Studies of shelly macrofauna by others have associated mismatches between live and dead molluscan assemblage with recent, rapid, anthropogenic changes. The southeastern Mediterranean is naturally highly oligotrophic, but recent urbanization of the Israeli coastal plain has enriched the littoral environment by injection of large amounts of treated wastewater onto the shelf. The largest point source is the Shafdan Wastewater Plant, offshore of Palmahim, Israel. The Shafdan sludge is dispersed in winter by storms and accumulates during summer and fall due to water column stratification. We studied the taxonomy and community structure of modern (sediment-top) death assemblages vs. live-collected mollusk assemblages, from two clean control stations (PL29, PL64) and a polluted site (PL3), near the Shafdan sewage sludge outlet at 35 m water depth. Seasonal variability was captured by box-core sampling in winter (Jan.), spring (May), summer (July) and fall (Nov.) of 2012. Live and dead mollusks were taken from the upper 2 cm of the sediments. A vessel-operated dredge was used to acquire a larger volume of sediment containing live mollusks. A total of 10,938 mollusks from polluted and control stations were collected and analyzed. 76 species were identified, of which 10 account for over 90% of all assemblages. Assemblages are highly dominated by bivalves, with gastropods comprising a maximum of ~9% of total individuals in the death assemblage, and only maximum of ~1% in the live assemblage. Species richness, Shannon-Wiener and Margalef indices are higher in the death assemblages in both control and polluted stations. Cluster analysis shows there are significant differences between live and dead assemblages of all samples, and that live assemblages are further clustered into two seasons, winter and summer. Differences between the live and dead assemblages are statistically significant (ANOSIM, \(R=0.984, p<0.05\)), as well as between seasons within the live assemblages (ANOSIM, \(R=0.652, p<0.05\)). Fidelity of the live to dead assemblage is very high; all species found live were also found dead. Assemblages are dominated by *Corbula gibba*, a cosmopolitan bivalve, which accounts for 20-30% of all individuals. Other common species include *Nucula nitidosa*, *Nuculana pella*, *Abra longicallus*, and *Pitar rudis*. Live-dead comparison of taxonomic composition in both stations, shows a decline in abundance of suspension feeders and rise of deposit feeders in the live assemblage, mainly of *Nuculana pella* and *Nucula nitidosa*. Temperature profiles of the water column show that strong storms in late fall (Nov.) caused early mixing of the water column, creating only two seasons, summer and winter. The storms mixed the water column and dispersed the sludge that accumulated on the seafloor. This may account for the similarity between the control and polluted sites, and within the live and dead assemblages.

Session 13-17: Sunday, 2:15 PM
Presenter: Kelsey M. Feser

ENHANCED RESOLUTION IN LIVE/DEAD MOLLUSCAN FIDELITY STUDIES THROUGH COMPARISONS AMONG MULTIPLE STRATIGRAPHIC INTERVALS

Feser, Kelsey M., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Miller, Arnold L., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Time-averaged death assemblages in shallow marine environments have been examined extensively for use as baseline indicators in areas that have experienced
anthropogenic modification (AM). Most live/dead studies, however, have examined only the top 20–30 centimeters of sediment and compared it en masse to the living fraction. In cases where the degree of sediment mixing is great, this approach may be valid. However, in areas like seagrass beds, where bioturbation is much less extensive, stratigraphic resolution may be enhanced. It may therefore be possible to extract more detailed stratigraphic records of environmental and biotic change in these settings, enhancing the possibility of comparing death assemblages in successive stratigraphic horizons with life assemblages, which would be an advance over previous bulk treatments of death assemblages in many studies. Our field areas are located in nearshore coastal environments around St. Croix, USVI. Many sites around the island have undergone unique and fairly well-documented AM. Seven localities, chosen primarily because of their proximity to sites that have experienced different types of AM along the coastline, were sampled: three on the south shore, and four on the north. All sites were collected from substrates covered by dense seagrass, which tends to inhibit the bioturbating activity primarily of callianassid shrimp; this promotes the preservation of primary sedimentation. At each locality, sampling was conducted every 10 m along transects that were generally 30 m in length; bulk sediments, collected down to 40 cm below the sediment-water interface with a 30 cm-diameter cylindrical template, were extracted using an airlift and sieved in situ through 2 mm mesh. These samples were collected in three discrete depth intervals of ~13 cm each to assess stratigraphic variation in molluscan composition. Taxonomic abundance data were collected from each sample, and data were subjected to nonparametric multidimensional scaling ordination (NMDS) and other multivariate techniques. For the present analysis, each of the seven sites was analyzed individually, and a majority showed fairly well-defined taxonomic changes with depth; the stratigraphically shallowest samples from a given site were often separated from the deepest on the first or second NMDS axis. We hypothesize that these changes reflect temporal biotic changes. We also calculated several metrics of live/dead fidelity using comparisons of the life assemblage with each of the three depth intervals at a station. We predicted that in non-AM environments, the shallowest samples should have the highest fidelity to the living assemblage. However, because of the complex histories of anthropogenic modification at each of these sites, this pattern does not always hold. A full dissection of these results, coupled with a related analysis of environmental variables that exhibit potential anthropogenic influences is ongoing.

Session 13-18: Sunday, 2:30 PM
Presenter: Rowan Lockwood

RECONSTRUCTING POPULATION DEMOGRAPHICS AND PALEOENVIRONMENT OF PLEISTOCENE OYSTER ASSEMBLAGES: ESTABLISHING A BASELINE FOR CHESAPEAKE BAY RESTORATION?

Lockwood, Rowan, Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187; Bonanni, S. I., Michael Baker Jr. Inc., 847 South Pickett Street, Alexandria, VA 22304; Kusnerik, K. M., Department of Geology, University of Georgia, 210 Field Street, Athens, GA 30602; Grant, Amanda N., 923 W. University Avenue Apt 130, Flagstaff, AZ 86001

Populations of Eastern oysters (Crassostrea virginica) in the Chesapeake Bay have declined precipitously in recent centuries due to disease, sediment influx, pollution, and overharvesting. The Pleistocene fossil record provides ample evidence of once-thriving oyster reefs in the mid-Atlantic region. By examining the age distribution, oyster growth rates, population densities, and paleoenvironment of these fossil assemblages, a clearer picture of oyster reefs before human disturbance can be established, which in turn can provide a baseline for modern restoration. This study focuses on five well-preserved Pleistocene oyster deposits in the mid-Atlantic: at Holland Point and Cherry Point (Virginia); Wailes Bluff (Maryland); and Stetson Pit and Lee Creek (North Carolina). Bulk samples were collected from the Holland Point site and obtained from the Virginia Museum of Natural History for the remaining sites. Oyster height, age, and growth rates were measured for 2800 left valves. Age was estimated using two techniques: counting bumps on the medial surface of the hinge, and counting growth lines on bisected hinges. Population demographics were compared to modern oyster populations in the Chesapeake Bay. The Holland Point assemblage, which is the only deposit still accessible for sampling, was dated using amino acid racemization, and the paleoenvironment was reconstructed via isotope geochemistry, shell orientation, and salinity tolerances of associated species. All five Pleistocene deposits were dominated by spat and juvenile oysters to a greater extent than modern reefs despite potential preservational biases against smaller specimens. The maximum age of Pleistocene specimens peaked at thirty years in comparison to six years in the modern bay. Pleistocene growth rates varied widely, presumably according to paleoenvironment. Minimum growth rates for Pleistocene specimens did not differ significantly from modern; however, maximum growth rates for fossil specimens were almost double. Population densities were an order of magnitude greater in the Pleistocene than today. The Holland Point oysters thrived approximately 125 Ka during Marine Isotope Stage 5e. Peak temperature during their growth season was approximately 14.1 +/- 5°C and salinity appears to have ranged between 15–32 ppt. The deposit preserves a shallow-dipping fringing reef running from north to south. The oysters in this deposit appear to have oriented themselves to make use of a variety of paleotidal current directions in the region; notably those following the orientation of the proto-Chesapeake Bay and the proto-Piankatank River. Understanding how Pleistocene oyster assemblages were structured and where they thrived in the past can help provide information needed for restoration today.

Session 13-19: Sunday, 3:15 PM
Presenter: Aaron O’Dea

SIZE-SELECTIVE EVOLUTION IN THE FIGHTING CONCH STROMBUS PUGILIS IN RESPONSE TO PREHISTORIC AND MODERN SUBSISTENCE HARVESTING

O’Dea, Aaron, Smithsonian Tropical Research Institute, Panama City, Panama

Intensive harvesting of the largest individuals from an ecosystem, whether for trophy, nutritional, or economic gain,
can impart strong directional selection to a smaller size at reproduction that is predicted to have significant negative effects on future yield, population structure, fecundity, and growth. Conversely, prehistoric, low-intensity subsistence harvesting is not considered an effective agent of size-selective evolution. Modern, archeological, and paleontological material show that size at maturity in the gastropod *Strombus pugilis* declined significantly from pre-human (~7ka) to prehistoric times (~1ka), and again to the modern period. Size also fell from early to late prehistoric periods synchronous with an increase in harvesting intensity as other resources became depleted. This decline in size at maturity means that the earliest prehistoric harvesters would have received over 50% more meat per conch than modern day harvesters. After exploring the potential effects of selection biases, environmental shifts, and habitat change, these observations collectively implicate prehistoric subsistence harvesting as an effective evolutionary force. Release from harvesting pressure using no-take areas could halt or even reverse deleterious size-selective evolution of this important marine resource.

Session 13-20: Sunday, 3:30 PM
Presenter: Amelinda E. Webb

**SHIFTING BASELINES IN ORDOVICIAN BRACHIOPOD COMMUNITIES—RESPONSE TO MINOR AND MAJOR ENVIRONMENTAL CHANGES**

Webb, Amelinda E., Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada; Leighton, Lindsey R., Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada

Shifting baselines present a challenge in modern conservation efforts; the fossil record is uniquely suited to exploring changing baselines. Here, four different regions from the Late Ordovician are used to compare how brachiopod communities respond to environmental changes of varying magnitudes. Each region represents multiple lithologies within different intervals. Two of the selected regions experienced an extinction pulse, the worst-case scenario of a shifting baseline. The Nashville Dome region (Patzkowsky and Holland, 1999) underwent a regional extinction event in the Late Ordovician, and Anticosti Island records the two extinction pulses of the end-Ordovician mass extinction. In contrast, both the Zhejiang-Jiangxi border region (Yangtze Platform, southern China; Zhan et al., 2002) and the Gelli-grin formation of Wales (Lockley, 1978) do not show evidence of major disturbances. These four regions offer a continuum of environmental changes from background environmental shifts up to environmental disturbances leading to mass extinction, thereby allowing for a comprehensive comparison of how ecological baselines shift during environmental changes. Brachiopod communities were selected for study because of their abundance and high preservation potential. Assemblages within each region were compared using richness, evenness, rank-abundance curves, and ordination (non-metric multidimensional scaling and polar). Each metric was used to ascertain total variation between temporally contiguous communities. Greater amounts of variation indicate a departure from baseline, and sometimes the shifting of a baseline. Different lithologies were associated with different communities and with different amounts of background variation in community structure (Wilcoxon and F-test, p < 0.05), suggesting a baseline for each broad environment/lithofacies, regardless of region. Faunas from the Nashville Dome and Anticosti Island experienced greater variation and distinct trends in community metrics related to the pulses of extinction. More importantly, both faunas from these regions underwent directional shifts of baseline within environmental types, underscoring the disturbances that led to an extinction event. These results suggest shifting baselines can be tracked across environmental changes, and that establishing a baseline in community variation for a broad environmental type allows detection of significant changes in communities and shifting baselines. Paleontological data can offer unique opportunities for conservation research related to the current biodiversity crisis, and Ordovician brachiopod communities are no exception.

Session 13-21: Sunday, 3:45 PM
Presenter: Laura L. Pullum

**ABRASION FROM DAM RELEASE DOES NOT AFFECT MORTALITY IN A FRESHWATER MUSSEL**

Pullum, Laura L., Department of Earth and Planetary Sciences, University of Tennessee at Knoxville, Knoxville, TN 37996; McKinney, Michael L., Department of Earth and Planetary Sciences, University of Tennessee at Knoxville, Knoxville, TN 37996

Over the last 12 years, attempts have been made to reintroduce several species of native mussels into the Pigeon River of Tennessee. All native mussels have been extirpated from this river, but due to recent major improvements in water quality, it is hoped that at least some of these native species will become re-established. Unfortunately, few of the reintroduction efforts seem successful, with one suspected reason being the large hydroelectric dam a few miles upstream. This dam has drastically affected water velocity in the river, causing daily and seasonal variations that often produce extremely rapid currents. Such currents often carry the mussels far downstream and cause abrasion from the numerous large boulders and pebbles in the river bed. Therefore, we tested the hypothesis that shell abrasion of large species may increase physiological stress and increase mortality. We photographed 17 live individuals of the Purple Wartyback (*Cyclonaias tuberculata*) and five recently dead individuals of the same species. We measured abrasion surface area of photos of both valves of each individual using ImageJ software. Average abrasion of live specimens was 21% (standard deviation, st. dev., = 12%) and 18% (st. dev. = 7%) for dead specimens. Statistical testing (t-test, F-test) to compare the abrasion damage between the live and dead populations was not significant, indicating no difference. Regression of abrasion damage between each valve for each live and dead specimen does show a significant correlation pattern, indicating that highly abraded individuals tended to suffer more damage to each valve. Our findings indicate that abrasion from high water velocities from dam release does not seem to be a clear factor in the lack of reintroduction success. Future study will focus on the thermal effects, as bottom-release water is extremely cold, and nutrient depletion (food), as organic matter tends to be retained by such impoundments.

82
ASSESSING TROPHIC IMPACT OF INVASIVE LIONFISH ON MODERN CORAL REEFS WITH LIMITED DATA: A ROLE FOR PALEOECOLOGICAL ANALYSIS IN THE STUDY OF MODERN SYSTEMS

Roopnarine, Peter D., Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA 94118; Hertog, Rachel C., Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616; Bucher, Hugo, Palaeontologisches Institut und Museum, Universität Zurich, Karl-Schmid-Strasse 4, Zurich, Switzerland

ASSESSING TROPHIC IMPACT OF INVASCIVE LIONFISH ON MODERN CORAL REEFS WITH LIMITED DATA: A ROLE FOR PALEOECOLOGICAL ANALYSIS IN THE STUDY OF MODERN SYSTEMS

Roopnarine, Peter D., Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA 94118; Hertog, Rachel C., Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616; Bucher, Hugo, Palaeontologisches Institut und Museum, Universität Zurich, Karl-Schmid-Strasse 4, Zurich, Switzerland

ASSessing trophic impact of invasive lionfish on modern coral reefs with limited data: A role for paleoecological analysis in the study of modern systems

Roopnarine, Peter D., Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA 94118; Hertog, Rachel C., Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616; Bucher, Hugo, Palaeontologisches Institut und Museum, Universität Zurich, Karl-Schmid-Strasse 4, Zurich, Switzerland
These frequencies are a beginning to the pre-dam era baseline that is needed to evaluate and assist in restoration efforts in the NGC.

Session 13-24: Sunday, 4:30 PM
Presenter: Sonja Reich

IDENTIFYING SEAGRASS HABITATS IN THE PAST: A CORNERSTONE FOR THE STUDY OF ECOCLOGICAL RESPONSE TO ENVIRONMENTAL CHANGE

Reich, Sonja, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands; Wesselingh, Frank P., Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands; Renema, Willem, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands

Seagrass meadows are world-wide distributed marine habitats with considerable ecological value. They are characterized by a three-dimensional framework of marine angiosperms and associated macroalgae that support coastal primary production, carbon storage, and biodiversity. Like other marine ecosystems, seagrass meadows are severely threatened by climate change, eutrophication, over-exploitation, and mechanical disturbance. Seagrasses originated in the Late Cretaceous, and it is generally agreed that they maintained their important role throughout their geological history. The deeper understanding of this habitat in the past, including ecological response to small- and large-scale environmental changes, such as climate change and sea-level fluctuations, may help us to identify processes underpinning recent seagrass decline. However, detailed studies on seagrass distribution patterns and habitat responses to environmental changes during the Cenozoic are scarce. Assessments of biodiversity patterns of seagrass-associated organisms through time on global or wide regional scales are lacking. Likely this is due to the challenge of the reliable identification of seagrass meadows in the fossil record. Fossilized seagrasses are rare because marine angiosperms, including their pollen, easily disintegrate. To reliably infer the occurrence of paleo-seagrass vegetation, we rely on indirect indicators, e.g., the presence of fossil organisms that are interpreted as typical for seagrass associations. Mollusks have a high fossilization potential, are diverse and abundant in seagrass meadows, and occupy various ecological niches within the habitat. Therefore they are regarded as good potential indicators for seagrass vegetation. A study on modern shell material at San Salvador, Bahamas, confirms differences between the species composition of seagrass associated gastropods and those from unvegetated sandflats. Furthermore, it is investigated how fossil mollusk assemblages, including species composition, ecology, and isotope signals of shells, can be used to identify seagrass vegetation in the Miocene of Indonesia. In conclusion, mollusk species composition, gastropod feeding-guild composition and, for support, carbon isotope signals are useful indicators for paleo-seagrass. The methods used in this study can be applied to investigate diversity and community dynamics of tropical seagrass ecosystems in the Plio/ Pleistocene and Holocene time intervals as well, potentially capturing first impacts of human interference.

Session No. 14 (continued): The Cretaceous-Paleogene Gondawanan expressway

Chairs: Maria A. Gandolfo and Elizabeth J. Hermsen

Sunday Afternoon 1:30 PM to 2:30 PM

Session 14-11: Sunday, 1:30 PM
Presenter: Steven Manchester

REVISITING THE OLIGOCENE BELÉN FRUIT AND SEED FLORA OF NORTHEASTERN PERU

Manchester, Steven R., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Herrera, Fabiany, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Martinez, Jean-Noel, Instituto de Paleontologia de la Universidad Nacional de Piura, Piura, Peru

In the 1920s, E.W. Berry published an assemblage of permineralized fruits and seeds from the vicinity of a former railway stop known as Belen in the petroleum-rich area near Talara, in northwest coastal Peru. This flora remains important today as the only Paleogene carpoflora known from South America. Prior estimates of the age of the Belén flora ranged from early Eocene to Oligocene, but marine diatoms recovered recently from the same horizon favor an early Oligocene age. The Belén flora provides insight into the vegetation and paleoclimate that occurred in this region prior to the uplift the Andes in western Peru. Newly recovered specimens, together with reexamination of the original specimens, provide the basis for updating the taxonomic composition of the flora. Berry described 33 species, attributed to 24 genera. Some identifications have been revised and new taxa have been recognized, leading to a current inventory of 38 species in 34 genera. Extant families identified with confidence include Palmae, Annonaceae, Euphorbiaceae, Humiriaceae, Icacinaceae, Leeaceae, Vitaceae, and Rutaceae. The prior identifications of Anacardiaceae, Myristiaceae are rejected, while the determinations of Boraginaceae, Cucurbitaceae, Malvaceae, Rubiaceae, and Sapindaceae remain unsubstantiated. Securely identified genera provide insights into the Oligocene vegetation and paleoclimate of this region. These include Ampelocissus, Cissus, Duckesia, Leea, Pyrenacantha, and Vantanea, which are ecologically out-of-place relative to the modern arid vegetation in this part of Peru.

Session 14-12: Sunday, 1:45 PM
Presenter: Luis Felipe Hinojosa
LIGORIO MARQUEZ FORMATION AND CLIMATIC NICHE EVOLUTION OF NOTHOFAGUS

Hinojosa, Luis Felipe, Ecology Department and Institute of Ecology and Biodiversity, Universidad de Chile, Santiago, Chile; Campano, Francisca, Ecology Department and Institute of Ecology and Biodiversity, Universidad de Chile, Santiago, Chile; Carvajal, Francy, Ecology Department and Institute of Ecology and Biodiversity, Universidad de Chile, Santiago, Chile; Quattrochio, Mirta, Departamento de Geología—CONICET, INGEOSUR, Universidad Nacional del Sur, San Juan 670, 8000, Bahía Blanca, Argentina; Pérez, María Fernanda, Ecology Department and Institute of Ecology and Biodiversity, Pontificia Universidad Católica de Chile, Santiago, Chile; Gasiola, Aurora, Institute of Ecology and Biodiversity, Pontificia Universidad Católica de Chile, Santiago, Chile; Nishida, Harufumi, Department of Biological Sciences, Chuo University, Tokyo, Japan; Uemura, Kazuhiko, Graduate School of Science, University of Tokyo, Tokyo, Japan; Yabe, Atsushi, National Museum of Nature and Science, Tokyo, Japan

The relationship between the landmass of the Southern Hemisphere has been broadly highlighted in the literature since Hooker’s times, where Nothofagus is considered key to understand the biogeographical history of the western Gondwanland. The fossil records of Nothofagus species are rich and diverse, recorded especially in Australia, New Zealand, South America, and Antarctica. The oldest record comes from the Upper Cretaceous and was part of the so-called ‘Weddellian Province,’ which dominated the southern polar region (including western Antarctica) by the Campanian through Paleocene. In southern South America, and particularly from the middle Eocene, Nothofagus is present in forest association at mid-latitudes, when cool climatic conditions dominated the area after the early Eocene climatic optimum. The Ligorio Marquez Formation is a terrestrial clastic deposit consisting of fluvial channel, flood plain, and marsh deposits located on the border of Chile and Argentina (46°S). The age of Ligorio Marquez is dated as early Middle Eocene or older, with a K/Ar date of 47.6 ± 0.78, just after the early Eocene climatic optimum, and shows a diverse flora with pollen and leaf remains, including Nothofagus. In this talk, we will show the paleoclimatic reconstruction of Ligorio Marquez using both coexistence approach and leaf physiognomy analysis of the micro and macroflora. These results are compared with our climatic niche reconstruction on Nothofagus phylogeny. Our paleoclimatic reconstruction suggest mesothermal and wet environmental conditions, close to the modern Brassospora subgenus but warmer than the Eocene reconstructed temperature niche. Finally, we propose a broader realized niche to the Eocene Nothofagus with a trend toward narrow niche in the modern taxa, particularly if we consider the modern South American taxa. Stabilizing selection would generate a reduction of the realized niche along the evolutionary history of the genera, given as results the difference observed between fossil and extant Nothofagus.

Session 14-13: Sunday, 2:00 PM
Presenter: Gregg F. Gunnell

NEW MYZOPODIDAE (MAMMALIA, CHIROPtera) FROM THE LATE PALEOGène OF EGYPT AND

THEIR BIOGEOGRAPHIC IMPLICATIONS FOR THE ORIGIN OF NOCTILIONOID BATS

Gunnell, Gregg F., Division of Fossil Primates, Duke Lemur Center, 1013 Broad St., Durham, NC 27705
Simmons, Nancy B., Department of Mammalogy, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024; Seiffert, Erik R., Department of Anatomical Sciences, Stony Brook University, Stony Brook, NY 11794

Myzopodidae is a family of bats today represented by two extant species of the genus Myzopoda that are restricted to the island of Madagascar. These bats possess uniquely derived adhesive pads on their thumbs and ankles that they use for clinging to smooth roosting surfaces. Only one fossil myzopodid has been reported previously, a humerus from Pleistocene deposits at Olduvai Gorge in Tanzania that was tentatively referred to the genus Myzopoda. Field work in the Fayum Depression in Egypt over the past 40 years has produced an extensive assemblage of Eocene and Oligocene fossil vertebrates from the Birket Qaran, Qasr el Sagha, and Jebel Qatrani formations. The Fayum is most famous for the broad diversity of early fossil anthropoid primates (20+ species) found there, but substantial assemblages of other mammals, including representatives of seven families of bats, are also present. Among the bats found at Fayum are a new genus and two new species of Myzopodidae which are by far the oldest known representatives of the family. The type species is represented by four specimens from Quarry I in the early Oligocene Jebel Qatrani Formation, while a second species is known from a single specimen from BQ-2 Quarry in the late Eocene Birket Qaran Formation. Together, these specimens extend the temporal range of Myzopodidae by 36+ million years, and the geographic range by nearly 4000 kilometers. The new genus differs from living Myzopoda in having a relatively longer p5; a p4 that is more elongate and narrow, positioned labially and more closely appressed to p5; m1 and m2 of same length and m3 only slightly reduced in length; m1 with an especially robust and anteriorly angled paraconid; and all molars with more robust labial cingulids. The Oligocene species of Fayum myzopodid differs from the Eocene species in having sub-myotodont lower molars, a relatively larger m3 compared to m2, deeper hypoflexids on m2-3, more steeply sloping entocristids on m2-3, and m2 with a more robust, distinct, and anteriorly-oriented paraconid. Many molecular phylogenetic analyses place Myzopodidae as the sister group to all other bat groups included in the super family Noctilionoidea. In these analyses, Mystacidae, now restricted to New Zealand but previously documented based on Miocene fossils from Australia, is the sister group to other noctilionoids exclusive of myzopodids. All other noctilionoids (Thyropteridae, Furipteridae, Noctilionidae, Mormoopidae, and Phyllostomidae) are found exclusively in southern North American and Central and South America today. The new Fayum myzopodids, along with previously described bats from North Africa and Australia, suggest that eastern Gondwana (Africa, Australia, and Antarctica) played a critical role in the origin and diversification of the chiropteran superfamily Noctilionoidea.

Session 14-14: Sunday, 2:15 PM
Presenter: Donald Prothero
NEW LATE MIOCENE DROMOMERYCINE ARTIODACTYL FROM THE AMAZON BASIN: THE PANAMA LAND BRIDGE WAS OPEN AT 10 MA

Prothero, Donald, Natural History Museum of L.A. County, 900 Exposition Blvd., Los Angeles, CA 90007; Beatty, Brian L., NYIT College of Osteopathic Medicine, Old Westbury, NY 11568 Campbell, Kenneth C., Natural History Museum of L.A. County, 900 Exposition Blvd, Los Angeles, CA 90007; Frailey, C. David, Department of Human Sciences, Johnson County Community College, 12345 College at Quivera Road, Overland Park, KS 66210

A new dromomerycine palaeomerycid artiodactyl, Surameryx acrensis n. gen., n. sp., from upper Miocene deposits of the Amazon Basin, documents the first and only known occurrence of this Northern Hemisphere group in South America. Osteological characters place the new taxon among the earliest known dromomerycine artiodactyls, most similar to Barbouroameryx trigonocornerus, which lived in North America during the early to middle Miocene, 20–16 Ma. Although it has long been assumed that the Great American Biotic Interchange (GABI) began with the closure of the Isthmus of Panama in the late Pliocene, or ~3.0–2.5 Ma, the presence of this North American immigrant in Amazonia is further evidence that terrestrial connections between North America and South America through Panama existed as early as the early late Miocene, or ~9.5 Ma. This early interchange date was previously indicated by approximately coeval specimens of proboscids, peccaries, and tapirs in South America and ground sloths in North America. Although palaeomerycids apparently never flourished in South America, proboscids thrived there until the end of the Pleistocene, and peccaries and tapirs diversified and still live there today.

Session No. 16: Diversity, origination, and extinction

Chairs: Kristopher Rhodes and Blaine Schubert
Sunday Afternoon 3:15 PM to 4:45 PM

Session 16-1: Sunday, 3:15 PM
Presenter: Kristopher Rhodes

WHAT'S THE WORTH OF A TAXON? MODERN AND FOSSIL COMATULID CRINOIDs

Rhodes, Kristopher J., Earth and Environmental Sciences, 1100 N. University Ave., University of Michigan, Ann Arbor, MI 48109; Baumiller, Tomasz K., Earth and Environmental Sciences, Museum of Paleontology, University of Michigan, 1109 Geddes Ave, Ann Arbor, MI 48109

The fossil record of the comatulid crinoids is depauperate compared to the modern, with ten times higher generic diversity in the modern. Fossil and Recent comatulid species and genera are incommensurate, with fossil taxa largely described from a single element, the centrodorsal, while modern ones are described largely based on arms/pinnules and, more recently, molecular data. To solve the problem of incommensurate data, we apply the same discrimination method, Bayesian finite mixture analysis on shape data, to the centrodorsals of modern and fossil taxa. Using this method, four subgroups are identified within the modern Promachocrinus kerguelensis/Florometra mawsoni species complex, which are divided into two species in two genera based on traditional taxonomy, and as many as seven clades based on genetic characters. Fossil Jaekelometra, traditionally placed into one or two species, is best described as a single group via the Bayesian analysis on shape of the centrodorsal. Several other modern taxa are best described as a single group based on centrodorsal characters. While questions still remain about the relationship of modern and fossil taxa, these results show one group that is differentiated into more groups by centrodorsal shape than by traditional taxonomic characters. This suggests that the characters of the arms and pinnules used by neontologists need not always produce greater taxonomic resolution than those of the centrodorsal available to paleontologists, and that the differences in taxonomic practice alone are unlikely to be the sole explanation for the extremely high diversity of modern compared to fossil comatulids.

Session 16-2: Sunday, 3:30 PM
Presenter: Matthew Campbell

MOLLUSCAN FAUNAS OF THE ASHLEY FORMATION AND CHANDLER BRIDGE FORMATION (OLIGOCENE), CHARLESTON, SOUTH CAROLINA

Campbell, Matthew, Department of Physical Science, Charleston Southern University, 9200 University Blvd., Charleston, SC 29406

The molluscan faunas of the marine Ashley Formation and Chandler Bridge Formation around Charleston, South Carolina, have received little study. In the early literature, these beds were assigned ages from Eocene to Miocene. More recent papers have assigned these beds to NP 24 in the middle Oligocene, and described the vertebrate faunas. The Ashley Formation has a published fauna of 31 genera of Bivalvia, 11 genera of Gastropoda, and one genus of Scaphopoda. Curation of Charleston Museum collections and field work are providing new specimens from these strata. Preliminary identifications add one genus of Bivalvia and six genera of Gastropoda to the fauna of the Ashley Formation, and five genera of Bivalvia and two genera of Gastropoda to the fauna of the Chandler Bridge Formation. These specimens will more completely establish the molluscan faunas, and allow better comparisons with other Oligocene faunas.

Session 16-3: Sunday, 3:45 PM
Presenter: Joshua Doby

FOSSIL INSECTS OF THE GRAY FOSSIL SITE
SESSION 16-4: SUNDAY, 4:00 PM

Presenter: Jim L. Mead

LEPTOBOS (ARTIODACTYLA, BOVIDAE) FROM RENZIDONG CAVE, EARLY PLEISTOCENE (NIHEWANIAN) OF ANHUI, CHINA, AND AN OVERVIEW OF THE GENUS

Mead, Jim L., Department of Geosciences and Don Sundquist Center in Paleontology, East Tennessee State University, Johnson City, TN 37614; Jin, Changzhu, Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, 100044, China; Wei, Guangbiao, Chongqing Three Gorges Institute of Paleontology and Paleoanthropology, China Three Gorges Museum, Chongqing, 400015, China; Sun, Chengkai, Shandong Museum, Jinan, 250014, China; Wang, Yuan, Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, 100044, China; Swift, Sandra, L., Department of Geosciences and Don Sundquist Center of Excellence in Paleontology, East Tennessee State University, Johnson City, TN 37614; Zheng, Longting, Anhui Museum, Hefei, 230061, China

Leptobos (Artiodactyla, Bovidae, Bovini) was a bovine occupying mid-latitudes of Europe east through to eastern China. A number of species of Leptobos are described, with the greatest number occupying southern Europe. Here we report on L. crassus from Renzidong Cave, Anhui, China, and its relation to other species. There is an established variation in size between the various species, with L. furvis the smallest (slightest). The most robust overall is L. crassus; however, there is overlap in size of this species with L. bravardi and L. etruscus. Leptobos existed only during the middle/late Pliocene to middle Pleistocene; thus, it is a diagnostic taxon for the Villafranchian–Nihewanian land mammal ages of Europe and China. Leptobos occupied relatively open habitats and filled a grazing niche within the environment, although in eastern China (Renzidong Cave), it may have lived in a mixed forested grassland. The combination of size, environment, and distribution of Leptobos in greater Eurasia drastically alters with the climatic and environmental deterioration that takes place in the middle Pleistocene; its demise seems tied to this cooling event that launches habitats into the glacial episodes. Leptobos in its niches, or at least similar grazing niches, throughout it distribution in the early Pleistocene is replaced by the larger bovine, Bison, and in its more southern distribution, by Bubalus and Bos (including Bibos).

Session 16-5: Sunday, 4:15 PM

Presenter: Blaine Schubert

NEW FOSSIL RECORDS OF EARLY ALLIGATOR BRIDGE THE TEMPORAL GAP BETWEEN THE AMERICAN MIDWEST AND SOUTHEAST

Schubert, Blaine W., Department of Geosciences, East Tennessee State University, 325 Treasure Lane, Box 70357, Johnson City, TN 37614; Hastings, Alexander K., Martin Luther University, Halle-Wittenberg, Germany

Extant alligators have a disjunct distribution, with Alligator mississippiensis in the Southeast of North America, and A. sinensis in eastern Asia. The earliest Alligator fossils are from South Dakota and Nebraska, and range in age from late Eocene to early Oligocene. Thus, discussions on the origin of this group have focused on these upper Midwestern localities. Previously, the earliest records of Alligator in southeastern North America dated to the early Miocene with Alligator olsoni from Thomas Farm, Florida. Alligator material from two additional Florida sites reported here fill in the temporal gap between the American Midwest and Southeast. Scant but diagnostic fossils from the late Oligocene Brooksville 2 site are the oldest Alligator remains in the Southeast. Abundant Alligator specimens from the early Miocene Miller site represent a new diminutive species. Based on the mammalian fauna this site is considered to be approximately one million years older than Thomas Farm. The new taxon is closely related to A. mcgregori, with a unique combination of morphological characters, expanding the early diversity of Alligator. Phylogenetic analysis using 34 alligatorid taxa and 181 characters recovered 4,968 equally parsimonious cladograms. The strict consensus of this analysis placed the new species within a polytomy at the base of Alligator. However, an Adams consensus placed the new taxon as derived relative to a polytomy of A. prenasalis and A. mcgregori from the Midwest. The new taxon was placed basal to all other Alligator, with the next most derived form being Alligator olsoni from Florida, thus also bridging the morphological gap between early Alligator of the Midwest.
and Southeast. In addition, remains of this remarkably small new taxon were recovered with fragmentary fossils of a larger *Alligator* species at the Miller site. Thus, this record represents the first potential evidence of sympathy between different types of alligators. In sum, these discoveries indicate: 1) *Alligator* occurred in the Southeast United States millions of years earlier than previously known, 2) a more expansive early biogeographic range of *Alligator*, 3) early *Alligator* diversity was higher than previously realized, and 4) more than one *Alligator* species co-occurred in the early Miocene of Florida, and may represent the first example of niche partitioning in the genus.

Session 16-6: Sunday, 4:30 PM  
Presenter: Rashmi Srivastava  
**GONDWANAN ORIGIN OF SOME ANGIOSPERMS AND THEIR OUT OF INDIA DISPERSAL**  
Srivastava, Rashmi, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow, 226007, India

Session No. 17: Morphological Patterns  
*Chairs:* Kristin Polizzotto and Troy Dexter  
Sunday Afternoon 3:15 PM to 4:45 PM

Session 17-1: WITHDRAWN  
Presenter: Carol V. Ward  
**DIET AND MORPHOLOGY IN THE EVOLUTION OF EARLY AUSTRALOPITHECUS**  
Ward, Carol V., Pathology and Anatomical Sciences, University of Missouri, M263 Medical Science Building, One Hospital Drive, Columbia, MO, 65212

Ever since the discovery of *Australopithecus* in 1925, the ability to process a diverse array of dietary foods has been considered a hallmark of the origins of the *Australopithecus*—human clade. The ability to fall back on hard or tough foods is thought to have afforded early hominids the ability to exploit a variety of habitats, especially the expanding open woodlands and grasslands in East Africa during the early Pliocene, underlying the success of the australopith radiation. The earliest *Australopithecus* species is *A. anamensis*, known from 4.2–3.7 Ma. It is generally thought of as representing the early part of an anagenic lineage leading to *A. afarensis*, known from 3.7–2.9 Ma. *Australopithecus anamensis* and *A. afarensis* are broadly similar morphologically, and were originally thought to have shared a similar set of dietary adaptations. However, recent stable carbon isotope data reveal a significant difference in foods ingested, with *A. anamensis* consuming an almost pure C₃ diet, whereas *A. afarensis* consumed a range of C₃ and C₄ foods. This paper compares the dentognathic morphology of *A. anamensis* and *A. afarensis* in light of these new data on their dietary behaviors. These species display significant morphological differences associated with an increasing ability to process harder and/or tougher foods in *A. afarensis*, and perhaps changes in digestive behaviors. These data suggest that *A. anamensis* may not have exhibited a typical australopith diet, and Raises questions about the role of diet in australopith origins and the relationships between diet, morphology, and paleoecology.

Session 17-2: Sunday, 3:30 PM  
Presenter: Gregory M. Erickson  
**COMPLEX DENTAL STRUCTURE AND WEAR BIOMECHANICS IN HADROSAURID DINOSAURS**  
Erickson, Gregory M., Department of Biological Science, Florida State University, 319 Stadium Drive, Tallahassee, FL 32306; Krick, Brandon A., Department of Mechanical Engineering and Mechanics, Lehigh University, 19 Memorial Drive West, Bethlehem, PA 18015; Norell, Mark A., Division of Paleontology, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024; Sawyer, W. Gregory, Department of Mechanical and Aerospace Engineering, University of Florida, 231 MAE-A Building, P.O. Box 116250, Gainesville, FL 32611

Mammalian grinding dentitions are composed of four major tissues that wear differentially, creating coarse surfaces for pulverizing tough plants and liberating nutrients. Although such dentition evolved repeatedly in mammals (such as horses, bison, and elephants), a similar innovation occurred much earlier (~85 million years ago) within the duck-billed dinosaur group Hadrosauridae, fueling their 35-million-year occupation of Laurasian megaherbivorous niches. How this complexity was achieved is unknown, as reptilian teeth are considered a hallmark of the origins of the *Australopithecus*–*Homo* clade. The ability to process a diverse array of dietary foods has been considered a hallmark of the origins of the human clade. The ability to fall back on hard or tough foods is thought to have afforded early hominids the ability to exploit a variety of habitats, especially the expanding open woodlands and grasslands in East Africa during the early Pliocene, underlying the success of the australopith radiation. The earliest *Australopithecus* species is *A. anamensis*, known from 4.2–3.7 Ma. It is generally thought of as representing the early part of an anagenic lineage leading to *A. afarensis*, known from 3.7–2.9 Ma. *Australopithecus anamensis* and *A. afarensis* are broadly similar morphologically, and were originally thought to have shared a similar set of dietary adaptations. However, recent stable carbon isotope data reveal a significant difference in foods ingested, with *A. anamensis* consuming an almost pure C₃ diet, whereas *A. afarensis* consumed a range of C₃ and C₄ foods. This paper compares the dentognathic morphology of *A. anamensis* and *A. afarensis* in light of these new data on their dietary behaviors. These species display significant morphological differences associated with an increasing ability to process harder and/or tougher foods in *A. afarensis*, and perhaps changes in digestive behaviors. These data suggest that *A. anamensis* may not have exhibited a typical australopith diet, and raises questions about the role of diet in australopith origins and the relationships between diet, morphology, and paleoecology.
hadrosaurids broke from the primitive reptilian archetype and evolved a six-tissue dental composition that is among the most sophisticated known. Three-dimensional wear models incorporating fossilized wear properties reveal how these tissues interacted for grinding and ecological specialization.

Session 17-3: Sunday, 3:45 PM
Presenter: Casey M. Holliday

TRIGEMINAL NERVE MORPHOLOGY IN ALLIGATOR MISSISSIPPIENSIS AND ITS SIGNIFICANCE FOR CROCODYLIFORM FACIAL SENSATION

Holliday, Casey M., Integrative Anatomy, University of Missouri, M263 Medical Science Building, One Hospital Drive, Columbia, MO 65212; George, Ian D., Integrative Anatomy, University of Missouri, M263 Medical Science Building, One Hospital Drive, Columbia, MO 65212

Extant crocodilians evolved a derived sense of face touch, in which numerous trigeminal nerve-innervated dome pressure receptors speckle the face and mandible and sense mechanical stimuli. However, the morphological features of this system are not well known, and it remains unclear how the trigeminal system changes during ontogeny and how it scales with other cranial structures. Finally, when this system evolved within crocodyliforms remains a mystery. Thus, new morphological insights into the trigeminal system of extant crocodilians may offer new paleontological tools to investigate this evolutionary transformation. A cross-sectional study integrating histological, morphometric, and 3D imaging analyses was conducted to identify patterns in cranial nervous and bony structures of Alligator mississippiensis. Nine individuals from a broad size range were CT-scanned followed by histomorphometric sampling of mandibular and maxillary nerve divisions of the trigeminal nerve. Endocast volume, trigeminal fossa volume, and maxillomandibular foramen size were compared with axon counts from proximal and distal regions of the trigeminal nerves in order to identify scaling properties of the structures.

The trigeminal fossa has a significant positive correlation with skull length and endocast volume. We also found that axon density is greater in smaller alligators and total axon count has a significant negative correlation with skull size. Six additional extant and fossil crocodyliforms were included in a supplementary scaling analysis, which found that size was not an accurate predictor of trigeminal anatomy. This suggests that phylogeny or somatosensory adaptations may be responsible for the variation in trigeminal ganglion and nerve size in crocodyliforms.

Session 17-4: Sunday, 4:00 PM
Presenter: Kristin Polizzotto

ORGANIC ORIGIN OF PSEUDOSUTURES IN LATE CRETAEOUS AMMONITES

Polizzotto, Kristin, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024; and Department of Biological Sciences, Kingsborough Community College, Brooklyn, NY 11235

Pseudosutures are markings found on the inner shell surface or steinkern of numerous coiled ammonoid fossils, and have often been used in interpretations of growth patterns. Recently, pseudosutures have been described in uncoiled baculitid ammonoids as well, with morphological patterns similar to those found in coiled ammonoids. Therefore, it is hypothesized that baculitid pseudosutures had a similar origin and function in both groups. Previous work in other ammonoid groups suggests that the animals produced an organic secretion that coated the entire inner surface of each chamber, and that pseudosutures were composed of ridges of this secreted substance that accumulated during pauses in the forward movement of the animal within the body chamber. Thus, the number and spacing of pseudosutures may provide significant information about the pace and timing of chamber formation. However, the question remains as to whether baculite pseudosutures were originally organic or mineralized structures. Knowledge about their composition may shed additional light on pseudosuture origin and function. In this presentation, I present research exploring the elemental composition of pseudosutures in Baculites sp. from the upper Owl Creek Formation at its type locality in Tippah County, Mississippi. Energy dispersive spectroscopy indicated phosphorus enrichment (8–10 weight %) in pseudosutures, as well as on the septal surface and inner shell surface. This result supports the idea that the animal produced chamber linings and pseudosutures from a single secretion, that the secretion was originally organic, and that it was secondarily mineralized following the death of the animal. If they were indeed an organic secretion, the frequent preservation of pseudosutures is striking given that soft-tissue preservation is extremely rare in ammonoids, and raises an interesting taphonomic question for future study.

Session 17-5: Sunday, 4:15 PM
Presenter: Caroline E. Rinaldi

GROWTH RATES IN GIANT BEAVER INCISORS INFERRED FROM PERIRADICULAR BANDING REVEALS ATYPICAL FEEDING BIOMECHANICS

Rinaldi, Caroline E., University of Missouri-Kansas City School of Medicine, Kansas City, MO 64108

Periradicular bands are incremental structures seen on the external dentin surfaces of rodent incisors. These structures reflect circadian developmental rhythms in dentin formation. Measurements of the increments located between these bands along the longitudinal axis of the tooth can be used to infer the eruption and wear rates of the incisor. In this study, average eruptive growth rates were calculated from periradicular bands on the incisors of beavers representing four taxa. Teeth from three fossil taxa and the Recent Castor canadensis were examined for comparison. The specimens included 13 Dipoides incisors, six Procastoridae incisors, 11 Castoridae incisors, and 40 C. canadensis incisors. Distances between all periradicular bands were measured in sequence in all 70 teeth (= 6000 incremental measurements), and the average growth rates and inferred wear rates determined. Despite large differences in overall incisor size among the rodents in the four taxa, average growth rates for all individual specimens fell within the range of rates found among the 40 C. canadensis specimens. These results indicate the absence of a linear relationship between incisor growth rates and rodent body size. The growth rates of C.
canadensis and Dipoides followed a pattern typical for rodents: lower incisors grew significantly faster than upper incisors. However, a surprising finding was that the upper incisors of Procastoroides and Castoroides grew faster than their lowers, a relationship presently undocumented for any other rodent species. In most rodents, upper incisors are used as an anchor while lower incisors are used for the gnawing power stroke. This system subjects the lowers to higher rates of wear during gnawing than the uppers, and necessitates the lowers growing faster to counter their greater wear. Increased upper incisor growth rates relative to lower incisor growth rates in giant beavers (Procastoroides and Castoroides) suggests their incisor use differed mechanically from that typical of rodents.

Session 17-6: Sunday, 4:30 PM
Presenter: Meghan A. Balk

**BODY SIZE CHANGE OF CARCHAROCLES MEGALODON THROUGH TIME IN COMPARISON WITH CONTEMPORANEOUS MARINE MEGAFAUNA**

Balk, Meghan A., Department of Biology, University of New Mexico, 167 Castetter Hall, MSC03 2020 1, University of New Mexico, Albuquerque, NM 87131; Pimiento, Catalina, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Body size is a universal measure of all organisms, and is intrinsically related to an organisms’ ecology. Metabolic rate, generation time, and trophic level have previously been shown to scale with body size in some taxa. These relationships can be used to broadly characterize ecologies of past animals. Paleomarine megafauna are understudied, yet underwent reorganization in response to both climatic change and extinction of apex predators, which is similar to problems facing modern marine ecosystems. Here, we explore body-size estimates for Carcharocles megalodon, test the evolution of body size in C. megalodon, and compare trends in body-size change of C. megalodon to that of other marine megafauna. From eight museums, we collected records of C. megalodon with a temporal span from middle Miocene through late Pliocene. Ultimately, we seek to understand fundamental characteristics of the paleoecology of this marine apex predator, as well as community-level changes in body-size distributions in the marine realm. Future research will explore how these marine communities changed in response to the extinction of C. megalodon in conjunction with other global abiotic changes, and how these patterns compare to modern ocean disturbances.
FIRST EVIDENCE OF CORAL-INHABITING GALL CRABS (CRYPTOCHRIRIDAE) FROM THE FOSSIL RECORD

Portell, Roger W., Division of Invertebrate Paleontology, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Klompmaker, Adiël A., Division of Invertebrate Paleontology, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Members of the brachyuran crab family Cryptochiridae, commonly known as gall crabs, are small, fragile, parasitic crabs that live on the surface of or in shallow depressions of modern scleractinian corals. Depending on the species of cryptochirid, either galls or most often open pits (domiciles) are formed on/in the coral host. Domiciles are typically circular, oval, or crescent in shape depending on the crab species. Worldwide, the family consists of 47 species arranged in 21 genera. Until now, fossil remains or evidence of the domiciles of this unique decapod family has not been reported. We provide the first evidence for the presence of cryptochirids in the fossil record. Two quarries (GKK and Star Ranch) both in Palm Beach County, southeastern Florida, which are excavated almost exclusively for early to middle Pleistocene marine shells, produced a total of five Scleractinia coralla, each with one to ten crescentic cryptochirid domiciles without the remains of the crabs inside. These domiciles occurred predominately in specimens of Siderastrea hyades. However, one corallum of Siderastrea siderea also exhibits these domiciles. Today, both coral genera inhabit the circum-Caribbean region, with S. hyades preferring turbid environments and S. siderea preferring shallow reef habitats. Two cryptochirid species are known from modern shallow-marine habitats around Florida: Troglocarcinus coralicola and Opecarcinus hypostegus. Both crabs form crescentic cavities. Thus, these crabs are considered to be the most likely causes of the crescent-shaped pits in the Pleistocene corals. Detailed examination of Neogene and Quaternary coral collections may yield further examples of domiciles of this very unusual family of crabs.

FOSSIL GORGONIAN (OCTOCORALLIA) HOLDFASTS AND AXES FROM THE UPPER EOCENE OCALA LIMESTONE OF FLORIDA

Starmer, John, Division of Invertebrate Zoology, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Portell, Roger W., Division of Invertebrate Paleontology, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Gorgonian octocorals, commonly referred to as sea fans or sea whips, can be a conspicuous component of modern Atlantic and Caribbean hard-bottom environments, such as coral reefs. Gorgonians are comprised of a fleshy body,
typically reinforced with minuscule calcareous sclerites, supported on a proteinaceous central axis that may be more or less calcified. Upon death, the remains of these organisms quickly dissociate. Outside of calcareous spicule microfossils, scattered reports of fossil gorgonians are of holdfasts (the attachment point of the axis to the seafloor) or portions of the axis itself. Here we report on the abundant occurrence of holdfast and axis remains of at least two gorgonian forms from the upper Eocene Ocala Limestone of Florida. Relatively smooth, laminar holdfasts, attached to hard substrate, resemble those reported from the mid-Eocene of Texas and lower Oligocene of Mississippi. A uniquely ornamented holdfast with a grooved and pocked surface is reported for the first time. Abundant rounded axis fragments, some with opposing grooves, were collected with holdfasts, but cannot be unequivocally associated with specific holdfast forms. Furthermore, the occurrence of branching in grooved axes casts doubt on previous identifications of similar fossils as sea pens (Graphularia, Pennatulacea).

Session 18-Poster 30: Sunday, 4:45 PM
Presenter: Kurt Auffenberg

A REVISION OF THE FLORIDA OLIGOCENE TO MIocene LAND SNAILS ASSIGNED TO HYPERAULAX (GASTROPODA: ODONTOSTOMIDAE)

Auffenberg, Kurt, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Slapcosky, John, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Portell, Roger W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Orthalicoid terrestrial snails recorded from the upper Oligocene to lower Miocene Tampa Member of the Arcadia Formation (Hawthorn Group) of southern Florida and St. Marks Formation of northern Florida are reviewed. These taxa, previously allocated to the genus Hyperaulax Pilsbry, 1897 (Odontostomidae), will be reassigned to a new genus of Bulimulidae on the basis of a distinctive suite of morphological characters, particularly those of the peristome and the embryonic whorl sculpture. Examination of all type material of the fossil taxa historically assigned to Hyperaulax reveals that only three species are separable (Partula americana Heilprin, 1886, Bulimulus americanus wakullae Mansfield, 1937, and Bulimulus floridanus Conrad, 1846). The status of B. americanus wakullae from northern Florida is problematic. Although clearly not conspecific with P. americana, it will be tentatively assigned to the new genus. Fossiliferous deposits in North America and South America have not yielded taxa with the combination of shell characters found in the new genus and relationships with other bulimulid genera are unknown. However, it is probable that the new genus, like other non-marine mollusks from the Tampa Member of the Arcadia Formation, dispersed to Florida after contact between the Caribbean Plate and the Bahama Platform (~38 Ma).

Session No. 19: Morphological patterns (poster session)

Sunday Afternoon 4:45 PM to 5:45 PM
Session No. 20: Reconstructing past continental environments from the biogeochemistry of fossils (poster session)
Sunday Afternoon 4:45 PM to 5:45 PM

Session 20-Poster 32: Sunday, 4:45 PM
Presenter: Nicole Little

STABLE ISOTOPE DIFFERENCES AMONG THREE MODERN, SYMPATRIC LAND SNAIL SPECIES AND THE PALEOENVIRONMENTAL SIGNIFICANCE

Little, Nicole, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Macias, Guadalupe, Universidad de Cordoba, Cordoba 14071, Spain; Yanes, Yurena, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Stable isotope values found in land snail shells can help gauge what the surrounding environment was like while the snail was alive and forming its shell. It is thus becoming more common that snail shells found in paleontological and archaeological sites are being used as paleoenvironmental proxies. Some studies have suggested that different species of snails, from the same area and time frame, collect the same environmental data whereas others indicate that different species may record differing stable isotope values. In this study, three species of modern sympatric snail shells were collected from Sierra Elvira (Granada, Spain) for stable isotope analysis, and their isotopic composition was used to evaluate potential environmental differences among them. The species included the omnivorous Rumina decollata (n=7), the herbivorous Iberus gualtierianus (n=9), and the herbivorous and xerophilous Sphincterochila candidissima (n=8). Though all three species were modern and sympatric, they showed notably different stable isotope values for both δ13C and δ18O within their shells. Rumina showed the lowest values of the three species (−9.3±1.2‰ and −1.1±0.8‰ respectively), Sphincterochila showed the highest values (−4.7±1.1‰ and +2.1±0.6‰ respectively), and Iberus showed values in between the two other species (−7.7±0.6‰ and +0.5±0.7‰ respectively). Xerophilous Sphincterochila showed higher stable isotope values because it has developed a physiological mechanism to minimize water loss through evaporation, which allows it to be active during drier conditions (in the daytime or dry seasons). On the other hand, we can infer that omnivorous Rumina showed the lowest stable isotope values because it creates its shell in wetter conditions (throughout the night or rainy seasons). This study shows how three different land snail species from the same time frame and area have notably different stable isotope values because of differing biological behaviors. In conclusion, it is imperative that we understand the biological behaviors of snail species before we use those species for paleoenvironmental inferences. Not knowing the biological behaviors of the species, and just using multi-taxa stable isotope values, could bias inferences of past environments.

Session 20-Poster 33: Sunday, 4:45 PM
Presenter: Nasser M. Al-Qattan

INTERPRETATION OF OXYGEN ISOTOPIC VALUES

OF NORTH AMERICAN LAND SNAILS

Al-Qattan, Nasser M., Department of Geology, Miami University, 114 Shideler Hall, 501 East High St., Oxford, Ohio 45056; Rech, Jason A., Department of Geology, Miami University, 114 Shideler Hall, 501 East High St., Oxford, Ohio 45056; Pigati, Jeffrey S., U.S. Geological Survey, 520 N. Park Avenue, Tucson, AZ 85719; Nekola, Jeffrey C., Department of Biology, University of New Mexico, MSC03 20201 University of New Mexico Albuquerque, NM 87131; Yanes, Yurena, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Land snails are highly abundant and diverse in both the modern world and the Quaternary fossil record, occupying a wide range of climatic regimes and environments. Their aragonitic shells incorporate oxygen isotopes as they grow, principally from environmental water. Previous studies on modern systems have found a positive relationship between the δ18O values of the precipitation and the shell. However, this relationship seems to break down in colder environments and high latitude areas, where snails generally exhibit higher δ18O values than expected. Moreover, preliminary δ18O values reported here on Last Glacial Maximum (LGM) snails from North America, as well as published values on LGM snails from Europe, are higher than expected if indeed the δ18O values of the precipitation and the air temperature were the main controls on the isotopic composition of the shell. These findings suggest that other environmental parameters, such as the δ18O values of the water vapor and the relative humidity, may, at least in part, affect the δ18O values of the shell. This study investigates the oxygen isotopic composition of terrestrial gastropod shells from several modern taxa along a north-south gradient in North America (from 24° to 58° N) to further understand the environmental controls on shell δ18O values. Measured shell δ18O values are compared to observed δ18O values of precipitation, and to shell δ18O values predicted by a published flux balance model that incorporates four environmental variables (i.e., δ18O values of rain and water vapor, temperature and relative humidity). Finally, the shell δ18O values of late Pleistocene fossil sequences from areas where past climate and environmental changes are well known are presented to discuss their potential for recording past environmental changes in the continental fossil record of North America.
Stable isotope analysis has proven to be a powerful analytical tool for understanding paleoecology in both modern and ancient ecosystems. Many studies concentrate on determining ecology in (paleo)ecosystems that contain both C3 and C4 plants due to the large differences in 13C/12C incorporated into plant tissues as the results of their utilizing different photosynthetic pathways, and the subsequent incorporation of these values up the food chain. Studies concentrating on ecosystems that are dominated by C3 plants are rarer. However, C3-dominated ecosystems are typical today as well as in the past. In fact, ecosystems with a measurable abundance of C4 plants only become apparent after about 7 million years ago worldwide. One area where a better understanding of C3-dominated ecosystems is needed is within Europe during the Pleistocene. Having an understanding of paleoecology within Pleistocene European localities is critical for understanding mammalian evolution, including human evolution, as well as the effects of climate change on paleoecosystems. Although there have been many isotopic studies on Pleistocene European sites, there has been a limited isotopic framework for understanding this data within Europe during this time period. Here we present isotopic data from mammals collected in Parque Natural de El Hosquillo (Hosquillo Natural Park, Cuenca, Spain) with the aim of providing a framework for understanding the isotopic values of more ancient mammals in Europe. Samples of scat, hair, bone apatite, bone collagen, and tooth enamel were collected from over 100 individuals and were sampled for δ13C, δ15N, and δ18O values, depending on the type of tissue sampled. Species sampled within the park include: *Capreolus capreolus*, *Cervus elaphus*, *Dama dama*, *Ovis orientalis*, and *Sus scrofa*. For each species, isotopic discrimination factors were determined for each sampled tissue type (i.e., scat, hair, collagen, bone apatite, and tooth enamel). Once calculated, these discrimination factors were then utilized to better understand the isotopic values obtained from mammals within more ancient Pleistocene-aged sites. The data obtained from the modern samples within Parque Natural de El Hosquillo permit a more accurate understanding of more ancient samples from the Pleistocene of Europe.

### Session No. 21: Modern approaches to educational outreach in palentontology (poster session)

**Sunday Afternoon 4:45 PM to 5:45 PM**

Session 21-Poster 35: Sunday, 4:45 PM  
**Presenter:** Tiffany S. Adrain

**DISCOVERING IOWA’S FOSSIL TREASURE: ENHANCING OUTREACH EDUCATION RESOURCES AT IOWA’S DEVONIAN FOSSIL GORGE**

Adrain, Tiffany S., Department of Earth and Environmental Sciences, University of Iowa, 121 Trowbridge Hall, Iowa City, IA 52242; Horgen, Sarah E., University of Iowa Museum of Natural History, 10 Macbride Hall, Iowa City, IA 52242; Roberts, Trina E., University of Iowa Museum of Natural History, 10 Macbride Hall, Iowa City, IA 52242; Sims, Hallie J., Department of Earth and Environmental Sciences, University of Iowa, 121 Trowbridge Hall, Iowa City, IA 52242

The Devonian Fossil Gorge is Iowa’s best-known, and most easily accessible, paleontological treasure. The Gorge is a half-mile-square horizontal exposure of Devonian sea floor, exposed by the catastrophic floods of 1993 and 2008 which scoured away more than 20 feet of topsoil and bedrock below the Coralville Dam Spillway to reveal beautifully preserved articulated crinoids, brachiopods, sponges, corals, trilobites, cephalopods, conularids, and pieces of arthropod fish. In the last twenty years, millions of visitors have walked across the Gorge, and thousands of school groups have visited to explore and learn about the fossils there. Along with the U.S. Army Corps of Engineers (COE) at Coralville Lake, who maintain the Information Plaza at the site and provide displays of fossils and a video about the Gorge at the Coralville Lake Visitor Center, several groups have been involved with enhancing visitor experience at the Devonian Fossil Gorge. The University of Iowa Paleontology Repository (UIPR) organizes students to assist with school tours and outreach events, and is the repository for research specimens from the site; the Iowa Geological and Water Survey (IGWS) developed interpretive guides; and the Mid America Paleontology Society (MAPS) assisted with the salvage of the best preserved specimens immediately following the 2008 flood, and prior to 2010 site modifications. MAPS members are preparing some of the specimens while others were brought to the Paleontology Repository, and exhibit-grade specimens placed on display at the Coralville Lake Visitor Center. With support from a Paleontological Society Outreach and Education Award (2010), the UIPR collaborated with the UI Museum of Natural History (UIMNH) to incorporate the Devonian Fossil Gorge, the UIPR Devonian collections, and the Museum’s paleontology exhibits and striking diorama reconstruction of Iowa’s Devonian sea into existing and new educational resources. The most significant result of the collaboration is the development of the Geo2Go: Devonian Discovery Trunk resource for schools, including lesson plans, activities, real and replica fossils, books, posters, videos and a flash drive of Powerpoint presentations, available for loan at no cost. In addition, undergraduate students in the Department of Earth and Environmental Sciences (formerly Geoscience) and the UI Museum Studies Certificate Program continue to gain skills and hands-on experience in video production, website development, and exhibit design. Future plans include the development of a geocaching activity, expansion of teaching modules for preparation for school and undergraduate lab visits to the UIMNH Iowa Hall geology exhibits, and development of themed virtual public access to the Devonian Fossil Gorge, UIMNH exhibits and the UIPR collections.
A NEW ICHNOLOGY WEBSITE AT THE UNIVERSITY OF KANSAS (HTTP://ICHNOLOGY.KU.EDU): A GUIDE TO IDENTIFY TRACE FOSSILS, INTERPRET ORGANISM BEHAVIORS, AND RECONSTRUCT

Connolly, Andy M., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Golab, James A., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Wolfe, Ben A., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Hammersberg, Sean R., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Wildermuth, Sarah, Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Jackson, Adam M., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Dzenowski, Nicole D., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Falk, Amanda R., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Jones, Matt F., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045; Hasiotis, Stephen T., Geology Department, University of Kansas, 1475 Jayhawk Blvd., Room 120, Lawrence, KS, 66045

A website dedicated to ichnology—from ichnatoxonomy to ichnological concepts, including traces in modern environments—is currently being constructed by the IchnoBioGeoScience (IBGS) Research Group in the Department of Geology at the University of Kansas. Academics, professionals, and laypersons interested in ichnology (encompassing microbial, plant, and animal behaviors) can provide feedback at ichnology@ku.edu to this evergreen project. The most recent definitive compilation on ichnatoxonomy and ichnological principles was published in 1975 as the Treatise on Invertebrate Paleontology—Part W (Revised and Enlarged) Miscellanea, Supplement 1, Trace Fossils and Problematica. Since that time, no compilations that evaluate all known invertebrate ichnotaxa have been produced. There also has never been a compilation that includes all known vertebrate and microbial ichnotaxa and root trace morphologies with invertebrate ichnotaxa, as well as modern analogs. The purpose of this website, therefore, is to provide an open-access, online catalogue of all known ichnotaxa, and provide examples of modern terrestrial and aquatic traces for use by professionals, academics, and the general public. The overall objective of this project is to make information available on how ancient and modern behaviors are understood, and how they are applied to interpreting environments, hydrogeology, ecology, and climate since the time life has existed on Earth. The website (www.ichnology.ku.edu) has individual pages tailored to concepts in ichnology, including: 1) an introduction to ichnology; 2) ichnoecoenoses and ichnofacies models; 3) tiering and ichnofabrics; 4) a glossary; 5) how to erect new ichnotaxon; 6) how to assign a trace fossil to an ichnotaxon; 7) ichnatoxonomy; 8) videos, anaglyphs, and animations of modern and ancient traces; 9) references to modern and ancient tracemaking organisms; and 10) links to other ichnological websites. The ichnatoxonomy page is organized in alphabetical order and subdivided by interpreted tracemaker: i.e., microbial, plant, invertebrates, and vertebrates—fish, amphibians, nondinosaurian reptiles, dinosaurs, birds, and mammals (including therapsids). All ichnotaxa will have the following information: name; reference that erected that ichnotaxon; any junior synonym(s) that may be a part of that ichnotaxon; geologic range; description; interpreted behavior; environment(s) in which the trace fossil is found; possible tracemaker(s); any remarks concerning that ichnotaxon; and additional references, including references that emend the ichnotaxon. Each ichnotaxon will be illustrated with one or more images as photographs and/or line drawings.
context of the grassland transition. Our exhibit design reflects lessons learned both from the museum education literature and from an initial prototype phase that established that visitors enjoyed and learned from the graphical structure of the tree better than from text-based descriptions of evolutionary process. In our formative evaluation of the prototype, visitors wanted a clearer picture of the reasons for extinctions within the tree. To accommodate this desire, our final design incorporates clear depictions of character-state transitions on the tree, coupled with plain-text explanations of the evolutionary ratchet and adaptive radiation stories. Independent research has confirmed that depictions of trees rich with character state information capture visitor interest and result in better comprehension of evolutionary processes. One of the biggest challenges of the design process was to include these additional data without overwhelming the visual design. Now that our exhibit is complete and open to the public, we plan to begin remedial evaluation that will lead to refinements in our local approach and assist with future evolutionary exhibit design.

Session 21-Poster 38: Sunday, 4:45 PM
Presenter: Dana J. Ehret

DIGITIZING PALEONTOLOGICAL COLLECTIONS AND EXHIBITS TO TEACH EVOLUTION IN ALABAMA, USA

Ehret, Dana J., Alabama Museum of Natural History, Box 870340, Tuscaloosa, AL 35487; Grimes, James D., Department of Art and Art History, University of Alabama, 103 Garland Hall, Box 870270, Tuscaloosa, AL 35487

Recent technological advances have greatly reduced the price and complexity of digitization hardware and software. As a result, it is much more affordable and user-friendly to employ state-of-the-art equipment for educational purposes. At the University of Alabama, the College of Engineering, the Department of Art and Art History, and the Alabama Museum of Natural History have partnered to incorporate 21st Century technology into an informal learning environment. Fossil specimens from the University of Alabama Museum collections, including a recently discovered elasmosaurid vertebral, a toxochelyid turtle skull, and a Carcharocles megalodon tooth, were scanned using an ARTEC hand scanner and then printed using an Stratasys Dimension printer at the College of Engineering. By printing the specimens in durable plastics, copies of the fragile, original specimens were sturdy enough to be handled by the general public. These specimens are similar to traditionally molded and cast models, except they can be scanned and printed at a much quicker rate. Specimens were then used at the University of Alabama Museum for outreach activities, including guest lectures to the Alabama and Birmingham Paleontological Societies discussing the recent elasmosaurid discovery, as well as an open house National Fossil Day event at the museum. These teaching models are an important tool for discussing “hot button” issues (i.e., evolution) in the southeastern United States, where such topics are still difficult to present. Allowing fossil enthusiasts, students, and families to touch, handle, and observe the 3-D replicas of the original fossil specimens opens a door for educational discussion. Furthermore, individuals learn in different manners (i.e., tactile, auditory, visual) and by allowing durable reproductions of the specimens to be handled, a teacher can engage and reach more individuals, making topics like evolution easier to understand. Future directions at the University of Alabama include using a Leica scanner to scan the inside of the University of Alabama Natural History Museum, in particular the model of our state fossil Basilosaurus cetoides, for online use. Many underprivileged school districts in Alabama cannot afford to visit the University of Alabama Museum and take advantage of guided tours. It is our hope that in the future, classes will be able to take online tours of our exhibits from their own classrooms.

Session 21-Poster 39: Sunday, 4:45 PM
Presenter: Andrew B. Heckert

PROMOTING PALEONTOLOGY ON PRECAMBRIAN BASEMENT: FINDING FOSSILS ON FRIDAYS AND OTHER PROGRAMS IN THE DEPARTMENT OF GEOLOGY AT APPALACHIAN STATE UNIVERSITY

Heckert, Andrew B., Department of Geology, Appalachian State University, Box 32067, Boone, NC 28608

Appalachian State University’s location in the Blue Ridge Mountains of North Carolina is a key attraction for recruiting students, especially geology majors, but the multiply metamorphosed basement rocks limit field opportunities in paleontology to longer (multi-hour drive) field trips. As a mid-sized school (17,000 students) in a similarly-sized city, our small (1200ft²) teaching museum lacks the large pool of potential visitors and volunteers of major natural history museums in metropolitan areas. Furthermore, because we are an undergraduate-only program, it is necessary to build basic student skills. Finally, as a microvertebrate paleontologist, one of my most pressing needs is data collection, specifically the time-consuming identification of fossils culled from screenwash concentrate. To maximize our strengths, I schedule time to pick concentrate on Friday afternoons, dubbing the program “Finding Fossils on Friday” (FFF) because few students have courses scheduled on Friday afternoon before the weekly department seminar at 4PM. These sessions routinely draw 2–8 students, including many not specifically interested in paleontology but willing to help, either from latent interest or else a desire to build their resume. The project has expanded to involve others, including precocious school children and high school students with a “shadow a mentor” assignment. Some members of FFF are now formal in the “geology cluster” of an NSF-funded “Academy of Science” project hosted in the physical sciences. Pedagogically, microvertebrate projects are ideally suited for undergraduates. The initial infrastructure is low-cost, requiring only a few microscopes and light sources. Students rapidly build skills in identifying fossils, starting by picking coarse-grained matrix with the naked eye before advancing to finer-grained concentrate. Students that demonstrate aptitude, interest, and maturity then progress to heavy-liquid separation and/or image acquisition (using 3-D or scanning electron microscopes). The most advanced and driven students parlay the experience into student research (senior theses) and presentation of results at paleontological meetings and coauthored journal publications. Importantly, the whole project is portable, and we have taken FFF on the road to fossil fairs and other.
outreach events at museums and science centers regionally. This not only provides outreach through hands-on activities, but also showcases undergraduate students performing real research (data collection) in action, which we view as a recruiting tool. Anecdotally, children, especially teenagers, are much more interested in others actively looking at sediment than on static displays of microvertebrates. Future directions include incorporating the outcomes of FFF not only into presentations and published papers, but also outreach, including using images in both physical and digital exhibits in our museum.

Session 21-Poster 40: Sunday, 4:45 PM
Presenter: Pennilyn Higgins

SOCIAL MEDIA AND THE PROCESS OF PALEONTOLOGY

Higgins, Pennilyn, Department of Earth and Environmental Sciences, University of Rochester, Rochester, NY 14627

There are plenty of things about paleontology that are unknown to the public at large. There are an equal number of misconceptions about what paleontology is and how it works. Misconceptions arise in two general areas of the science: 1) how field work actually works, and 2) what paleontologists do when they’re not in the field. Social media provides a direct line for the public to observe paleontologists at work and dispel common confusions or misunderstandings. Two easy-to-implement formats of social media are use of the micro-blogging platform, Twitter, and maintaining a longer format web log or blog. Field work can be illustrated in real-time, provided that the paleontologist has an available broadband wireless signal. Posts to Twitter can be made directly from the field area using a smart phone or tablet. Short daily blog posts as a travelogue can also illustrate the practical aspects of paleontology, and can also be prepared using a smart phone or tablet with wireless broadband capabilities. These posts don’t have to be complex, nor do they have to focus only on the science. Highlighting the fun that paleontologists have while in the field can go a long way to dispel the myth of the ivory-tower scientist. Once the paleontologist is back in the office, Twitter and blogging can show readers what the daily life of a scientist involves—not just laboratory work, but the daily, ordinary, bureaucratic tasks that we must complete the same as everyone else. Twitter can be used as a teaching and communication tool in classes as well (for those that teach), placing students in contact with other paleontologists globally and revealing that we, as scientists, don’t work in a vacuum. I am a constant Twitter user, utilizing it in my classes and in my professional work. I also maintain a blog and post daily. This last summer, I kept a blog travelogue of my 25-day field season, posting daily from my smart phone and tweeting when ever I had sufficient signal to do so. The travelogue posts have garnered 780 individual page views, about 31 views per field day. This does not include views from the main page when a series of posts could be read without individually clicking a link. These travelogue posts continue to get hits on a regular basis. Each post took me about 15 minutes to prepare and upload, which was mostly spent selecting photos taken with the camera on my phone. These posts and tweets show paleontology like it really is, not as it’s portrayed in movies and on television. Students interested in pursuing a career in paleontology can observe in real-time what’s involved. The public at large has the opportunity see new discoveries as they are made, rather than waiting for things to hit the popular press. They can ask questions, make observations, and potentially contribute directly to the science.

Session 21-Poster 41: Sunday, 4:45 PM
Presenter: Elysia Howe

UTILIZING THE PALEOBIOLOGY DATABASE FOR UNDERGRADUATE EDUCATION

Howe, Elysia R., Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187; Lockwood, Rowan, Department of Geology, The College of William and Mary, PO Box 8795, Williamsburg, VA 23187

The Paleobiology Database (PaleoDB) is an underutilized educational resource that can provide the raw material for active learning activities for undergraduate geology classes. Active learning encourages students to engage material through reading, writing, talking, listening, reflecting, and presenting. Active learning encourages students to teach the material to their peers. This results in significantly higher retention rates because students are required to independently synthesize and explain the material. Although this approach has been demonstrated to increase student participation and retention, active learning approaches have not been widely implemented in paleontological education at the undergraduate level. The PaleoDB was initiated in 2000 as the Phanerozoic Marine Paleofaunal Database, supported by the National Center for Ecological Analysis and Synthesis (NCEAS). The goal of the database is to compile all paleontological data on all fossil organisms, from the Proterozoic to the Pleistocene, in one location. The PaleoDB currently contains data derived from 48,405 references, entered by 359 scientists from 132 institutions in 24 countries. Syntheses and analyses of these data have already resulted in 182 official publications. Information is available for 1,154,582 taxonomic occurrences (ranging from microorganisms to mammals); 280,154 taxa; and 151,655 global fossil collections. Four laboratory and classroom activities for paleontology and historical geology courses have been developed using data from the PaleoDB. Topics explored include extinction, paleogeography, and local fossil assemblages, focusing specifically on Virginia. These activities are designed so that students must become familiar with using the PaleoDB to complete the exercise. This not only encourages students to engage in the material, it also exposes them to actual paleontological data and methodologies. Students in three paleontology and historical geology courses at a local two- and a four-year college were divided into two groups: those taught specific concepts in lecture format versus those taught the same concepts using the PaleoDB-based activities. Both populations were assessed pre- and post-educational intervention to quantify understanding and retention. These activities emphasize the important role that the PaleoDB can play in introducing undergraduates to active research in the paleontological classroom.

Session 21-Poster 42: Sunday, 4:45 PM
Presenter: Christy C. Visaggi
INFUSING PLACE-BASED LEARNING AS A MODEL FOR THE STUDY OF FOSSILS, LIFE HISTORY, AND DEEP TIME

Visaggi, Christy C., Department of Geosciences, Georgia State University, P.O. Box 4105, Atlanta, GA 30302

Three courses at Georgia State University incorporate place-based learning to enhance understanding of concepts in paleontology. Geology 1122 is a second-semester introductory course focused on processes in sedimentary environments with an exploration into the history of the Earth. Students are largely composed of non-majors. ISCI 2001 integrates biological and geological concepts using an Earth system framework and is a required course for preservice elementary school teachers. This course is taught collaboratively with faculty from the College of Education. Principles of Paleontology is a mixed upper-division and graduate-level course for students studying biology or geology as their primary discipline. The urban setting of Georgia State University in downtown Atlanta presents challenges for exposing students to paleontology in the field; however, utilizing place-based learning approaches in classroom activities and assignments provides a method for connecting to the history of life in a meaningful way. Time and space are well-represented in Georgia, with physiogeographic provinces representing rocks from the Precambrian through the Quaternary. Shallow marine seas and plant fossils of the Paleozoic are preserved in northwest Georgia, Mesozoic marine reptiles and dinosaur remains are found along the fall line through the center of the state, and diverse invertebrate and vertebrate faunas reminiscent of higher sea levels during the Cenozoic are deposited across the Coastal Plain. An overwhelming majority of students at Georgia State University come from the 1.59 counties in the state, offering a strong sense of familiarity to regional landscapes that can be used to foster interest in and comprehension of paleontological concepts and applications (e.g., fossilization, evolution, conservation, climate change). Place-based learning activities in all courses incorporate mapping provinces in Georgia, identifying suites of fossils found in different regions, and reconstructing changes in paleoenvironments through time. Tools designed for classroom use that stress paleontological perspectives through the lens of geography include worksheets, concept maps, cooperative learning games, inquiry-based data collection, and writing assignments. Evaluation of pre-and post-surveys in these courses indicates that although most students lack an understanding of concepts in paleontology initially, learning about fossils as related to their surroundings is embraced. Formative and summative means of assessment demonstrate improved appreciation and knowledge of the history of life in space and time through place-based investigations. Development of materials used in these courses shall be modified next for education and outreach purposes for the Georgia Geographic Alliance.

Session 21-Poster 43: Sunday, 4:45 PM
Presenter: Natasha S. Vitek

BRINGING MUSEUM COLLECTIONS TO THE PUBLIC THROUGH A SMARTPHONE APPLICATION

Wang, Zixiao, School of Information, The University of Texas at Austin, 1616 Guadalupe St., Austin, TX 78701; Vitek, Natasha S., Department of Biology, University of Florida, Gainesville, FL 32611; Karadakar, Unnil P., School of Information, The University of Texas at Austin, 1616 Guadalupe St., Austin, TX 78701; Molineux, Ann M., Non-vertebrate Paleontology Laboratory, The University of Texas at Austin, 2400 Trinity St., Stop D1500, Austin, TX 78712

Specimen collections are a core resource at paleontologists’ disposal. Specimens are a well-recognized source of outreach opportunity. However, museum curators and outreach workers are limited in the amount of material they can present at any given time and location and often lack the resources or technical expertise to make more specimens available to a wider audience. Researchers in the Non-vertebrate Paleontology Laboratory, the School of Information, and the Jackson School of Geosciences at The University of Texas at Austin collaborated to build a smartphone application (mobile app). This app, called Fossil Roulette, takes advantage of the wealth of specimens in the UT Non-vertebrate Paleontology collections and is part of a NSF-funded grant. The app is targeted to non-scientists at a high-school level of education and above. Fossil Roulette has three main goals. First, the app aims to excite public interest in a variety of fossil specimens. Second, the app aims to provide accurate and engaging commentary on each specimen. Third, the app aims to increase the utility of specimens in research collections by making images and information freely available to anyone with a smart phone. App development challenges include building an intuitively useable interface in order to easily connect the user to information, selecting appropriate specimens, and relying solely on volunteer effort for creating specimen entries that include images for a fossil, its scientific classification, and a brief textual description that is oriented toward non-technical audiences. Currently, entries for twelve specimens ranging in time and taxonomic breadth from a Cambrian chancellorid to a Pleistocene insect are available on the app, with work in progress on additional entries. Each entry opens to an eye-catching photograph of a specimen and displays basic identifying information such as common name, scientific name, and age. Viewers can click a button to learn more about the specimen, view a close-up photograph, and read the specimen’s classification. The written commentary is designed to be readable in a short time frame, and to convey a fascinating aspect of the specimen from a paleontological perspective. Topics include but are not limited to paleoecology, diversification, taphonomy, and morphology. Our future plans are to add more content to a simple, manageable database, develop more interactivity within the app and develop assessment metrics.
Previous studies have suggested the late Oligocene and early Miocene represent an important time for the ‘modernization’ of the North American lizard fauna, but geographic, temporal, and taxonomic biases have thus far precluded a thorough characterization of this transition. Paleokarst deposits from the medial Arikareean and the early Hemingfordian of northern Florida preserve undescribed herpetofaunal remains that fill important gaps in our understanding of Cenozoic lizard evolution. The Brooksville 2 local fauna (Ar2) and the Miller local fauna (He1) are particularly informative, and the non-anguimorph lizard diversity of both is discussed here. A scincid, a culepoleherapod gekkotan, a rhineurd amphibiasbaenian, an iguanine, an iguand of uncertain phylogenetic affinities, and two different anoles are present in the Brooksville 2 LF. The Miller LF preserves an anole, a coryphantohine closely resembling Basiliscus, a diminutive phrynosomatine, an iguanine closely resembling Cryptosaura, a scincid, and a “cnemidophorine” teiid. Notably, anoles from Brooksville 2 and Miller bear little resemblance to members of the modern Anolis carolinensis subgroup radiation inhabiting the region today. Scincids from the two sites compare favorably with both Pliosodon and Mesosaurus, highlighting the need for a better understanding of the skeletal morphology of the latter. Although fossils of rhineurd amphibiasbaenians are known from the Paleogene and early Neogene of much of mid-continental and western North America, their occurrence in the Arikareean of Florida represents a substantial temporal extension within the confines of a very limited modern geographic range. The conspicuous absence of “cnemidophorine” teids in the Arikareean, their sudden appearance in the Hemingfordian in the Miller LF and the previously described Thomas Farm LF, and their persistent presence in all subsequent North American Land Mammal Ages corroborates molecular studies suggesting an early Miocene date of an intercontinental dispersal event of the group to North America. This work complements recent studies of older, Eocene lizards by others and lends paleontological support to aspects of the tropical conservatism hypothesis: lineages now confined to the tropics were present at higher latitudes when megathermal climates were more extensive. Importantly, these new records from Florida demonstrate that some of these elements maintained extralimital distributions beyond their modern northern boundaries well after the climatic deterioration of the early Oligocene while temperatures remained warmer than they are today.
Session 22-Poster 46: Sunday, 4:45 PM
Presenter: Toljagic Olja

EVOLUTIONARY RATES IN UNGULATES: A TWO-PRONGED APPROACH

Toljagic, Olja, Centre for Ecological and Evolutionary Synthesis, University of Oslo, Blindernveien 31, Oslo, Norway; Lynne Voje, Kjetil, Centre for Ecological and Evolutionary Synthesis, University of Oslo, Blindernveien 31, Oslo, Norway; Liow, Lee Hsiang, Centre for Ecological and Evolutionary Synthesis, University of Oslo, Blindernveien 31, Oslo, Norway

The Neogene is characterized by environmental changes such as increases in higher latitude aridity and temperature seasonality. The climatic shift from low to high seasonality might have induced the expansion of open and arid habitats. Forests or woodlands gave way to grassland, most notably in North America, Eurasia, and Africa. Against this backdrop of environmental changes, ungulates diversified, likely adapting to new habitats and diets. In this study, we are interested in understanding the contribution of dietary traits to diversification as well as the rate of dietary trait evolution.

Session No. 23: Form and function: Tracing the foundations of animal diversity, ecology, and functional morphology (poster session)
Sunday Afternoon 4:45 PM to 5:45 PM

Session 23-Poster 47: Sunday, 4:45 PM
Presenter: John C. Handley

ESCALATION WITHIN BIVALVE PREY OF CHESAPEAKE GROUP NATICID GASTROPODS: A CRITICAL REAPPRAISAL

Dietl, Gregory P., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850; Kelley, Patricia H., Department of Geography and Geology, University of North Carolina Wilmington, Wilmington, NC, 28403; Handley, John C., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850

In 1989, Kelley published a study detailing the evolutionary response of five genera of Miocene bivalves to their shell-drilling naticid gastropod predators. This classic study presented evidence for increases in prey shell thickness (TH), a trait that affects the outcome of a predator-prey interaction by determining the duration of the drilling process, for all five genera analyzed during the three-million-year interval of study. Evolution of thickness was interpreted as dominated by gradual trends, as indicated by significance of Spearman's rank correlation coefficients. Prey taxa that were attacked the most frequently displayed the greatest change in TH, as comparison with the success of this model to those that lacked a covariate. We used model ranking techniques (Akaike Information Criterion; AIC) to assess the total empirical support each model received. A preliminary reanalysis of the dataset resulted in mixed support for Kelley's original interpretations. The covariate model had the most support (60.7% using AIC) for Dallarca, suggesting that drilling frequency significantly influenced TH evolution in this taxon. AIC scores (70.5%), however, indicate that stasis was the most-supported model for Astarte. Stasis and random-walk models were equally supported for Stewartia and Corbula based on AIC scores (45.0% and 41.4% and 47.0% and 38.2%, respectively), and the random walk model was most supported for Marvacrassatella (57% using AIC). These results suggest that evolutionary trends in TH are more complicated than originally inferred by Kelley. Additional model testing is ongoing. For instance, further work is needed to assess the possibility that evolutionary modes changed throughout the history of these bivalve lineages, especially for taxa represented by multiple species (Dallarca, Marvacrassatella, and Astarte). We are also incorporating results based on internal volume, another trait affecting the predator-prey interaction. Adding additional covariates, such as temperature and productivity, may also shed further light on the nature of morphologic changes within these bivalve lineages.

Session 23-Poster 48: Sunday, 4:45 PM
Presenter: Ashwini Kumar Srivastava

INSECT PLANT COALITION

100
Insect and insect activities are poorly documented in fossil flora of India. Careful search, and proper handling and identification have helped to identify well-preserved assemblages of insect and insect activities in fossil flora of India. Earliest presence of insect remains are known from the early Permian sequence of Talchir Formation in Peninsular India, and well-preserved records of blattids are also recorded from the early Permian strata of Kashmir. The middle Permian *Glossopteris* flora have found to contain maximum diversity of insect fossils represented by different families and genera. The remains of coleopteran and mectopteran perhaps represent their earliest records in fossil flora. The Triassic flora also demonstrates the body fossils of insects. Presence of insect galls in Jurassic/Cretaceous flora of Rajmahal hills, insect remains from Deccan Intertrappean flora of central India, and insect and insect activities discovered in Tertiary flora of Kerala, Jharkhand, and Assam amply suggest the well-documented association of plant with insects. Insect activities in the flora are known by insect galls, chewing and eaten marks of leaf margin, disfigurement of lamina, egg-like pouches, trailing marks, mining activity, and discovery of insect traces in the form of trailing and crawling behavior certainly suggest the well knit coalition of insect in fossil flora of India at different time spans.

Session 23-Poster 49: Sunday, 4:45 PM
Presenter: Jeffrey Thompson
A NEW BASAL CIDAROID (ECHINOIDEA) FROM

**Session No. 24:** Conservation paleobiology: Ecosystem, community, and species response to environmental change (poster session)

Sunday Afternoon 4:45 PM to 5:45 PM

Session 24-Poster 50: Sunday, 4:45 PM
Presenter: Katherine Cummings
SEAGRASS-ASSOCIATED MOLLUSCAN DEATH ASSEMBLAGES IN THE BIG BEND REGION OF FLORIDA, GULF OF MEXICO

Cummings, Katherine E., Interdisciplinary Ecology, University of Florida, Gainesville, FL 32611; Kowalewski, Michał, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Barry, Savannah, Fisheries and Aquatic Science, University of Florida, Gainesville, FL 32611; Frazer, Thomas K., School of Natural Resources and the Environment, University of Florida, Gainesville, FL 32611

Seagrasses provide a broad suite of ecosystem services of both ecological and economic value, including sediment stabilization and coastal erosion control, carbon sequestration, and forage and refuge habitat for many important fishery species. Seagrass beds worldwide have been vanishing at alarming rates, due in large part to anthropogenic stressors, and are expected to decline further from the effects of global climate change. Because seagrasses do not fossilize well, it is difficult to examine their long-term responses to past environmental changes and develop informed forecasting models for how they might respond to future global and regional environmental change. We evaluate the use of mollusk assemblages as a proxy for seagrass beds in the Big Bend region of the Gulf of Mexico to assess how seagrass beds have responded to historical environmental conditions. Herein, we describe preliminary results using a molluscan death assemblage unique to seagrass beds along the Florida Gulf Coast. Sediment samples were collected from a series of sites along the central Gulf Coast of peninsular Florida that have been monitored for water quality for 15 years, and, more recently, for seagrasses to describe patterns of abundance and distribution. Sites were chosen to capture a steep environmental gradient in nutrient concentrations, phosphorus in particular, with N:P ratios decreasing markedly in the northward direction. All sites are vulnerable to degradation caused by the human-mediated influx of nutrients into adjacent watersheds, but sites in the south are more likely affected by excess P and those in the north by excess N. We also present comparative data collected from seagrass beds off San Salvador Island, Bahamas. Modern
mollusks, echinoderms, and other organisms were separated by species and counted to obtain a diversity index. These data will be used to assess if mollusk death assemblages provide us with a reliable means for tracking the environmental nutrient gradient in the study area.

Session 24-Poster 51: Sunday, 4:45 PM
Presenter: Luis Patricio Soto

PALEOECOLOGY OF NEW CHONDrichthyAN FAUNA FROM MIDDLE MIOCENE (BARSTOVIAN), GADSEN COUNTY, FLORIDA, USA.

Soto, Luis P., Biology Department and Florida Museum of Natural History, University of Florida, P.O. Box 118525, Gainesville, FL 32611; MacFadden, Bruce J., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

The Torreya Formation crops out in the southern Georgia and northern Florida (approx. 30.6° N, 80.3° W) region of the United States. Within the formation are preserved specimens from several taxa including mammals, invertebrates, bony fishes, Chondrichthyes, and invertebrates. The date for this assemblage, based on Sr-ratios and magnetostratigraphy, is between 15.3 to 15.9 Ma, corresponding to the early Barstovian NALMA. Earlier reports have concentrated on invertebrates and mammals, leaving the Chondrichthyes theretofore unpublished. This study reports on the chondrichthyan assemblage from the Willacooche Creek, FL. Chondrichthyan samples at the Florida Museum of Natural History Florida have been studied to reconstitute this Chondrichthyes assemblage structure. For this study, 1588 corporal remains including teeth, spines, denticles, and vertebrae were used. This material documents a moderately diverse fauna with representation from ten genera of sharks and four genera of batoids. Three taxa are numerically the most abundant, including Carcharhinus sp. (38.5%), Myliobatis sp. (12.8%), and Negaprion brevirostris (11.6%); in addition, Myliobatidae (6.6%), Hemipristis serra (6.6%), and Rhizopionodon sp. (5.7%) have a discreet representation. The remaining species are relatively rare, each representing < 5%, with a collective total of 18.2%. The dominance of corporal remains of relatively medium-small genera such as Carcharhinus and Myliobatis indicates a shallow-water paleoenvironment, thus agreeing with previous paleoecological reconstructions for this area, and along with the previous vertebrate studies, gives a comprehensive idea of the ancient biodiversity and paleoecological context of the Torreya Formation.
Session No. 25: Celebrating public participation in paleontology

*Chairs:* Austin J.W. Hendy and Bruce J. MacFadden

**Session 25-1:** Monday, 8:15 AM

**Presenter:** Jack Horner *(Invited Keynote)*

**EGG MOUNTAIN PALEONTOLOGICAL FIELD STATION: INTEGRATING SCIENCE AND EDUCATIONAL OUTREACH**

**Horner, John R.,** Museum of the Rockies, Montana State University, 600 W Kagy Blvd, Bozeman, MT 59717

The “Egg Mountain Paleontology Field School” was established in 1989 as an additional way for the Museum of the Rockies to share paleontological knowledge with the public. It was a joint venture of the Museum’s departments of Education and Paleontology, and the Nature Conservancy, owner of the land. Public participants paid tuition for week-long classes that involved actual participation on four different research projects: 1) *Maiasaura* nesting horizon excavations and mapping, 2) *Maiasaura* bonebed excavation and mapping, 3) *Troodon* nesting horizon excavation, and 4) Geologic studies. Participants were taught all aspects of searching, photographing, excavation, mapping, data collection, and some preparation techniques. Many of the participants were K–12 teachers, but most were simply interested members of the public. The field school shut down in 2002 because of financial and preparation issues. In 2005, a donor purchased the land for the Museum of the Rockies Inc., creating the Beatrice Taylor Field Paleontological Research Site, otherwise known as the Egg Mountain Paleontology Field Station. Since its acquisition, research laboratories and more permanent facilities have been constructed on site, and the field station is once again prepared to accept public participants to aid in recovery of research materials and data. This new version is not a school, but a true research facility where scientists and volunteers work hand in hand without “expert” oversight, and with only the methods of science to guide their process. Volunteers are being integrated into each project as research scientists utilizing their own skills from other fields. In addition, these citizen scientists will be invited to coauthor the scientific papers in which their data is presented. Citizen scientists are being celebrated by being invited to be equal partners in exploration and research.

**Session 25-2:** Monday, 8:45 AM

**Presenter:** Glenn W. Storrs

**PARTNERING FOR POSTERITY: COMMUNITY COLLABORATION IN THE FURTHERANCE OF COLLECTIONS-BASED PALEONTOLOGY AT CINCINNATI MUSEUM CENTER**

**Storrs, Glenn W.**, Cincinnati Museum Center, 1301 Western Avenue, Cincinnati, OH 45203; **Hunda, Brenda R.**, Cincinnati Museum Center, 1301 Western Avenue, Cincinnati, OH 45203; **Meyer, David L.**, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Museum paleontological collections are challenged with inherent curatorial and collection-management needs, historical backlogs, and limited resources. However, research and acquisition activities and new programming initiatives must simultaneously continue in order for collections to remain relevant. Given the large size of many repository collections, the operation and completion of these varied tasks can be a daunting prospect. Cincinnati Museum Center is fortunate to be able to leverage long-standing professional and amateur relationships in conducting research and collection activities in paleontology. A strong community awareness of the value of regional paleontological resources provides volunteers and expertise in the form of the world’s longest-running amateur paleontological society, the Dry Dredgers. Paleontology in Cincinnati and elsewhere has benefited for over 70 years from the commitment of this group to the promotion of paleontological research and education. Additionally, professional paleontologists at the Museum and the University of Cincinnati have long been active in the mentoring and cultivation of the society. Dry Dredger members are thus active in collection-management, exhibition, specimen acquisition, and educational programming at the Museum. Independent volunteers, students, and Dry Dredgers furthermore operate an active preparation laboratory on the Museum exhibit floor that is essential to the health to the collections. Here, they prepare and conserve fossils and/or discuss these activities with the visiting public, each according to their individual levels of comfort. Many of the prepared specimens originate via a well-established Dinosaur Field School program that has allowed community members and volunteers to facilitate and participate in active collecting and research projects for over a decade. In each of these areas of collaboration, crucial components of the professional/amateur relationship are a continued mutual respect and the recognition that our community partners/volunteers deserve to benefit equally from the relationship. They do so especially in the willingness of Museum staff to offer guidance and continuing education, the provision of volunteer appreciation events, and the knowledge that an important and valued function is being performed for posterity. Fostering such relationships has been critical for the implementation and development of several important collections and research initiatives at Cincinnati Museum Center. Equally important, but sometimes overlooked, is the fact that satisfied volunteers will additionally perform the essential task of advocacy as community ambassadors for a Museum and its paleontology programs.
Session 25-3: Monday, 9:00 AM
Presenter: J.-P. Cavigelli

**USING A VOLUNTEER ARMY TO HELP A SMALL MUSEUM COLLECT LARGE VERTEBRATE SPECIMENS**

Cavigelli, Jean-Pierre, Tate Geological Museum, Casper College, C125 College Dr., Casper, WY 82601

Recently, the Tate Geological Museum at Casper College collected two large fossil specimens. Assistance from the public was integral to the recovery of these specimens. In 2006 and 2007, a nearly complete disarticulated Columbian mammoth skeleton was collected in central Wyoming. In 2011, a partial *Tyrannosaurus rex* skeleton was collected in eastern Wyoming. The Tate has a small staff, and we generally reserve field work opportunities for the few regular volunteers who give tours of the museum, or work in the prep lab or gift shop. Both of these large specimens needed more manpower than our usual volunteers could offer. The Museum issued a press releases for both, and announced a need for help with these projects. In the end, hundreds of people helped dig these specimens. They were all trained in the basics of looking for bones, while some of the more seasoned volunteers and staff focused on dealing with bones once they were exposed. A few of the people who volunteered to help excavate also signed up to become regular museum volunteers after the digs. Volunteers registered beforehand to ensure that we would not have too many people on any day; there was no on-site registration. Each dig was limited to 12 or 20 people per day. We also asked for help with heavy equipment. Local businesses came to the rescue and also helped out by donating various tools, gear, and supplies for both projects. The mammoth was found by a bulldozer operator while making an oil-well pad. The operator’s boss was excited by the find and lent us some heavy equipment as needed. For the tyrannosaur dig, we were able to borrow a skid-steer to do some overburden removal. The help of many volunteers was crucial in the successful and timely excavation of both of these specimens. The public was also encouraged to participate in a less hands-on way; we offered on-site tours once a week during the digs, which averaged almost a hundred people per tour.

Session 25-4: Monday, 9:15 AM
Presenter: Stephen J. Godfrey

**ENGAGEMENT WITH THE PUBLIC AND AVOCATIONAL PALEONTOLOGISTS AT THE CALVERT MARINE MUSEUM**

Godfrey, Stephen J., Paleontology, Calvert Marine Museum, PO Box 97, 14200 Solomons Island Road, Solomons, MD 20688

The Calvert Marine Museum is a mid-size, county-funded museum that interprets three themes: paleontology of the Miocene epoch, natural history of the region, and maritime history of southern Maryland. The mandate of the department of paleontology is to collect, preserve, and interpret the local paleontological resource, principally fossils from Calvert Cliffs along the western shore of Chesapeake Bay. We cultivate relationships with cliff-front property owners, encourage the participation of volunteers and avocational paleontologists in our activities, and sponsor a fossil club. In the State of Maryland, private property extends to the mean high tide. Therefore, before the museum can excavate, permission must be granted by the property owner. There is no substitute to fostering trusting relationships with property owners, whom in their large majority very generously grant us access to their bay-front cliffs to quarry fossils as they become exposed through natural erosion. Among our volunteers and fossil club members are individuals who actively donate their finds (many of which are scientifically important) to the museum. We have also been the beneficiary of donations from specialized collectors—i.e., individuals who scuba dive the bottoms of rivers in Maryland, Virginia, and North Carolina. Volunteers further contribute to our department by helping with field work, preparing fossils in our museum gallery prep lab, and assisting with the cataloging of our extant comparative osteology collection, library, and the fossils in our permanent collection. We attribute our success to a mix of the following (although no formal attempt has been made to find out which and how many of these attract volunteers, interns, and club members): 1) An institution that values the contributions amateurs, interns, and volunteers can make to the fulfillment of departmental mandates. 2) Individuals who oversee, cultivate, and train volunteers to focus their willingness to help. 3) A local fossil resource that the amateur community can collect legally. 4) A museum-sponsored fossil club where like-minded individuals can interact. 5) Club-sponsored field trips to diverse fossil localities to facilitate collectors to collect. 6) A fossil club newsletter, *The Ecphora*, published quarterly with timely articles. 7) An ongoing public lecture series where experts in the field of paleontology present in a free public forum. 8) Host high school and college paleontology interns. 9) Paleontology-related presentations to community groups like the Rotary Club. 10) Contribute to museum events like fossil camp, SharkFest, Road Scholar, and First Free Friday. 11) Receive donations into a permanent collection and ‘reward’ donors with inclusion of their items in our newsletter, ability to offer donors a formal letter for income tax purposes, and, although rarely, the possibility of including their finds in formal scientific publications or the naming of a new species in their honor.

Session 25-5: Monday, 9:30 AM
Presenter: Tiffany S. Adrain

**PARTNERS IN PALEONTOLOGY: SUCCESSFUL SYNERGIES AND COLLABORATIONS BETWEEN AMATEURS AND PROFESSIONALS, ILLUSTRATED BY THE UNIVERSITY OF IOWA PALEONTOLOGY REPOSITORY, THE MID AMERICA PALEONTOLOGY SOCIETY, AND THE BLACK HAWK GEM AND MINERAL SOCIETY**

Adrain, Tiffany S., Department of Earth and Environmental Sciences, University of Iowa, 121 Trowbridge Hall, Iowa City, IA 52242; Preslicka, James E., Mid America Paleontology Society, Iowa; Blume, Thomas, Black Hawk Gem and Mineral Society, Iowa

The University of Iowa Paleontology Repository (UIPR) has enjoyed a close relationship with amateur paleontologists throughout its 158-year history, attested by the presence of fossil collections made by well-known amateurs such as...
AVOCATIONAL PALEONTOLOGISTS AND VOLUNTEERS: CRITICAL PARTNERS WITH THE NON-VERTEBRATE PALEONTOLOGY COLLECTIONS AT UT AUSTIN.

Molineux, Ann M., Non-vertebrate Paleontology Laboratory, The University of Texas at Austin, 2400 Trinity St. Stop D1500, Austin, TX 78712; McCall, Linda, Non-vertebrate Paleontology Laboratory, The University of Texas at Austin, 2400 Trinity St. Stop D1500, Austin, TX 78712

The University of Texas at Austin's National Museum of Natural History (NMNH) has a rich history with avocational paleontologists. Many of these early paleontologists and their collections played a critical role in the growth and development of the NMNH's collections, particularly the non-vertebrate paleontology collection. The relationship between avocational paleontologists and the NMNH has been one of mutual benefit, providing support and expertise that has enhanced the museum's ability to expand and preserve its collections.

Many avocational paleontologists have contributed their time and resources to the NMNH, both through direct contributions of their own finds and through support of the museum's research and exhibition needs. These contributions have ranged from simple donations of fossils to more complex partnerships, such as the establishment of endowments or the provision of research funds. The NMNH has also benefited from the expertise of avocational paleontologists, who often have extensive knowledge of specific areas of the Southwest and other regions.

In turn, the NMNH has provided resources and opportunities to avocational paleontologists, such as access to the museum's collections, research opportunities, and educational programs. This reciprocal relationship has been critical in fostering a strong and sustainable community of avocational paleontologists, who continue to contribute to the advancement of paleontology and the NMNH.

The NMNH is committed to recognizing and celebrating the contributions of avocational paleontologists. In 1999, the NMNH established the Harrell L. Strimple Award for Avocational Paleontologists, which recognizes outstanding contributions to paleontology by avocational paleontologists. The award is presented annually, and previous recipients have included leading avocational paleontologists who have made significant contributions to the field.

The NMNH continues to seek ways to foster relationships with avocational paleontologists and to recognize their contributions. Efforts are underway to develop new initiatives and programs to support and recognize avocational paleontologists, including the establishment of new awards and the funding of research projects.

Session 25-7: Monday, 10:30 AM

Presenter: Patricia Noell

THE DALLAS PALEONTOLOGICAL SOCIETY'S CONTRIBUTIONS TO PUBLIC PARTICIPATION IN PALEONTOLOGY

Noell, Patricia, Dallas Paleontological Society, P.O. Box 223846, Dallas, TX 75222

The Dallas Paleontological Society (DPS) is a vital component of the community's engagement in paleontology. DPS has a long-standing tradition of promoting public participation and education in the field of paleontology. The society's mission is to foster an appreciation for the study of paleontology and to provide opportunities for people of all ages to explore the fascinating world of fossils.

DPS achieves this mission through a variety of initiatives, including educational programs, events, and public outreach. The society's annual Paleontology Exposition is a prime example of its commitment to public engagement. The exposition is an annual event that celebrates the science of paleontology and provides a platform for researchers, collections, and enthusiasts to share their work.

In addition to the exposition, DPS hosts a range of educational programs, such as field trips, workshops, and lectures, which are designed to provide opportunities for people of all ages to learn about paleontology. These programs are led by professional paleontologists and avocational paleontologists alike, ensuring a diverse range of perspectives and expertise.

DPS also supports volunteer efforts in the field, including fossil collecting and preparation. This allows volunteers to contribute to the scientific community and gain firsthand experience in paleontology.

In conclusion, the Dallas Paleontological Society is a vital resource for promoting public participation in paleontology. Through its programs and initiatives, DPS continues to foster a love of fossils and the science of paleontology in the community.

Session 25-8: Monday, 11:00 AM

Presenter: Geigerman

THE GEORGETOWN PALEONTOLOGICAL SOCIETY'S CONTRIBUTIONS TO PUBLIC PARTICIPATION IN PALEONTOLOGY

Geigerman, Faye C., Georgetown Paleontological Society, 901 W. 12th St., Georgetown, TX 78626

The Georgetown Paleontological Society (GPS) is a chapter of the Dallas Paleontological Society (DPS) and has a mission similar to that of DPS. GPS is committed to promoting public engagement in paleontology through a variety of initiatives, including educational programs, public outreach, and volunteer opportunities.

GPS holds regular meetings that feature talks by professional paleontologists and avocational paleontologists on a wide range of topics related to paleontology. These meetings are open to the public and provide an opportunity for people of all ages to learn about paleontology.

GPS also hosts field trips and workshops throughout the year, allowing members and the public to explore paleontological sites and learn about paleontology in a hands-on manner. These events are led by professional paleontologists and avocational paleontologists alike, ensuring a diverse range of perspectives and expertise.

In addition to these formal events, GPS promotes public participation in paleontology through its volunteer efforts. GPS members volunteer to assist with the society's projects, such as fossil collecting and preparation, and contribute to the scientific community.

In conclusion, the Georgetown Paleontological Society is a vital resource for promoting public participation in paleontology. Through its programs and initiatives, GPS continues to foster a love of fossils and the science of paleontology in the community.
The idea of Dallas Paleontological Society (DPS) began with Charles Finsley, Director (ret.) of the Dallas Museum of Natural History, now the Perot Museum of Nature and Science, and volunteer preparators working on a mammoth at the museum. DPS was founded in 1984 for the purpose of promoting interest in and knowledge of the science of paleontology. DPS sustains a membership level around 300, who range in expertise from local professional and student paleontologists, preparators, geologists, serious and amateur collectors, to new fossil enthusiasts and kids. Among the unique activities that DPS sponsors include the FBI (Fossil Bureau of Investigation), Fossilmania, Mineral Wells Fossil Park (MWFP), a biannual paleontology symposium; and book publishing. The FBI assists local professionals with excavation, preparation, and identification of fossils for the public. Fossilmania is an annual fossil show drawing vendors and shoppers from around the country to Glen Rose, Texas. MWFP is one of the few city-owned fossil parks in the country, and features fossils of the Pennsylvanian period. DPS publishes Occasional Papers, compilations of scholarship written by lay, as well as professional, members. As with many other paleontological societies, DPS leads field trips for members and the public. These may include private sites (e.g., Ash Grove cement quarries near Midlothian, Texas, for shark teeth) and more popular public field trip sites (e.g., Jasper, Texas, for fossil wood). DPS participates in local, regional, and statewide gem and mineral shows; discovers and/or works digs and provides fossils to several local science and paleontology museums; takes educational programs into the schools, Scouts, and other children’s groups; and provides scholarships to graduate students in local universities. The DPS is very active in National Fossil Day events across north central Texas. DPS convenes a biannual paleontology symposium where local professors, graduate students, and out-of-state paleontologists can present their work. DPS holds the honorary Chuck Finsley Lecture annually, inviting a renowned professional paleontologist to Dallas to speak. In conjunction with The Heard Natural Science Museum and Wildlife Sanctuary, DPS provides educational programs for adults featuring a mosasaur specimen excavated by the FBI and prepared by DPS volunteers. A shark teeth workshop, which includes almost all the large species of the Cretaceous, is offered by DPS. During monthly Society meetings, knowledgeable speakers, both academic and amateur paleontologists, come from across the country to speak. DPS members have discovered many significant fossils that have been subsequently described in peer-reviewed publications including: a baby nodosaur, a mosasaur, several pterosaurs, the oldest sauropod in North America, and Cretaceous fossil pearls. A number of DPS members have gone on to achieve graduate degrees stemming from their paleontological discoveries.

Session 25-8: Monday, 10:45 AM
Presenter: Linda J. McCall
THE PURPOSE AND FUNCTION OF FOSSIL CLUBS: A PERSONAL PERSPECTIVE
McCall, Linda J., North Carolina Fossil Club, PO Box 25276, Raleigh, NC 27611
Fossils have broad appeal across a wide demographic, regardless of gender, age, race, vocation, education, or affluence. This fascination ranges from casual interest to driving passion. Those of us drawn to them irresistibly either go on to be professionals or pursue our passion on the side as hobbyists in the amateur/avocational realm. Wherever like-minded people gather, a club is born. My observations stem from over three decades of personal affiliation with the Paleontological Society of Austin (PSoA), Dallas Paleontological Society (DPS), Southern California Paleontological Society (SCPS), and North Carolina Fossil Club (NCFC). These clubs are 501(c)(3) organizations created exclusively for educational and scientific purposes, and all have mission statements concerning educating the public, advancing science by promoting interest in and knowledge of paleontology, and providing a network for the exchange of data between professionals and serious amateurs in the field. PSoA and NCFC give out paleontological grants or scholarships, and/or volunteer their time to aid in paleontological research at various museums or universities. As an example, PSoA is helping inventory the invertebrate paleontology collection at UT in preparation for photography and digitization. PSoA hosts an annual “Fossil Fest,” with fossil dealers from around the country as well as educational displays for the general public. The NCFC Fossil Fair showcases North Carolina fossils at a different museum each year. Some individuals within these clubs will partner with the established paleontological community and publish peer reviewed material. I have personally worked with Dr. Ann Molineux and Dr. Jim Sprinkle at the University of Texas to publish three papers. The ethics of fossil clubs and their members are often questioned among professional paleontologists. PSoA has adopted and holds their members to a Code of Ethics and Conduct which states in part: “...We will not barter, sell, or purchase scientifically significant fossils unless we bring them into or keep the fossils within a public trust. We should contact the appropriate professionals upon discovery of scientifically significant fossils and consider donating such fossils to the appropriate facilities. Members who do not abide by these rules are expelled and denied future club membership...” NCFC is in the process of adopting the same guidelines. For all of these reasons, fossil clubs are a vastly underutilized and invaluable resource for the paleontological community. We are often the eyes, ears, hands, and boots on the ground in the field and beyond.

Session 25-9: Monday, 11:00 AM
Presenter: M. Gail Jones
WHERE ARE THE WOMEN AND MINORITY FOSSIL COLLECTORS? A STUDY OF THE DEVELOPMENT AND CHARACTERISTICS OF SCIENCE HOBBYISTS
Jones, M. Gail, STEM Education, North Carolina State University, Box 7801, Raleigh, NC 27695; Andre, Thomas, College of Human Sciences, Iowa State University, E262 Lagomarcino Hall, Ames, IA 50011; Childers, Gina, Education, North Carolina State University, Box 7801, Raleigh, NC 27695; Corin, Elysa, Education, NCSU, Box
Many Americans engage in fossil collecting and fossil clubs as hobbyists and make contributions the science of paleontology through sharing their knowledge with youth, informal science centers, and K–12 schools. These hobbyists have extensive commitments to their hobbies and have developed in-depth science expertise. Who are these hobbyists and what motivates, sustains, and defines their interests? This research examined characteristics of hobbyists, what they do, how their hobbies evolved, and how hobbyists interact with other people and organizations in pursuit of their leisure interests. The data included transcripts from 107 in-depth interviews with hobbyists (67% male, 33% female; 93% Caucasian, 7.5% minority) from different locations in the United States. Hobbyists were recruited from clubs, email lists, Internet postings, and science centers. Interviews were conducted either face-to-face or through telephone contacts. The results of the study showed that most of the hobbyists participated in an organized club (78%), and over half of all the hobbyists indicated that their hobby started in childhood (51%). Other participants noted that they first began their hobby in secondary school (19%), college (5%), and as adults (25%). Eighty-two percent of the hobbyists noted that they were encouraged in their hobby participation. Most of the hobbyists reported that a family member or friend had encouraged them. Only 4% of hobbyists were encouraged by a teacher to pursue their hobby. Hobbyists reported that they often engaged in educational outreach to share their hobby interests. Schools and science centers were both mentioned by over 60% of all the hobbyists interviewed as outreach audiences. Clubs and workshops were also mentioned as outreach groups (57% and 40% respectively). For those that worked with schools, hobbyists were engaged in sharing with elementary schools (28%), middle schools (17%), high schools (16%), and colleges (14%). The findings of this research showed that hobbyists are disproportionately male and Caucasian. The lack of minority hobbyists has serious implications for STEM advocates later in life. As these interviews showed, these individuals are highly involved and support science in formal (school-based) and informal settings. If these findings are indicative of hobbyists nationwide, then the lack of hobby engagement could be a contributing factor to the disparities seen in minority participation in the STEM workforce.

IN COLORADO PALEONTOLOGY

Smith, Dena M., CU Museum and Geological Sciences, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309; Karim, Talia S., CU Museum, 265 UCB-CU Museum-Paleontology, University of Colorado Boulder, Boulder, CO 80309

Colorado possesses a rich community of paleontology enthusiasts that have historically worked to promote paleontology within the state and formed many fruitful collaborations with academic researchers and government agencies. Here we present information on two important groups that have been working in the Colorado paleontological community since the 1980s: The Friends of the Florissant Fossil Beds (Friends Group) and the Western Interior Paleontological Society (WIPS). Both non-profit organizations have active and enthusiastic members and missions that focus on serving scientific and educational work related to paleontology. WIPS, based in Denver, Colorado, serves paleontological interests across the state and beyond. Monthly meetings are hosted at the Denver Museum of Science and Nature, where members enjoy lectures by local paleontologists, and take classes on fossil preparation, basic geology, and curation. During the summer months, members participate in field trips to collect fossils in Colorado and neighboring states and sometimes participate in fieldwork of area researchers. The group also holds an annual ‘Founders Symposium’ that consists of two days of lectures, workshops, and events centered around a theme (e.g., Ice Worlds and Their Fossils). Funds generated by group activities support two important scholarships, available only to WIPS members, for paleontologic research and continuing education. WIPS has recently started a separate kids and family group that focuses on paleontology education and activities for K–12 students. In contrast, the Friends Group is specifically focused on assisting and promoting Florissant Fossil Beds National Monument. They support an annual seminar series held at the national monument and fund graduate student research and student interns who work in the park. They also contribute to their outreach mission through support of the junior ranger program and with improvements to exhibits and visitor experiences (e.g., purchasing an all-terrain wheelchair). Future collaborations are planned with both groups related to two NSF funded projects; Insect Response to Eocene-Oligocene Climate Change and the Fossil Insect Collaborative TCN project. Projects include the development of educational modules and teacher training at Florissant, iDigPaleo—a collections management and collaborative hub for the paleontological community that will provide access to specimens and associated data as well as tools and mobile apps that will allow club members to interact and engage with images and data produced by the projects.
Session No. 26: Critical paleobiological transitions in Earth history: The value of interdisciplinary approaches

Chairs: Sandra J. Carlson and Philip D. Gingerich

Monday Morning 8:30 AM to 11:45 AM

Session 26-1: Monday, 8:30 AM
Presenter: STEPPE Executive Director

STEPPE: A VOICE FOR RESEARCH ON EARTH'S DEEP-TIME SEDIMENTARY CRUST

STEPPE Executive Director, STEPPE, P.O. Box 9140, Boulder, CO 80301

STEPPE—Sedimentary geology, Time, Environment, Paleontology, Paleoclimate, and Energy—is a new consortium whose purpose is to promote multidisciplinary research and education on Earth’s deep-time sedimentary crust (including paleontology); to encourage us to think about big problems that need to be solved; and to encourage collaborative research to tackle these issues. The community of scientists involved in deep-time sedimentary crustal research is large and diverse, including many specialties—paleontology, sedimentary geology, stratigraphy, geochronology, paleoclimatology, sedimentary geochemistry, and more—and roughly one-third of earth-science faculty in US universities. The size of the community is itself a barrier to formation of collaborative, multidisciplinary teams, especially for early-career researchers. Keeping track of events and developments in sedimentary crustal research is a daunting and time-consuming task. STEPPE will act as a clearinghouse for information on research opportunities and educational activities (research developments, workshops, conferences, funding opportunities, etc.). STEPPE will also provide web-hosting services, team-building resources, help with coordinating workshops, a community calendar, and social media for disciplines that study the sedimentary crust in deep time, focusing on collaborations among those disciplines. Initial funding for the consortium is from NSF, with contributions from GSA, PS, and SEPM. This symposium is intended to highlight some of the types of research that are central to STEPPE’s mission.

Session 26-2: Monday, 8:45 AM
Presenter: Johnny A. Waters

ANOXIA, EXTINCTION, AND FAUNAL REBOUND IN THE LATE DEVONIAN IN THE CENTRAL ASIAN OROCENIC BELT: A MULTI-PROXY APPROACH

Waters, Johnny A., Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Carmichael, Sarah K., Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Suttner, Thomas J., Department of Geology, University of Graz, 8010 Graz, Heinrichstraße 26, Austria; Kido, Eirka, Department of Geology, University of Graz, 8010 Graz, Heinrichstraße 26, Austria; Moore, McCaïn, Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Batchelor, Cameron, Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; DeReuil, Aubry A., Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112

The Devonian was a time of dynamic long-term climate change and substantial changes in biodiversity. The Late Devonian is bracketed by two mass-extinction events at the Frasnian–Famennian (F–F) and the Devonian–Carboniferous (D–C) boundaries. The close stratigraphic association between the extinction events and the Kellwasser and Hangenberg Events support a link between oceanographic anoxia and extinction. Both anoxic events previously have been identified primarily in epicontinental basinal settings in Laurussia, Gondwana, Siberia, and South China. Geochemical signals preserved in marine sediments can act as proxies for anoxia, primary productivity, and changes in sea level. These methods include a combination of whole rock geochemistry (including major, minor, trace, and rare earth element analyses), mineralogical modal analysis, detailed SEM and cathodoluminescence (CL) microscopy, stable isotope analyses (carbon, oxygen, and strontium), and magnetic susceptibility. In addition, the size and distribution of pyrite framboids can be used to assess redox conditions. Proxies for enhanced productivity include whole rock Ba and P anomalies in addition to excess SiO₂ in the form of authigenic quartz silt. The Hongguleleng (Late Devonian) and Heishantou Formations in northwestern Xinjiang, China, contain the F–F boundary and the D–C boundary in a highly fossiliferous shallow marine setting associated with a Devonian oceanic island arc complex in the Central Asian Orogenic Belt. Here we show that these units also record the Upper Kellwasser and the Hangenberg anoxic events in a single continuously exposed section. Even though black shales often associated with these events are missing, we can document their presence through the multi-proxy approach outlined above. In contrast to previous studies asserting that these anoxic events were restricted to epicontinental seaways, our results indicate that they occurred not only along the shallow continental margins of the closing Rheic Ocean, but also in shallow water in the open oceanic part of Paleoethys. The presence of the Kellwasser Event in shallow, open-ocean environments indicates that anoxia in the Late Devonian was likely due to global effects of a changing climate rather than increased nutrient and sediment fluxes from continents. The Hongguleleng Formation is characterized by an abundant and diversified fossil flora and fauna consisting of acritarchs, spores, radiolarians, sponges, corals, trilobites, ostracods, gastropods, cephalopods, brachiopods, bryozoans, echinoderms (blastoids and crinoids), conodonts, and fish teeth. Although taxonomic studies are ongoing, current estimates of diversity in the Hongguleleng exceed 100 genera. Faunas from the Hongguleleng Formation, particularly bryozoans and echinoderms, demonstrate that the rebound from the F–F extinction event happened much more rapidly than previously thought, and suggest that central Asia acted as a
A MULTIDISCIPLINARY APPROACH FOR UNDERSTANDING UPPER KELLWASSER BLACK SHALE DEPOSITION, NEW YORK STATE: COMBINING ICHNOLOGICAL, ORGANIC, AND INORGANIC GEOCHEMICAL PROXIES

Haddad, Emily E., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Boyer, Diana L., Geology, State University of New York, Oswego, Oswego, NY 13126; Love, Gordon D., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Droser, Mary L., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521

Anoxia and euxinia are commonly evoked as mechanisms of marine extinction during the Phanerozoic. Notably, the pervasiveness of black shale preservation in association with the Late Devonian biocrises suggests anoxia played a major role in the permanent ecological turnover of reefs and other marine taxa in the Famennian, but neither the extinction mechanisms nor the mechanisms of black shale deposition at this time are well-understood. Because developing our understanding of these two issues requires in-depth and simultaneous analysis of many biological, chemical, and physical factors, multidisciplinary research combining paleontology, sedimentology, and inorganic and organic geochemistry is the best course for resolving the complexity of black shale deposition in the Late Devonian. Multiproxy studies continue to show that black shales can be deposited under a range of bottom-water conditions, and during the Late Devonian, depositional conditions were not homogeneously or pervasively anoxic or euxinic. In our study, bottom-water oxygen conditions are interpreted from four upper Kellwasser (uKw) black shale localities in western New York State, using inorganic and organic geochemical proxies and trace fossils at high resolution (at a mm-cm scale) to constrain relative oxygen levels and identify signals of anoxia and euxinia in the Devonian Appalachian Basin. Mo concentrations are suggestive of suboxic conditions and perhaps intermittent euxinia, indicating that the uKw black shale preserves reduced-oxygen bottom-water conditions. Levels of enrichment are muted, however, especially as compared to other Phanerozoic euxinic black shale intervals. Lipid biomarker patterns are typical for Paleozoic marine rocks, indicating that the biomarker molecules in the extracted bitumens are syndepositional and not significantly affected by contamination. The Appalachian samples contain very low amounts of aryl isoprenoids, up to several orders of magnitude lower than concentrations reported in other Phanerozoic euxinic basins, and isorenieratene is not present in detectable amounts. These data are consistent with a local paleoredox model lacking a persistently shallow sulfidic zone. Extremely low hopane/sterane ratios (below the Phanerozoic average) indicate high relative input of eukaryotes during deposition of the uKw black shale, in contrast to epeiric settings during other major Phanerozoic extinction events. The trace-fossil record through the uKw black shale interval complements the geochemical proxies well; the presence of horizons with abundant bioturbation between well-laminated intervals provides incontestable biological support for intermittently oxygenated bottom waters. While each proxy considered in isolation does not reveal a complete story of bottom-water conditions, combining proxies from different disciplines can provide the best possible understanding of the mechanisms of uKw black shale deposition.

Session 26-4: Monday, 9:15 AM
Presenter: Matthew E. Clapham

ORGANISM, SPECIES, AND COMMUNITY-LEVEL RESPONSES TO AN ICEHOUSE-GREENHOUSE TRANSITION AFTER THE LATE PALEOZOIC ICE AGE

Clapham, Matthew E., Earth and Planetary Sciences, UC Santa Cruz, Santa Cruz, CA 95064

The late Paleozoic ice age was a critical environmental transition from a glaciated to an ice-free greenhouse world, providing excellent opportunities to investigate the biological response to climate change. The biological consequences of post-glacial warming in the marine realm must be assessed at multiple scales, from regional or global patterns of diversity, extinction, and migration, to local community change and the physiological response of individual organisms. Quantitative paleoecological analysis of eastern Australian samples suggests that the climate transition led to substantial paleocommunity restructuring. In contrast, the composition of bulk samples from Bolivia only changed gradually, likely in response to the slow northward motion of Gondwana. Additional studies are required to clarify the potential importance of geographic variations in the magnitude of the biotic response. The broader context of those local community changes can be studied with regional or global occurrence data from the Paleobiology Database. Clear evidence for climate-driven migration is difficult to obtain from literature compilations, but there are signs that warmer intervals in eastern Australia enabled invasion of taxa more typical of lower-latitude regions. Understanding the primary driver of these large-scale changes, whether direct effects of thermal stress or indirect effects via ecological interactions, remains a key outstanding issue. Sclerochronology provides a way of reconstructing seasonal patterns in shell growth and provides the first evidence that thermal stresses may have acted directly on marine invertebrates, leading to reductions in ecological dominance and ultimately extinction. Targeted studies yielding more precise correlation of high-resolution faunal, climate proxy, and model data have excellent potential for elucidating the faunal response to climate change from the poles to tropics following the late Paleozoic ice age.

Session 26-5: Monday, 9:30 AM
Presenter: Silvia Danise

THE RESPONSE OF MARINE BENTHIC COMMUNITIES TO INCREASED PCO2 AND TEMPERATURE IN THE EARLY TOArcIAN

Danise, Silvia, School of Geography, Earth and
Environmental Sciences, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA UK; Clémence, Marie-Emilie, Institute of Geology and Palaeontology, University of Innsbruck, Innsbruck, Austria; Murphy, Daniel P., Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, Southampton, UK; Price, Gregory, School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA UK; Gómez, Juan J., Departamento de Estratigrafía, Universidad Complutense de Madrid, Madrid, Spain; Twitchett, Richard J., School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA UK

Severe environmental change in the early Toarcian (Early Jurassic, ~183 Ma), characterized by a major perturbation in the carbon cycle, higher seawater temperatures, and widespread deposition of organic-rich shales in many shallow seas, coincided with an extinction event in the marine realm. Although the onset of anoxia has been hypothesized as a major cause of marine extinction, this has recently been brought into doubt as the extinction event has also been recorded in localities that remained oxygenated throughout. Macraufaunal changes through the late Pliensbachian and early Toarcian interval have been analyzed from well-preserved sections of the Iberian Range (central Spain) where no evidence of anoxia has been recorded. The assemblages are mostly dominated by bivalves (~60%) and brachiopods (~40%), with other taxonomic groups being rare. Stable isotope analyses ($\delta^{13}C$, $\delta^{18}O$) were performed on the bulk sediment and on selected calcitic brachiopod shells from the same sampled horizons. Temporal changes in carbon isotopes may be partly driven by fluctuating atmospheric $CO_2$ concentrations, and changes in the $\delta^{18}O$ signature of biogenic marine calcite can be interpreted in terms of relative changes in paleotemperature. The main negative peaks in the carbon and oxygen isotope records coincide with an abrupt decline in species richness and evenness, and the main turnover in the bivalve and brachiopod faunas. The community that colonized the sediments soon after the extinction interval was dominated by small-sized brachiopods and pelecypods bivalves that, respectively, disappear and dramatically decrease in abundance at the terminations of the negative isotope excursions. The ecological metrics, represented by the main axis of ordination, when correlated with the measured environmental factors are significantly positively rank correlated with $\delta^{18}O$, suggesting that changes in temperature might have driven changes in the benthic fauna. This correlation is recorded for the full dataset, and also when brachiopods and bivalves are analyzed separately, indicating a similar response to paleotemperature change and a similar vulnerability to rapid temperature rise.

Session 26-6: Monday, 9:45 AM
Presenter: Shari Hilding-Kronforst

NEW AND REVISED PLANKTONIC FORAMINIFERAL BIOEVENTS OF THE (MIDDLE) EOCENE

Hilding-Kronforst, Shari L., Department of Geology and Geophysics, Texas A&M University, College Station, TX, 77843; Wade, Bridget S., Room 27 South Wing, Department of Earth Sciences, University College London, London, WC1E 6BT UK

Extinction and evolutionary events in planktonic foraminifera are extensively employed in regional and global biostratigraphy and are a fundamental component of Cenozoic chronostratigraphy. The calibration of planktonic foraminiferal bioevents has been based largely on correlations to the magnetostratigraphy in Deep Sea Drilling Project and Ocean Drilling Program (ODP) cores, as well as outcrop sections (Berggren et al., 1995; Wade et al., 2011). However, the calibration of many Paleogene planktonic foraminiferal events has been hindered by poor core recovery, the absence of Earth Sciences, University College London, London, WC1E 6BT UK

Extinction and evolutionary events in planktonic foraminifera are extensively employed in regional and global biostratigraphy and are a fundamental component of Cenozoic chronostratigraphy. The calibration of planktonic foraminiferal bioevents has been based largely on correlations to the magnetostratigraphy in Deep Sea Drilling Project and Ocean Drilling Program (ODP) cores, as well as outcrop sections (Berggren et al., 1995; Wade et al., 2011). However, the calibration of many Paleogene planktonic foraminiferal events has been hindered by poor core recovery, the absence of biogenic carbonate and a lack of magnetostratigraphic and/or cyclostratigraphic age control. Here we review critical planktonic foraminiferal bioevents of the Eocene, focusing on the Lutetian, and discuss their utility and calibration to the global polarity and astronomical time scales. Planktonic foraminiferal biochronology for the middle Eocene has recently undergone extensive revisions that have resulted in large changes in the duration of biochrons (Payros et al., 2007; Wade et al., 2011). We examine planktonic foraminiferal assemblages from Ocean Drilling Project (ODP) Leg 171B, Site 1051, Blake Nose in the western North Atlantic Ocean. Planktonic foraminifera are abundant, with diverse assemblages. Quantitative biostratigraphy was conducted on planktonic foraminifera from 119 to 369 meters below sea floor. This interval corresponds to magnetochrons C18r to C21n. All planktonic foraminifera are well-preserved (although recrystallized), and assemblages are diverse. We present an integrated magnetobiochronology of middle Eocene planktonic foraminifera with significant revision and recalibration of Eocene planktonic foraminifera Zones E7 through Zone E11.

Session 26-7: Monday, 10:30 AM
Presenter: Christina L. Belanger

DISENTANGLING THE DRIVERS OF BIOTIC RESPONSES TO CLIMATE CHANGE USING A MULTIVARIATE ENVIRONMENTAL PROXY RECORD

Belanger, Christina L., Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701; Villarosa Garcia, Marites, Geophysical Sciences, University of Chicago, Chicago, IL 60637

Climate changes are multivariate in nature, and disentangling the proximal drivers of biotic responses to paleoclimate events requires time series of multiple environmental proxies. We combine paleoecological data from benthic foraminifera and mollusks with geochemical proxies and sedimentary data to create a multivariate time series of local ecological and environmental change for the early Miocene Newport Member of the Astoria Formation in Oregon (20.26–18 Ma). We evaluate the association of individual environmental proxies, and combinations of proxies, to changes in faunal composition observed in benthic foraminiferal and molluscan communities collected from the exact same sediments as the environmental data. Of the measured environmental proxies ($\delta^{18}O$, $\delta^{13}C$ and $\Delta\delta^{13}C$ from foraminiferal calcite and $\delta^{15}N$ and % mud from bulk sediment), $\delta^{15}N$ values are the most parsimonious correlates
with major changes in foraminiferal composition, while molluscan composition is most closely related to δ¹³C values, suggesting that oxygenation is affecting the foraminiferal community while changes molluscan community composition are related to surface water productivity. Interestingly, when these most supported correlates are removed to simulate the absence of proxy data, significant environmental relationships can still be found, which could lead to incorrect attribution of environmental drivers to faunal change. Paleoenvironmental studies of biotic response that test multiple environmental drivers for multiple taxonomic groups are powerful tools for identifying the ecological consequences of past warming events and the regional drivers of ecological changes.

Session 26-8: Monday, 10:45 AM
Presenter: Kenneth Johnson

THIRTY YEARS OF FIELD-BASED ‘BIG PALEONTOLOGY’ ON CENOZOIC SHALLOW-MARINE ECOSYSTEMS

Johnson, Kenneth G., Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK; Klaus, James S., Department of Geological Sciences, University of Miami, Department of Geological Sciences, 43 Cox Science Building, Coral Gables, FL 33124; Todd, Jonathan A., Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, UK; Renema, Willem, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands; Budd, Ann F., Department of Geoscience, University of Iowa, Iowa City, IA 52242

Since the 1980s, two large-scale field-based paleontology projects worked towards understanding the Cenozoic history of shallow-marine ecosystems of the Caribbean: 1) the Dominican Republic Project, organized by the Natural History Museum in Basel, Switzerland; and 2) the Panama Paleontology Project, organized by a team at STRI in Panama. Scientific aims include description of faunas, past episodes of biotic turnover, and the response of ancient ecosystems to environmental change. Project management and team composition varied in response to constraints imposed by funding and availability of collaborators. The resulting databases include at least 10,000 samples and more than 1,000,000 specimens from thousands of taxa. In some groups, a significant proportion of this diversity was previously unrecognized. Over 100 publications resulted, including dozens of taxonomic monographs. As implemented, each project has strengths and weaknesses, yet all made significant progress in understanding the Neogene biota of the Caribbean. Our experiences have provided insights into factors required for a successful large-scale project in paleontology, including: 1) long-term funding either through strong support of lead institutions or by funding agencies; 2) strong collaborative links among project partners, including strategies for managing intellectual property; and 3) rigorous stratigraphic, paleoenvironmental, and taxonomic frameworks based on integration of multiple data sources. Building on the success of these projects, THROUGHFLOW is a consortium of academic institutions, industrial partners, and the Indonesian Geological Agency funded by the European Union as a Marie Curie Initial Training Network. The primary scientific aim of THROUGHFLOW is to document the biotic and environmental history of shallow-marine ecosystems of Southeast Asia. Southeast Asia contains the global center of extent diversity for marine biota, yet the timing and factors responsible for the origins and continued maintenance of this hotspot remain obscure. Existing collections are inadequate to document the biodiversity or to reconstruct the changing environmental and ecological conditions in the region. The network includes earth-systems modelers, geochemists, paleoceanographers, paleontologists, sedimentologists, and stratigraphers. We have deployed two field parties, totaling 1117 researcher-days, to study the Miocene shallow marine facies of East Kalimantan, Indonesia. Eight tons of samples were collected from 160 exposures. Preliminary results confirm high diversity in various shallow marine habitats during the Miocene. For reef facies, there was a switch from assemblages constructed by tabular to platy colonies to facies dominated by branching and small, free-living forms. This change might coincide with rapid cooling during the Middle Miocene, or might result from regional environmental change associated with tectonic evolution of the Indonesian Throughflow.

Session 26-9: Monday, 11:00 AM
Presenter: David J. Bottjer (Invited Keynote)

DEEP-TIME CONSERVATION PALEOBIOLOGY

Bottjer, David J., Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089

Conservation paleobiology focuses on data from the fossil record that can help understand and manage changes seen in modern ecosystems. Many early conservation paleobiology studies have emphasized analyses of relatively young and well-studied groups, a significant proportion of this diversity was previously unrecognized. Over 100 publications resulted, including dozens of taxonomic monographs. As implemented, each project has strengths and weaknesses, yet all made significant progress in understanding the Neogene biota of the Caribbean. Our experiences have provided insights into factors required for a successful large-scale project in paleontology, including: 1) long-term funding either through strong support of lead institutions or by funding agencies; 2) strong collaborative links among project partners, including strategies for managing intellectual property; and 3) rigorous stratigraphic, paleoenvironmental, and taxonomic frameworks based on integration of multiple data sources. Building on the success of these projects, THROUGHFLOW is a consortium of academic institutions, industrial partners, and the Indonesian Geological Agency funded by the European Union as a Marie Curie Initial Training Network. The primary scientific aim of THROUGHFLOW is to document the biotic and environmental history of shallow-marine ecosystems of Southeast Asia. Southeast Asia contains the global center of extent diversity for marine biota, yet the timing and factors responsible for the origins and continued maintenance of this hotspot remain obscure. Existing collections are inadequate to document the biodiversity or to reconstruct the changing environmental and ecological conditions in the region. The network includes earth-systems modelers, geochemists, paleoceanographers, paleontologists, sedimentologists, and stratigraphers. We have deployed two field parties, totaling 1117 researcher-days, to study the Miocene shallow marine facies of East Kalimantan, Indonesia. Eight tons of samples were collected from 160 exposures. Preliminary results confirm high diversity in various shallow marine habitats during the Miocene. For reef facies, there was a switch from assemblages constructed by tabular to platy colonies to facies dominated by branching and small, free-living forms. This change might coincide with rapid cooling during the Middle Miocene, or might result from regional environmental change associated with tectonic evolution of the Indonesian Throughflow.
including acidification, also led to an Early Triassic mass extinction of marine benthic environments characterized by low biodiversity, cosmopolitan taxa, and reducts and depth and extent of bioturbation. A similar environmental trigger led to the end-Triassic mass extinction, which was caused by an increase in environmental stress due to development of the Central Atlantic Magmatic Province (CAMP), and is the most severe mass extinction experienced by the Modern Fauna. This mass extinction probably included episodes of ocean acidification.

FROM C3 TO C4 ECOSYSTEMS

Neogene Grasslands of the Indian Subcontinent: DYNAMICS OF THE TRANSITION FROM C3 TO C4 ECOSYSTEMS

Badgley, Catherine, Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI 48109; Behrensmeyer, Anna K., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; Cerling, Thure E., Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112; Morgan, Michele E., Peabody Museum of Archaeology and Ethnology, Harvard University, 11 Divinity Avenue, Cambridge, MA 02138; Barry, John C., Peabody Museum of Archaeology and Ethnology, Harvard University, 11 Divinity Avenue, Cambridge, MA 02138; Pilbeam, David, Peabody Museum of Archaeology and Ethnology, Harvard University, 11 Divinity Avenue, Cambridge, MA 02138

The Neogene Siwalik record of fluvial ecosystems in Pakistan documents a prolonged transition from C3 to C4 vegetation between 8.0 and 4.5 million years ago. Intensive sampling of paleosols over millions of years and laterally across paleo-landscapes reveals how vegetation and soils changed during this transition. Stable isotopes of carbon from paleosols over millions of years and laterally across paleo-landscapes reveals how vegetation and soils changed during this transition. Stable isotopes of carbon from paleosols predominantly C3 vegetation across the entire floodplain from the middle to late Miocene up to 8.0 Ma. During the transition period, patches of C3 and C4 vegetation coexisted in different floodplain habitats; C4 grasses dominated drier floodplain surfaces and C3 vegetation occupied mesic swales associated with abandoned channels. From 4.5 Ma to at least 1.0 Ma, C4 grasses dominated the floodplain ecosystem, with sparse patches of trees and shrubs. Carbon isotopes along with dental microwear and mesowear sampled from mammalian lineages over millions of years show greater taxonomic and trophic diversity when C3 vegetation covered the floodplains. C3 vegetation included forest, shrubs, and grasses, as inferred from the dental morphology, body sizes, carbon isotopes, and dental microwear of large mammals. During the transition from C3 to C4 vegetation, herbivorous mammals experienced a significant decline in both species diversity and trophic diversity. Losses occurred among many groups of large mammals, with frugivorous and browsing lineages disappearing without replacement; mixed feeders and grazers persisted or were replaced by immigrant and endemic species. A few lineages adapted their diets to the changing vegetation and persisted through the transition. Bovids (antelope) and equids (horses) responded differently to this transition. Most bovids continued to feed on C3 plants and disappeared without replacement. A few lineages altered their diets to include increasing amounts of C4 grasses and persisted through the transition. Equids fed from a wide range of C3 and C4 plants even before the transition began, and gradually incorporated more C4 plants in their diets, but did not become exclusive C4 grazers until the transition was complete. Modern ecosystems most similar to C4 grasslands of the late Neogene Siwalik record are the monsoonal grasslands of the northern Indian subcontinent, with high annual precipitation but very long dry seasons.

HOW DID LATE MIOCENE RODENTS RESPOND TO CHANGES IN THE GRASSLAND BIOME OF SOUTHERN ASIA?

Flynn, Lawrence, J., Department of Human Evolutionary Biology, Harvard University, 11 Divinity Ave., Cambridge, MA 02138; Kimura, Yuri, Shuler Museum of Paleontology Southern Methodist University, 3225 Daniel Ave., Dallas, TX 75275; Nelson, Sherry V., Anthropology, University of New Mexico, Albuquerque, NM 87131

The thousands of meters of fluvial deposits that comprise the Siwaliks of the Indian Subcontinent include many superposed fossil horizons in a composite set of sediments that is largely complete for the Miocene on the scale of 100,000 years. Terrestrial fossil vertebrates occur throughout, and faunal change coincides with the late Miocene revolution in grassland composition. The response of small mammals to changes in the grassland biome, especially turnover...
associated with replacement of C\textsubscript{3} by C\textsubscript{4} grasses, begins to complement the story of faunal change that has already emerged for large mammals. In the South Asia setting, particularly the Potwar Plateau of Pakistan, changes among small mammals were evident well in advance of major turnover in grass composition, possibly attesting to increasing seasonality of rainfall in advance of the spread of C\textsubscript{4} grasses. By 10 Ma, galericine hedgehogs had disappeared and cricetid rodents were in decline in both abundance and number of taxa. Conservative, ground-dwelling rhizomyine rodents continued from the early Miocene, but were becoming higher-crowned. By about 9.5 Ma, specialized subterranean rhizomyines of the modern bamboo rat clade appeared, and the group diversified during the next million years. Bamboo rats demonstrate that by this time, underground nutrient storage organs of plants were being exploited by herbivores. Prior to 9 Ma, as the grasslands changed, murine rodent lineages began to show morphological divergence, presumably reflecting adaptations to different fall-back or preferred vegetation. Isotopic evidence suggests that the murines persisted in exploiting C\textsubscript{3} vegetation until after 8 Ma, well after some large mammals had begun to incorporate C\textsubscript{4} vegetation into the diet. Enamel isotopes suggest that by 7.4 Ma, larger murines apparently were consuming proportionally more C\textsubscript{4} vegetation than smaller mice. Differential consumption of C\textsubscript{3} and C\textsubscript{4} plants in these lineages is based on stable carbon isotope ratios in molar enamel. In contrast, conservative terrestrial rhizomyines showed no isotopic change in incisor enamel from 16 to 7 Ma. This suggests that their food source remained the preferred food throughout this time. Siwalik rodents were highly diverse and showed diversity in response to changes in the grasslands of South Asia during the Late Miocene. They indicate faunal change with increasing seasonality of rainfall in advance of the spread of grasslands. Our preliminary data suggest that woody plants, including palms, remained prominent in vegetation through the middle Miocene. Grass phytoliths constitute as much as ~30–45% in some samples, but the grass communities appear to not have been dominated by open-habitat grasses such as pooids and PACMADs. Instead, forest-dwelling grasses, such as bamboos, seem to have comprised a chief part of the grassy understory. This pattern suggests that, unlike for North American and Eurasian ungulates, grass-dominated habitats were likely not important for Cenozoic hypsodonty evolution in South American herbivores. Instead, we hypothesize that availability of inorganic dietary abrasives (e.g., volcanic ash) may have triggered evolutionary changes in cheek-tooth crown heights in southern South America.

Session 27-3: Monday, 9:15 AM
Presenter: Caroline A. E. Strömberg

**EVOLUTION OF GRAZER MORPHOLOGIES IN THE ABSENCE OF GRASSLANDS IN SOUTHERN SOUTH AMERICA**

Strömberg, Caroline A. E., Department of Biology and Burke Museum of Natural History & Culture, University of Washington, Box 353010, Seattle, WA 98195; Dunn, Regan E., Department of Biology and Burke Museum of Natural History & Culture, University of Washington, Box 353010, Seattle, WA 98195; Madden, Richard H., Department of Organismal Biology and Anatomy, University of Chicago, Chicago, IL 60637, United States; Kohn, Matthew J., Department of Geosciences, Boise State University, Boise, ID 83725; Carlini, Alfredo A., Departamento de Paleontología de Vertebrados, Universidad Nacional de La Plata, La Plata, Argentina

High-crowned (hypsodont) and ever-growing (elodont) cheek teeth evolved independently in several herbivore lineages in southern South America, starting in the middle Eocene, a pattern that was long thought to mark the spread of savanna vegetation 20 million years earlier than on any other continent. Recent pollen and plant silica (phytolith) data contradict this idea, indicating that grasses were rare in Patagonia for most of the Cenozoic, and did not form grasslands until sometime after the early Miocene. Initial hypsodonty evolution, therefore, did not reflect a shift from closed forest to grass-dominated vegetation. Still, it is possible that grasslands spread later, in the middle or late Miocene, and that observed crown-height changes in Patagonian meridiungulates, rodents, and marsupials were evolutionary responses to this ecological change. To test this hypothesis, we used phytolith assemblages to reconstruct vegetation at late early–middle Miocene (16.87–11.78 Ma) faunal sites along the Argentine and Chilean Andes. Phytoliths can provide information about both the relative cover of grass and woody vegetation and of the types of grasses present, making them a suitable tool for tracking the spread of grasslands. Our preliminary data suggest that woody plants, including palms, remained prominent in vegetation through the middle Miocene. Grass phytoliths constitute as much as ~30–45% in some samples, but the grass communities appear to not have been dominated by open-habitat grasses such as pooids and PACMADs. Instead, forest-dwelling grasses, such as bamboos, seem to have comprised a chief part of the grassy understory. This pattern suggests that, unlike for North American and Eurasian ungulates, grass-dominated habitats were likely not important for Cenozoic hypsodonty evolution in South American herbivores. Instead, we hypothesize that availability of inorganic dietary abrasives (e.g., volcanic ash) may have triggered evolutionary changes in cheek-tooth crown heights in southern South America.

Session 27-4: Monday, 9:30 AM
Presenter: Robert Feranec

**ISOTOPIC EVIDENCE FOR PATCHY C\textsubscript{4} ABUNDANCE IN SOUTHERN CALIFORNIA DURING THE MEDIAL MIocene**

Feranec, Robert S., Research and Collections, New York State Museum, Cultural Education Center, 222 Madison Avenue, Albany, NY 12230; Pagnac, Darrin, Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701

The evolution and spread of grasslands was critical for the development of modern North American ecosystems, and is also linked to the diversification of many mammalian clades, particularly ungulates. The mammalian diversification, coincident with the spread of grasslands, resulted in the highest diversity of mammalian herbivore genera on the continent in the Cenozoic. Grassland evolution is suggested to have occurred in two phases. The first phase, which occurred in the late Oligocene and early Miocene, involved the spread of grasses that primarily utilized C\textsubscript{3} photosynthesis, while the second phase, occurring in the late Miocene, involved the spread of grasses that utilized C\textsubscript{4} photosynthesis. This late Miocene rapid increase in C\textsubscript{4} ecosystems does not appear to be contemporaneous with diversification events in many mammalian clades, and its influence on mammalian evolution is suggested to have been negligible. Here we analyze tooth-enamel stable carbon and oxygen isotope values from horses found in three localities in
THE RISE AND SPREAD OF GRASSES IN MONTANA
PRELIMINARY MULTI-PROXY 40 MA RECORD OF
THE RISE AND SPREAD OF GRASSES IN MONTANA

Sheldon, Nathan D., Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103; Smith, Selena Y., Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103; Strömberg, Caroline A.E., Department of Biology and Burke Museum of Natural History, University of Washington, Seattle, WA 98195; Hyland, Ethan G., Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103; Cotton, Jennifer M., Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103; Harris, Elisha B., Department of Biology and Burke Museum of Natural History, University of Washington, Seattle, WA 98195; Hamer, Jessica M.M., Lampton School, Hounslow TW3 4EP UK; Chen, Stephanie T., Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103; Frederickson, Erik K., Department of Biology and Burke Museum of Natural History, University of Washington, Seattle, WA 98195; Smith, Kimberly J., Department of Biology and Burke Museum of Natural History, University of Washington, Seattle, WA 98195

While the global spread of grasslands is reasonably well understood, regional patterns and processes are still poorly characterized. Typically, grasses are reconstructed on the basis of a single proxy (e.g., phytoliths or carbon stable isotopes), but multi-proxy comparisons, which can provide a higher level of confidence in data interpretation as well as insights into biases associated with individual proxies, are still relatively rare. Here, we present a preliminary multi-proxy paleovegetation reconstruction for the past 40 Ma from southwestern Montana, where we document the rise and spread of grasses from minor players in the Paleogene to ecosystem-scale dominance by the late Miocene. Paleovegetation was reconstructed using a combination of phytoliths (plant silica microfossils) and stable isotopes from paleosol carbonates and organic matter. These paleovegetation data are placed into a local paleoclimatic context derived from paleosol geochemistry and physical properties such as Bk horizon depth. We recognize three distinct vegetation stages: 1) from 40 to 24 Ma, forest vegetation dominated with episodic incursions of C3 grasses; 2) following the Oligocene-Miocene transition (~24 Ma) until 8 Ma, habitats opened up into woodland and open C3 grasslands with a persistent but minor (~25%) component of C4 vegetation; 3) by 8 Ma, grasses dominated, including 20–50% C4 grasses. Both isotopes and phytoliths from lateral transects of single paleosols indicate patchiness in terms of grass abundance at all three of these stages (including C4 abundance in stages 2 and 3). Climate change was relatively modest locally during this time period with reconstructed mean annual precipitation <900 mm yr⁻¹ (modern ~260 mm yr⁻¹) and mean annual temperature <13°C (modern ~6°C) for the past 40 Ma and virtually no change from at least 10–3 Ma. Thus, the large expansion of C4 grasses could not have been driven entirely by climate change. At the same time, despite these high levels of C4 in the Miocene, most of southwestern Montana today has 10–20% C4 grasses, significantly lower than the Late Miocene peak. This decline could be due to local Late Miocene tectonics, because C4 abundance is typically elevation-limited. Ongoing work will test whether tectonics were a primary driver for C4 spread in Montana, or whether seasonality of precipitation, which is more poorly constrained, was a significant driver of grassland and C4 spread.

THE ROLE OF PALEOGENE GRASSES IN SOUTHWESTERN MONTANA PALEOEcosystemS INFERRED FROM COMBINED PHYTOLITH AND PALEOSOL ANALYSIS

Smith, Selena Y., Department of Earth and Environmental Sciences and Museum of Paleontology, University of Michigan, Ann Arbor, MI 48103; Sheldon, Nathan D., Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103; Strömberg, Caroline A.E., Department of Biology and Burke Museum of Natural History, University of Washington, Seattle, WA 98195; Dennis, Meredith, Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48103

Understanding local-to-regional responses of vegetation to changes in abiotic factors, such as plate tectonics or climate, is important in understanding overall dynamics regarding the evolution and spread of grasses to eventually dominate whole ecosystems in the Miocene. The mid-late Eocene was a period of active tectonism in western North America, and
saw a global pattern of cooling climate culminating in the Eocene–Oligocene transition (EOT; ~33.7 Ma) from a hothouse to icehouse climate. Documenting vegetation response to these changes is important for our understanding of ecosystem evolution of western North America. In southwest Montana, the Renova Formation is preserved in a number of Eocene and Oligocene localities that allow us to infer Cenozoic vegetation changes in this region. Paleosols and phytolith assemblages from six localities (~39–32 Ma) have been studied. Paleosols are primarily Alfisols, which are consistent with a forested floodplain landscape, and Inceptisols and Entisols, consistent with mixed herbaceous and forest (woodland) vegetation. Paleosol geochemistry and δ13C of soil carbon indicate slight cooling and drying as part of a long-term climatic deterioration. The oldest site examined, Timberhills A (~39 Ma), produced a high-resolution record dominated by forest indicators, including tropical elements such as palms and zingiberaleans. The overall dominance of forest indicators is punctuated by short-term shifts to assemblages indicative of grass-dominated habitats or tropical zingiberalean-dominated assemblages. The younger sites examined here lack the tropical zingiberaleans, with palms present in low numbers in most assemblages, and show a similar pattern of rare grass-dominated assemblages interspersed with predominantly forest-dominated assemblages. These data suggest that climate change over the EOT was less drastic in southwest Montana than global temperature records would suggest. While the zingiberaleans become locally absent after ~39 Ma, vegetation was fairly consistently forest during the EOT. Combined with an increase in the cicada trace fossil Taenidium in local paleosols, this pattern suggests a shift to more open habitats, which subsequently, in the earliest Oligocene, become reforested. Our data, as well as previous phytolith and paleosol studies from Montana, indicate that grasses became more prevalent in generally forested plant communities of the mid-Paleogene, and that overall, the paleovegetation in southwestern Montana was heterogeneous on both spatial and temporal time scales.

Session 27-7: Monday, 10:45 AM
Presenter: Elisha B. Harris

**IMPACTS OF THE MID-MIOCENE CLIMATIC OPTIMUM ON VEGETATION IN THE NORTHERN ROCKY MOUNTAINS**

Harris, Elisha B., Department of Biology, University of Washington, 24 Kincaid Hall, Box 351800, Seattle, WA 98195; Strömberg, Caroline A.E., Department of Biology, University of Washington, 24 Kincaid Hall, Box 351800, Seattle, WA 98195; Sheldon, Nathan, Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI 48109; Smith, Selena Y., Museum of Paleontology and Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI, 48109

Today, nearly all cultures are agriculturally dependent on C₃ (e.g., corn) and C₄ (e.g., rice) grass production; however, the ability of these grasses to thrive may change substantially with further climate change. Reconstructing long-term effects of global warming on floral communities in deep time can provide insights that are critical for forecasting such potential changes in the global distribution of different grass subtypes. The mid-Miocene Climatic Optimum (MMCO; 17–14.5 Ma), characterized by a transient shift to higher atmospheric CO₂ levels and warmer, possibly wetter climatic conditions, was an important period of biotic modernization with accelerated spread of C₄ grass-dominated ecosystems. In eastern Idaho during the MMCO, faunal analysis has shown a turnover from faunas dominated by oreodonts to those dominated by equids, and paleosol (fossil soil) data has suggested a return to woodland communities during this time. Previous work using a small dataset of phytolith (biogenic plant silica) samples pointed to an opening up of landscapes during the late early-middle Miocene, with C₃ grasses dominating the understory. However, a detailed record of vegetation change that would allow comparisons with regional climate data is missing. Here, we use assemblage analysis of phytoliths and a low-resolution δ13C record of paleosol organic matter to track long-term changes in vegetation composition and structure in the Railroad Canyon, eastern Idaho, during the MMCO. Samples (n=226) were collected from late Hemingfordian–late Barstovian paleosols preserved in the Railroad Canyon Sequence (RCS) and were processed for phytoliths. Our results suggest that grasses dominated local RCS assemblages (<15% forest indicators) throughout the duration of the MMCO, and there were no major increases in relative abundance of forest indicators during this time. Grass communities consisted primarily of C₃ grasses, but potential C₄ grasses were present as early as the late Hemingfordian. Potential C₄ grass phytoliths vary in relative abundances (7–31% of all phytoliths as a maximum estimate) through the section, indicating spatial heterogeneity over short time scales or across space, but no consistent, long-term pattern is discernible. Similarly, paleosol δ13C results indicate 0–22% C₄ vegetation, and no consistent pattern of change through time. Overall, these data suggest that the MMCO did not result in any major changes in vegetation structure in eastern Idaho, which is inconsistent with previously published paleosol morphology data. However, there do appear to have been occasional changes in grass community composition during this time, which may have been driven by climatic factors. If these patterns hold, they may imply that faunal change in eastern Idaho was linked to grass community composition change during the MMCO.

Session 27-8: Monday, 11:00 AM
Presenter: Ethan G. Hyland

**DYNAMICS OF THE RISE OF C₄ GRASSLANDS IN SOUTHWESTERN MONTANA**

Hyland, Ethan G., Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI 48109; Sheldon, Nathan D., Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI 48109; Smith, Selena Y., Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI 48109; Cotton, Jennifer M., Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112; Strömberg, Caroline A.E., Department of Biology, University of Washington, 24 Kincaid Hall, Box 351800, Seattle, WA 98195
Due to the complicated dynamics of the global spread of C₄ grasses (crucial modern/future crop resources), the mid-late Miocene is an important time period for understanding modern and future ecological conditions, and how plants might respond to global climate change. Describing the timing and climatic/environmental conditions of these ecological changes may help to unravel both global and local drivers of C₄ grassland evolution, expansion, and their modern distributions. Western North America provides an excellent record of these changes due to the density of well-exposed Miocene sedimentary sequences, the well-constrained ages and climatic conditions of available localities, and the abundance of well-preserved floral material for vegetation reconstructions. Here we present a high-resolution multiproxy record of vegetation and climate history for the Beaverhead site in southwestern Montana during the onset of the period of near-global C₄ grassland expansion. The Beaverhead locality is a sedimentary section of fluvial and paleosol deposits (Sixmile Creek Fm.) that is Hemphillian in age (~8–6 Ma), and has well-characterized climatic and environmental conditions based on analysis of sedimentology, paleosol morphology, stable isotopes, and paleosol whole rock geochemistry. These paleosol-based climofunction and paleobarometric data suggest preindustrial pCO₂ values (~280 ± 70 ppm), low mean annual temperatures (~10 ± 2°C), and low mean annual precipitation (320–380 mm yr⁻¹) values, consistent with modern grasslands in this part of North America. We use paired bulk-soil and pedogenic carbonate-derived carbon isotope data and phytolith assemblages to describe changes in C₄ grass abundances through time at the Beaverhead locality and in comparison to Miocene sites in southwestern Montana. Shifts in the isotopic composition of bulk and carbonate δ¹³C suggest an increase from patchy C₄ vegetation at the nearby mid-Miocene (10.2–8.9 Ma) TFF site (0–25%, mean=7 ± 5%) to a significant C₄ proportion of local vegetation (~40%) at the Beaverhead locality. Preliminary phytolith results are congruent with isotopic data, suggesting that the C₄ contribution (both chloridoid and panicoid grasses) increased to 39%–52% of local paleovegetation during the Hemphillian. This substantial shift agrees well with other North American localities, and provides the transitional link for regional grassland reconstructions that show evidence for limited C₄ grasses before this time period, and for significant C₄ grasslands afterwards.

Session 27-9: Monday, 11:15 AM

**Session No. 28:** Exceptional Records: Evolution and ecology of microfossils

*Chairs:* Gene Hunt and Pincelli Hull

Monday Morning 8:30 AM to 11:45 AM

Session 28-1: Monday, 8:30 AM

Presenter: Willem Renema (*Invited Keynote*)

**THE EXCEPTIONAL FOSSIL RECORD OF LARGER BENTHIC FORAMINIFERA AND ITS RELEVANCE TO UNDERSTANDING MACROEVOLUTIONARY PATTERNS**

Renema, Willem, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, Netherlands

Accurate assessment of location and timing of speciation can
be used to discriminate between macroevolutionary models explaining large-scale biodiversity patterns. In centers of origination, speciation is concentrated in the most diverse areas, whereas in centers of accumulation, most speciation is located outside the most diverse regions. However, few taxa have a fossil record which is both spatially and temporally sufficiently resolved to allow the region in which speciation occurred. Here I will evaluate fossil evidence of variation in geographical ranges through time, as well as spatio-temporal variation in morphological parameters to examine geographical aspects of speciation and range variation. Specifically, I test for geographical morphological stability within time slices and for temporal modes of morphological change within lineages. Large benthic foraminifera are abundant in all tropical shallow-marine environments, and are one of the most likely candidates to have a sufficiently resolved fossil record. Traditionally, it has been assumed that rates of morphological change are homogeneous throughout their geographic range. With the advance of independent dating techniques, it is possible to test this assumption. In this talk, I will evaluate the fossil record of a single extant genus in detail. Samples from the entire paleotropical region, spanning from Spain and Tunisia in the west to Moorea in the east have been included in this study, spanning the past 34 million years. Past distribution ranges of all species of the large benthic foraminifera *Cycloclypeus* have been documented on paleogeographic maps. From those samples with sufficiently well preserved specimens, internal morphological data were measured and analyzed. Evidence of speciation was found in two cases. In the first case, variation in morphological characters increased, while in younger populations, one species is indistinguishable from the ancestral taxon, and a sister species is present. In the other case, variation is constant between all populations, but in a restricted part of the range, there is morphological change which later replaces the ancestral taxon. This is interpreted as sympatric and parapatric speciation, respectively. I will discuss examples from other groups in less detail, and evaluate how we can use this information for a better understanding of evolutionary patterns in benthic foraminifera.

Session 28-2: Monday, 9:00 AM
Presenter: Laura Cotton

**GLOBAL EVOLUTION OF RETICULATE NUMMULITES**

*Cotton, Laura*, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands; *Renema, Willem*, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands

Reticulate *Nummulites* are traditionally viewed as having a simple, linear evolution from their first occurrence in the Bartonian to their extinction in the Chattian. This has led to their frequent use in shallow carbonate biostatigraphy. However, the majority of studies of this lineage only focus on local populations, predominantly within the Tethyan realm. When viewed on a global scale, the evolution of reticulate *Nummulites* appears much more complex, and discrepancies occur that cannot be explained by a simple linear evolutionary model. New, well-dated specimens from the Bartonian, Priabonian, and Rupelian of Tanzania show consistently smaller proloculus size than their Tethyan counterparts, indicating a probable different evolutionary path. In India, several endemic species with unusual morphologies, such as saddle-shaped tests and exceptionally large proloculi, occur alongside more typical species; in Indonesia, reticulate *Nummulites* are not found until the Oligocene, while they are well established long before this elsewhere. These observations on global occurrences strongly suggest migration and subsequent radiation played a much more important role in determining distribution and diversity of reticulate *Nummulites* species than previously thought. In this study, we have gathered morphometric data from a large number of widely distributed localities, spanning East Africa, the Mediterranean, India, and Indonesia, and use this to reassess the evolutionary pattern of reticulate *Nummulites* and the role of migration in its global distribution.

Session 28-3: Monday, 9:15 AM
Presenter: Thomas Ezard

**MECHANISTIC MODELS TO (TRY TO) IDENTIFY THE LIMITING FACTORS OF DIVERSIFICATION**

Ezard, Thomas H.G., Centre for Biological Sciences, University of Southampton, Highfield Campus, Southampton, Hampshire, SO17 1BJ, UK

Unlike a phenomenological approach of correlations among more-or-less dependent variables, mechanistic models aim to identify which of several possible mechanisms, often acting in concert, determine some dynamics of interest. This is achieved by comparing a hierarchy of increasingly complex models of biological phenomena. Extracting sufficient data to enable their construction and evaluation is a major obstacle of mechanistic modeling on any macroecological scale. The astonishing abundance of microfossils offers the best chance of deploying these tools meaningfully in the fossil record, particularly at the species level. Using Cenozoic macroperforate planktonic foraminifera, I’ll construct a series of mechanistic models for diversity dependent clade growth and, in so doing, obtain statistical evidence for how climate, ecological composition, the oceanographic systems, and completeness of the fossil record set the limits to diversification of life of Earth.

Session 28-4: Monday, 9:30 AM
Presenter: Brian T. Huber

**NEW EVOLUTIONARY AND PALEOCLIMATIC INSIGHTS GAINED FROM STUDY OF CRETACEOUS FORAMINIFERAL LAGERSTÄTTE**

*Huber, Brian T.*, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; *Petizzo, Maria Rose*, Dipartimento di Scienze della Terra, Università di Milano, Via Festa del Perdono 7 - 20122, Milan, Italy

Recent studies of pristinely preserved foraminiferal assemblages across Cretaceous intervals of species turnover and climate transition provide valuable new insight to changes in species diversity, long- and short-term shifts in
Ocean surface and bottom water temperatures, and the history of vertical and latitudinal oceanographic carbon and oxygen isotope gradients. Stratigraphic analysis of upper Aptian–Maastrichtian clay-rich intervals recovered from a number of land-based boreholes in coastal Tanzania and select deep-sea cores in the Atlantic and Pacific Oceans has resulted in significant revisions in the taxonomy, phylogeny, and isotope paleoecology of benthic and planktic foraminifera, and has led to discovery of the biggest and most abrupt species turnover within the Cretaceous Period, which occurred at Aptian/Albian boundary. This event is marked by the extinction of large-sized, distinctly ornamented, thick-walled species and their replacement by small, smooth-walled, weakly calcified species. Less severe species turnovers are associated with oceanic anoxic events (OAEs) and have been linked to switches from oligotrophic to mesotrophic conditions (OAE1a, OAE1d) and water column warming and breakdown of the thermocline during the onset of the global Supergreenhouse (OAE2). As a result of studies of foraminiferal lagerssätté, the history of Cretaceous planktic foraminiferal species diversity is now much better constrained. Speciation rates were relatively high in the early Aptian, late Albian, late Turonian, early Santonian, and late Maastrichtian, and extinction rates were high across the Aptian/Albian boundary (~80%), moderate in the latest Cenomanian (~40%) and middle Turonian (~30%), and very high at the end of the Maastrichtian (>90%). Apart from the terminal Cretaceous, timing of the planktic foraminiferal species turnovers and diversity trends are not paralleled by those of the calcareous nanoplankton, radiolarians, or macroinvertebrates, and there are few events that correlate with oxygen and/or carbon isotope shifts. Planktic foraminiferal morphologic and taxonomic diversity are not predictably correlated to changes in vertical water column properties, as evidenced by the frequent iterative evolution of morphologic features under very different oceanographic conditions. Metabolic and constructional costs likely played a more important role than function in dictating test morphology.

Session 28-5: Monday, 9:45 AM
Presenter: Susan L. Richardson

FORAMS AND PHYLOGENY: WHERE DO THE FOSSILS FIT IN?

Richardson, Susan L., Wilkes Honors College, Florida Atlantic University, 5353 Parkside Dr., Jupiter, FL 33458

Molecular systematics has revolutionized our current understanding of the evolutionary relationships of Foraminifera; for example, it is now accepted that Foraminifera is a monophyletic clade of single-celled eukaryotes that branches as a subclade within the more inclusive clade Rhizaria. Molecular studies, however, depict crown groups only, so where do fossil foraminifera fit into these trees? To answer this question, a cladistic analysis of 79 foraminiferal taxa, both extinct and extant, was carried out using a morphological data set comprised of 145 binary and multistate characters. The resulting consensus trees are similar to recent molecular trees, showing fossil taxa branching as stem taxa to modern crown clades. These trees are used to examine evolutionary trends in Foraminifera, such as the evolution of biomineralization, the evolution of multi-chambered tests, and the evolution of algal endosymbiosis.

Session 28-6: Monday, 10:30 AM
Presenter: Pincelli Hull

RESOLVING COMMUNITIES THROUGH TIME: NEW APPROACHES FOR RAPIDLY ANALYZING THE >99.9%

Hull, Pincelli M., Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, CT 06511

Marine microfossils provide detailed empirical records of the evolution of ocean ecosystems in deep time. For instance, the many millions of nano- and microfossils within typical deep-sea samples allow for the reconstruction of past environments (through assemblage composition and geochemistry), of the evolution of populations and species (through geometric morphometrics), and of changing community composition (through species counts within and across taxonomic groups). With abundant, often continuously accumulating, deep-sea sediments from sites globally, it is now possible to reconstruct biotic interactions on thousand-year timescales back to the Cretaceous. However, with millions of fossils in every sample, we are limited by current technologies to studying a tiny fraction (often less than 0.01%) of the available record. High-throughput imaging approaches, particularly automated microscopy and image analysis, offer a powerful new means to document, measure, and exploit this fossil record to understand species and community dynamics in the geological past. Here I contrast classic approaches with multiple high-throughput methods for quantifying planktonic foraminifera community structure, with a focus on a new automated, compound microscopy system, downstream classification and shape analysis, and the types of questions well-suited to these technologies.

Session 28-7: Monday, 10:45 AM
Presenter: Timothy Astrop

MACROEVOLUTIONARY DYNAMICS OF SEXUAL SYSTEMS IN SPINICAUDATAN ‘CLAM SHRIMP’: PALEOBIOLOGICAL ASSESSMENT OF EVOLUTIONARY CANNON

Astrop, Timothy L., Program in Integrated Bioscience, Department of Biology, The University of Akron, Akron, OH 44325; Weeks, Steven C., Program in Integrated Bioscience, Department of Biology, The University of Akron, Akron, OH 44325; Park Boush, Lisa E., Department of Geology and Environmental Sciences Environmental Scanning Electron Microscope Laboratory, The University of Akron, Akron, OH 44325; Maia, Rafael, Program in Integrated Bioscience, Department of Biology, The University of Akron, Akron, OH 44325

From its inception, the study of evolution has progressed by a close tie between advances in the schools of paleontology and biology. However, one major area of evolutionary biology, the evolution of mating systems, has been difficult to assess in the fossil record. The difficulty of assessing the sex of fossils (and by extension, the sexual system employed in extinct organisms) is widespread, and in those taxa that do
show sexual dimorphism (e.g., ammonites, some arthropods, and vertebrates), reproductive mechanisms are often invariant, making assessments of the dynamics of reproductive evolution impossible. In this study, new techniques have been developed that will allow the identification of sexes in fossil crustaceans within the Order Spinicaudata (‘clam shrimp’): an enigmatic group of small crustaceans with a unique bivalved carapace. Clam shrimp are well-represented in the fossil record, and have a broad array of reproductive types: dioecy (males + females), androdioecy (males + hermaphrodites) parthenogenesis (asexual females), and selfing hermaphroditism. We have performed a series of studies that combine the wealth of information about the evolutionary transitions among these various reproductive types gleaned from extant Spinicaudata using modern molecular and comparative methodologies, with a comprehensive morphometric analysis of the extensive Spinicaudata fossil record (from the Devonian to the modern day) to address two canonical hypotheses of reproductive evolutionary theory: 1) that unusual species should be short lived and less speciose than their outcrossing counterparts; and 2) that androdioecy is an unstable, transitional system that should not persist over long periods of time.

Session 28-8: Monday, 11:00 AM
Presenter: Gene Hunt

EVOLUTIONARY MODES WITHIN FOSSIL LINEAGES: AN EXPANDED SURVEY
Hunt, Gene, Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; Hopkins, Melanie, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024; Lidgard, Scott, The Field Museum, 1400 S. Lake Shore Drive, Chicago, IL 60605

Two recent papers have compiled published studies in which paleontologists measure morphological traits in series of populations inferred to have ancestral-descendant relationships. These studies fit, via maximum-likelihood, to these time-series three standard models of evolutionary change: directional trend, random walk, and stasis. These analyses both found that 1) directional morphological trends are rarely observed in paleontological sequences, and 2) patterns resembling random walks and stasis are both common in trait time-series. Here we combine and expand these efforts in a survey analysis of over 600 time-series represented trait evolution in the fossil record. In addition to this larger database, we also consider a richer set of models of morphological evolution. In addition to the canonical modes of evolution, we add punctuational models, and models in which evolutionary rates shift within a sequence. We find that models more complex than the standard ones often garner substantial support, especially in longer sequences. These analyses illustrate the potential of the fossil record to understand evolutionary trajectories over long periods of time, and they highlight the importance role of micropaleontology in this endeavor. Microfossils are disproportionately represented in this compilation, especially for sequences with many samples, which are particularly important in permitting inference of complex (parameter-rich) evolutionary models. Without this rich data source, it would be very difficult to assess the importance of all but the simplest evolutionary modes.

Session 28-9: Monday, 11:15 AM
Presenter: David Bord

FORCING ON MORPHOLOGIC INSTABILITY DURING SPECIATION
Bord, David, Department of Earth and Planetary Science, Rutgers University, 610 Taylor Road, Piscataway, NJ 08854; Aubry, Marie-Pierre, Department of Earth and Planetary Science, Rutgers University, 610 Taylor Road, Piscataway, NJ 08854

The mode and tempo of speciation among marine protists remain unanswered, with some studies demonstrating gradual morphologic evolution (anagenesis) over extended periods of time, whereas other studies show patterns of rapid morphologic changes over short episodes bracketed by long periods of stability (cladogenesis). Coccolithophores have not been considered in this discussion, in part because few unambiguous lineages are known. However, the early Eocene (~55 Ma to ~50.6 Ma) Tribrichiatus lineage is one of the few uncontroversial lineages. It includes two main speciation events, at ~53.8 Ma and ~53.6 Ma, the first event being the T. bramlettei–T. contortus transition discussed here. This essentially consists of a 30° rotation of the arms of a symmetrical six-rayed coccolith into an asymmetrical six-rayed one. We used geometric morphometric analysis (coordinate-point extended eigenshape analysis), which is a quantitative technique of combined landmark- and outline based analysis that allows for the visualization and comparison of shapes and their transformation. Immediately preceding speciation, the morphology of the ancestral T. bramlettei is very stable (variance on the first eigenshape axis [ES1]=0.0030–0.0035). Initiation of speciation is marked by an abrupt increase in variance (ES1=0.0055–0.0075) that is then sustained over ~73 kyr. This high morphologic instability is overprinted by a pronounced morphologic shift leading to the stabilization of the T. contortus shape. A similar forcing on morphologic variability occurred during speciation of Helio-discaster mahmoudii, a short-lived earliest Eocene taxon that shows very little morphologic variance (traditional morphometrics; coefficient of variation [CV]~25% on diagnostic characters) throughout its ~370 kyr life span. Although its ancestor is uncertain, the earliest range of the species is marked by extremely high morphologic variability (CV~40 to 75%) over 83 kyr, ending in rapid fixation. Both speciation events are thus characterized by strongly directional high variance over a short duration (<100 kyr), and, importantly, by the appearance of the daughter species (albeit in small abundance) shortly after the initiation of speciation. Speciation through high variance has been documented for other marine protists (e.g., planktonic foraminifera), and forcing is apparent throughout the records. The early occurrence of the daughter species amidst extreme variability as seen in our coccolithophore records has not been discussed in other plankton group, although we suspect that this may be a regular occurrence.
Fossils, and indeed all organic remains that represent ancient ecosystems, are biological materials that escaped the processes of natural recycling. From an ecological point of view, fossils represent the loss of nutrients that play vital roles in cycles of life, death, decomposition, and regeneration. Incomplete natural recycling, in a broad sense, thus controls the fossil record of life through time. The short-term survival of dead organic remains is evidence that scavengers and decomposers did not immediately return all of the nutrients back to the original ecosystem, and long-term survival is evidence that the remains were protected by physical or chemical circumstances (e.g., rapid deep burial) from later recycling. Taphonomic research in modern ecosystems over the past five decades has greatly expanded understanding of ecological processes that control organic preservation versus destruction. The probability that an organism will become a fossil depends on: 1) its anatomy and life habits; 2) environmental context; 3) cause of death; and 4) biotic and abiotic (physical and chemical) processes affecting dead remains before, during, and after burial. All of these variables also affect the rates and efficiency of natural recycling once the organism dies, ultimately controlling what does or does not become preserved. Input to the fossil record can be seen as a race between recycling pressure and stabilization through burial and mineralization. Paleontologists are keenly aware of the patchiness of the fossil record in time and space—certain regions, geological formations and strata are consistently rich in fossils, while others are not. Along with sedimentary, diagenetic, and tectonic processes, variability in the efficiency of early post-mortem recycling may be a major contributor to this unevenness. Given that well-established ecosystems and their food webs typically are limited by essential nutrients, (e.g., carbon, nitrogen, phosphorus, calcium), the long-term survival of skeletal materials (shells, bones, lignin, etc.) in dense concentrations or dispersed fragments suggests departures from expected ecological processes of nutrient turnover. Survival of organic remains could relate to a local surf of the nutrients contained in these remains, and/or to depositional processes that take them out of the biologically active zone. This also implies that, throughout the Phanerozoic, many ecosystems and geographic areas left little or no fossil record because remains were efficiently and rapidly recycled (e.g., bones in phosphorus-limited tropical rain forests, plant litter in tropical arid environments). If so, our samples of past life could be skewed toward a sub-set of ecosystems that 1) were not limited by nutrients contained in the preserved remains and/or 2) were subject to variable or unusual biological, physical, or chemical conditions that allowed some of these remains to escape recycling and be preserved as fossils.
brecciated bone and bone dissolution features were observed. Bones from sterilized control mesocosms showed little signs of bone change, indicating observed bone damage was microbiologically mediated. Histological analyses of fossil bone recovered from marine sediments were found to have some similar bone destruction features indicating that they may have undergone a comparable bacterial decomposition history to the carcass-fall mesocosms. Our results provide the first glimpse into which bacteria might be responsible for microbial traces in fossil bone. Identifying current bacterial communities associated with certain bone degradation features may provide the starting point for using evidence of microbial activity in more detailed taphonomic analyses.

Session 29-3: Monday, 9:15 AM
Presenter: Caitlin Syme

PATTERNS OF AQUATIC DECAY AND DISARTICULATION IN JUVENILE INDO-PACIFIC CROCODILES (CROCODYLUS POROSUS), AND IMPLICATIONS FOR THE TAPHONOMIC INTERPRETATION OF FOSSIL CROCODYLIFORM MATERIAL

Syme, Caitlin E., School of Biological Sciences, The University of Queensland, Brisbane, QLD 4072, Australia; Salisbury, Steven W., School of Biological Sciences, The University of Queensland, Brisbane, QLD 4072, Australia

High levels of skeletal articulation and completeness in fossil crocodyliforms are commonly attributed to rapid burial, with less complete and disarticulated fossils considered to result from ‘bloat and float’: a phenomenon where the build-up of putrefactive gases cause carcasses to bloat and subsequently disarticulate while floating in water. These interpretations are predominantly based on patterns of decay in modern mammalian and avian dinosaur carcasses. At present, there is little in the way of experimental data for patterns of decay in extant crocodyliforms in either a terrestrial or an aquatic setting. To address this issue, we assessed the decay of buried and unburied juvenile Crocodylus porosus carcasses in a controlled fresh-water setting, with no current induced and minimal scavenging. We found that C. porosus carcasses progressed through typical vertebrate decay stages (fresh, bloated, active decay, and advanced decay), reaching the final-remains stage on average 55 days after death. Unburied carcasses commenced floating five days post-mortem during the bloated stage, and one buried carcass commenced floating 12 days post-mortem. While floating, skeletal elements remained articulated within the still-coherent dermis, except for thoracic ribs, ischia, and pubic bones. The majority of disarticulation occurred at the sediment-water interface as the carcasses sank approximately 36 days post-mortem during the advanced decay stage. Based on these results, we conclude that fossil crocodyliform specimens displaying high levels of articulation are not the result of prolonged decay while floating in a low-energy, aqueous environment. The timeframe of rapid burial is likely to be 0–4 days post-mortem, and would have to negate the positive buoyancy associated with bloating. High degrees of articulation could result from other mechanisms that prevent carcasses from floating and subsequently disarticulating upon sinking. The inference that a large proportion of skeletal elements could detach and drift from floating carcasses, thereby causing a loss of completeness, is unlikely for crocodyliforms that decay in low-energy aquatic environments.

Session 29-4: Monday, 9:30 AM
Presenter: Thomas Evans

A NEW UNDERSTANDING OF FLUVIAL BONE TRANSPORT PROCESSES

Evans, Thomas, Geology Department, Western Washington University, 516 High Street, Bellingham, WA, 98225

Commonly, terrestrial vertebrate fossil remains are interpreted using well-known fluvial taphonomic analytical tools (Voorhies Groups, bone orientation, etc). These tools have never been validated in natural fluvial systems with large numbers of bones to determine if the patterns they predict are observed in nature. The purpose of this research program is to directly test these analytical tools, observe bone fluvial transport processes, and generate a more comprehensive understanding of fluvial taphonomic processes. To observe the behavior of bones naturally occurring in rivers, fourteen rivers were searched for skeletal remains, and when discovered, notes were taken on the location, orientation, and facies associations of remains. To increase the sample size, 5421+ bones were seeded in three rivers at eight different times, and the bones tracked over time and distance. When relocated, the distance transported, orientation, and facies associations of bones were recorded. In all fourteen rivers, 586 isolated bones, 34 articulated units, and 10 terrestrial vertebrate bodies were found. Of the seeded bones, 226 were recovered after various lengths of time. These samples did not support any of the taphonomic analytical models existing, raising the question of why. What was observed was a complicated interplay between repeated bouts of bone transport and deposition, with bones behaving more like woody debris than other clasts in the system (floating, or semi-buoyant). These observations suggest that models that treat bones as bedload-transported clasts are oversimplified and insufficient to describe fluvial bone transport. Fluvial bone transport is primarily governed by bone bulk density because bones will often float or have densities at or near the surrounding fluid density, making them move more readily than other clasts. Bone bulk density can change radically throughout decay as the organic fraction is removed. When fresh bone decays, the organic material (marrow) can generate gasses that get trapped within the bone, thus lowering bone bulk density low enough for bones to float or gently skip along the bed at or near neutral buoyancy. As organic matter is removed, bones become more porous and hydrate faster, making them denser. If a dry, weathered bone is placed in water, it can take hours, weeks, or sometimes months to hydrate, making the bulk density of bones change throughout that time period. Consequently, bones must be treated as dynamically changing clasts in their density and shape (breakage and abrasion) rather than static objects moving as bedload. Because bones possess a lower density, they behave more like woody debris, and become reoriented based on interactions with the bed or banks rather than based on flow direction alone. As such, the orientation of bones does not reflect flow direction, but the lowest energy orientation relative to the bed and fluid flow, which is often not predictable based on flow direction alone.
Phosphatization, the replacement of soft tissue by phosphate minerals, is notable among mechanisms of fossilization because of the exceptional fidelity of tissue replication, in some cases even down to cellular level details. Previous laboratory experiments have successfully resulted in soft-tissue phosphatization, and elucidated certain aspects of the fossilization process, such as the effects of varying initial dissolved phosphate concentration and the relative phosphatization potential of different tissues. Similarly, more general studies not involving fossilization have indicated that organically mediated phosphate precipitation is due to the activity of specific, highly conserved enzymes that are active in archaea, bacteria, and eukaryotes, and that have distinctive signals of oxygen isotope fractionation between the phosphate source and the resultant precipitate. This experiment builds upon these previous results by applying the experimental conditions of the fossilization experiments and the analyses of the precipitation experiments in order to understand the key metabolic pathways and enzymes involved in the phosphatization of soft tissue. Equal masses of fish tissue were externally sterilized under UV radiation, and then decayed for six weeks in artificial seawater. Four different microbial inocula, *Vibrio fisheri*, *Marinobacter* sp., *Lumo* sp., and an anaerobically raised culture of sulfur-reducing bacteria were used as starting consortia, as well as one control experiment with no added microbes. Five replicate experiments were performed in each case. Over the course of the experiments, the growth of microbial populations was estimated by measuring the cloudiness of the water. The progress of phosphate mineral release, and re-precipitation was monitored by analyzing the phosphate concentration of the water, and directly observed through CT scanning of one set of replicates. At the end of the six weeks, any remaining fish tissue was degraded and any solid phosphate precipitated within the tissue during the course of decay was isolated. Differences in timing and amount of phosphate precipitation between the different inocula—representing typical abundant marine aerobes and a standard consortia of anaerobic sulfur reducers—will indicate which bacteria and which forms of metabolic activity contribute most significantly to soft-tissue phosphatization.
Much of life's phylogenetic diversity arose before the Phanerozoic began, but detailed understanding of these events is still in its infancy. For most of Precambrian time, we understand only a broad outline of events, and the biological affinities of most microfossils are unknown, in some cases even to the level of domain (e.g., Bacteria vs. Eukarya). Significant advances have been made in certain well-preserved or morphologically distinctive groups, making use of high-resolution imaging and careful comparative anatomy. These approaches compare preserved morphological features to the features of living taxa. In this study, we explore the hypothesis that taphonomic features—morphological change that occurs after death—may provide useful taxonomic information. We report the results of a series of studies that examine 1) relative preservability and rates of information loss in a variety of eukaryotes and bacteria; 2) alteration of morphology during early post-mortem decomposition; and 3) preservation of morphologically distinctive features within microbial taxa during early post-mortem decomposition. In these studies, modern algae (Eukarya) and cyanobacteria (Bacteria) were subjected to decomposition by mixed heterotrophic assemblages and examined by optical and electron microscopy to catalog morphological changes that occur immediately after death. The results of these experiments suggest that prokaryotes are generally more resistant to loss of morphological information than are eukaryotes, and that extracellular sheaths are durable compared to cell walls in most taxa. In addition, larger-scale complexity (e.g., branching, cell arrangement) of some eukaryotes can be preserved despite loss of cellular or ultrastructural integrity. To date, no taphonomic features diagnostic of domain-level affinity have been observed; however, taxon-specific taphonomic trends may help to resolve biological affinities in a wide variety of microbes.

Session 29-9: Monday, 11:15 AM
Presenter: Ehud Gilad

ANTHROPOGENIC MODIFICATION OF THE GULF OF EILAT (ISRAEL) CHARACTERIZED BY LIVE-DEAD BIVALVE ASSEMBLAGES

Gilad, Ehud, Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Ramat Aviv, Tel Aviv, 69978, Israel; Edelman-Furstenberg, Yael, Geological Survey of Israel, 30 Malchei Yisrael St., Jerusalem, 95501, Israel; Benayahu, Yehuda, Department of Zoology, George S. Wise Faculty of Life Sciences, Tel Aviv University, Ramat Aviv, Tel Aviv, 69978, Israel; Kidwell, Susan M., Department of Geophysical Sciences, University of Chicago, 5734 S. Ellis Ave., Chicago, IL 60637

The Gulf of Eilat is a naturally oligotrophic environment with a prosperous coral reef, but anthropogenic nutrient input over the last 50 years is suspected to have had a strong impact on the system. Factors with potential to shift the Gulf into eutrophic conditions include the deployment of fish cages between 1995–2008, runoff of untreated city sewage between 1980–1990, phosphate dust from Aqaba harbor, and accidental oil spills. We are using mollusks, especially bivalves, to test for evidence that soft-bottom benthic communities have been altered by this history of stress, using significant mismatch in the composition of modern time-
averaged death assemblages (dead remains from the top 5 cm of the seabed) and the local living community as a signal of a recent shift in baseline. Diver-acquired bulk samples from three 0.12 sq-m quadrats excavated to 5 cm sediment depth were taken at 15 and 30 m water depths along two transects: offshore of Wadi Arava, the former fish farm location (FF); and opposite the Dan hotel (DAN), located 500 m west of FF and farthest from known past point sources of nutrients. Living and dead bivalves were sampled at each site over four seasons using a 2mm mesh. We also used a vessel-operated dredge over a distance of 30m at each site (insertion depth of 5 cm) to augment the live sample size. So far, 60 samples have been identified to species level. A total of 1064 live and 5338 dead bivalve individuals were found in the fall and winter 2012–13 sampling seasons, representing 129 species. Approximately 78% of living species also occur dead, and ~45% of dead species are also present alive. Cluster analysis using species proportional abundance found two significantly different groups—live and dead assemblages (ANOSIM, R=0.864, p<0.05); multivariate analysis reveals that, as expected from time-averaging, dead samples exhibit less dispersion than do live samples and their centroids are offset. Our initial analyses suggest that lucinid bivalves, which typically include chemosymbionts and prefer seagrass beds, are significantly more abundant in the dead than among the living at both stations, suggesting a possible decline in that habitat type. Mixed deposit/suspension-feeding tellinds and mactrids take their place within the living fauna, especially at FF, but alternative preservational hypotheses are being considered. Seasonal variation in the living fauna is notable at all four sites, with mixed feeders and infaunal suspension-feeders switching dominance. Thus, additional sampling and data analysis are planned, along with selective amino-acid racemization dating of shells, to determine if and to what extent the seafloor of the Gulf of Eilat was impacted by human stressors.
Session No. 25 (continued): Celebrating public participation in paleontology

**Chairs:** Austin J.W. Hendy and Bruce J. MacFadden

Monday Afternoon 1:30 PM to 4:30 PM

Session 25-11: Monday, 1:30 PM

Presenter: Jason E. Osborne

**PALEO QUEST: ACCELERATING SCIENCE LITERACY, PALEONTOLOGICAL DISCOVERIES AND MUSEUM COLLECTIONS THROUGH CITIZEN SCIENCE, OUTREACH AND NOVEL FIELD RECOVERY METHODS**

Osborne, Jason E., President, Paleo Quest, Gainesville, VA 20155; Alford, Aaron A., Vice President, Paleo Quest, Gainesville, VA 20155

Paleo Quest is committed to the notion that avocational scientists can contribute significantly to the advancement of science. Paleo Quest is a Virginia 501(c)(3) volunteer organization that is structured for charitable, scientific, and educational purposes. Its original, collaborative platform brings together professional-amateurs, professionals, and citizen scientist in a variety of disciplines, providing a greenhouse for scientific innovation. This approach to science has helped its members identify and answer unique scientific and methodological questions in paleontology and stratigraphy. Paleo Quest fulfills its mandate through excavation, advancing the understanding of stratigraphy, and by donating materials of scientific significance to museums and universities. The organization donates fossils and fossil-bearing matrix as educational materials to museums and universities. Paleo Quest is committed to the notion that avocational scientists can contribute significantly to the advancement of science. Paleo Quest is a Virginia 501(c)(3) volunteer organization that is structured for charitable, scientific, and educational purposes. Its original, collaborative platform brings together professional-amateurs, professionals, and citizen scientist in a variety of disciplines, providing a greenhouse for scientific innovation. This approach to science has helped its members identify and answer unique scientific and methodological questions in paleontology and stratigraphy. Paleo Quest fulfills its mandate through excavation, advancing the understanding of stratigraphy, and by donating materials of scientific significance to museums and universities. The organization donates fossils and fossil-bearing matrix as educational materials to museums and universities.

Session 25-12: Monday, 1:45 PM

Presenter: Michael E. Sternberg

**STONEROSE INTERPRETIVE CENTER AND EOCENE FOSSIL SITE: AN INTEGRATIVE MODEL AT THE CROSSROADS OF RESEARCH, PUBLIC OUTREACH AND COMMUNITY INVOLVEMENT.**

Sternberg, Michael E., Stonerose Interpretive Center, 15 N. Kean St, Republic, WA 99166; Archibald, Bruce, Department of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6, Canada; DeVore, Melanie L., Biological and Environmental Science, Georgia College and State University, Milledgeville, GA 31061; Pigg, Kathleen B., School of Life Sciences, Arizona State University, Tempe, AZ 85287

Stonerose Interpretive Center and Eocene Fossil Site, located in Republic (Ferry County), eastern Washington State, serves as a unique model for the integration of scientific research, public outreach, and community involvement. The Center owns and oversees Boot Hill, a small shale outcrop close to the Interpretive Center. The Republic biota collected from this locality is a highly diverse assemblage of exceptionally preserved fossils representing a community that flourished in the forests surrounding an early Eocene upland lake. As the most thoroughly studied of the regional Okanogan Highlands sites, it has revealed the earliest representatives of several temperate plant families. Stonerose was established in 1987, and incorporated as a 501(c)(3) nonprofit in 1989. It was based on the conceptual model of Wes Wehr (d. 2004), Affiliate Curator of Paleobotany at the University of Washington Burke Museum of Natural History and Culture, Seattle; Republic City Councilman Bert Chadick; and Founding Director Madilane Perry. Stonerose is located in a remote part of eastern Washington, in a county that is twice the size of Rhode Island with a population of 7,500 (3 per sq. mi). Despite the nearest major cities (Spokane, Seattle) being 3–6 hours’ drive away, more than 6,000 visitors come each year—over 120,000 since inception. Stonerose enjoys the strong support of Ferry County and Republic City governments and local business owners who recognize the substantial economic benefits Stonerose attracts. The Center charges nominal fees for visitors who wish to dig for fossil plants, fish, and insects, and provides an orientation on the site and how to collect and identify their finds. Diggers are limited in number of specimens they may keep per visit with scientifically significant specimens retained by the Center. Stonerose hosts many K–12 school groups each year who not only collect fossils, but also attend presentations on the scientific significance of their discoveries. Free public talks are given by scientists from across the nation and abroad. The Center uses *Stonerose Strata*, a customized database, to record visitor information and specimen data (specimen numbers, loans, storage, etc.). Fossil finders are a key aspect to Stonerose. Each specimen retained by the Center has the finder's information permanently stored with it on paper and digitally in *Strata*. The fossil finders initially get a “finder’s letter” thanking them for their contribution with follow-ups if their specimen is published. The Center encourages researchers to acknowledge the finder’s contribution in publications, which has strengthened the connection between the public and scientists. Over the years, several new genera have been named in honor of finders’ contributions. The Stonerose model could easily be incorporated in other communities in the US and around the world to further expand the connection between the public, community, and scientists.
Session 25-13: Monday, 2:00 PM
Presenter: Lee Taylor Higginbotham

MINE RAL WELLS FOSSIL PARK, T E X AS
WWW.MINERALWELLSFOSSILPARK.COM AND ON
FACEBOOK

Higginbotham, Lee T., 10417 Marsh Lane, Dallas, Texas,
75229

Mineral Wells Fossil Park (MWFP), located 90 minutes west
of downtown Dallas, Texas, and 45 minutes west of
downtown Fort Worth, is one of few public fossil parks in the
United States. The fossiliferous nature of this site and the fact
that every fossil can be surface collected and the replenishing
of the site after every rainfall will allow this location to offer
years of learning for many, many people. In 1997, while
searching for possible field trip locations, Dallas
Paleontological Society (DPS) members Roger and Linda
Farish, discovered that the eight-acre, heavily disturbed and
eroded borrow-pit of the closed (since September 30, 1993)
City of Mineral Wells landfill was laden with Pennsylvania
fossils. Afterwards, fossil groups and individuals from
Houston, Austin, and Dallas regularly collected this location.
In early 2008, the City of Mineral Wells was approached
about selling the 75 acre former landfill, which included the
borrow pit. In April 2008, DPS members Lance Hall and Lee
Higginbotham met with the City Manager Lance Howerton;
Beth Watson, Executive Director of the Chamber of
Commerce, and Christina Childs, Tourism Director, to
present a DPS proposal to convert the former borrow-pit of
the closed landfill into a public fossil park where visitors
could keep the fossils that they find. The city had been
unaware that people came to Mineral Wells to hunt for fossils
in the borrow-pit of the city-owned landfill. DPS agreed to
raise money for the park and the City of Mineral Wells
agreed to match funds for the park. DPS raised more than
$7,000 from numerous individuals and organizations. The
City matched these funds. On May 8, 2010, MWFP was
opened to a crowd of 300–400 persons. MWFP continues to
be a popular attraction for many people from around the
region and beyond. Many schools, universities, and day
camps have brought students to MWFP throughout the
school year, and many visitors to town call for directions to
plan their spring and summer trips.

Session 25-14: Monday, 2:15 PM
Presenter: Gary Morgan

THE NEW MEXICO FRIENDS OF PALEONTOLOGY:
A VOLUNTEER GROUP COMMITTED TO THE
ADVANCEMENT OF PALEONTOLOGY IN NEW
MEXICO

Morgan, Gary, Vertebrate Paleontology, New Mexico
Museum of Natural History and Science, 1801 Mountain
Road NW, Albuquerque, NM 87104; Neely, Lannois, New
Mexico Friends of Paleontology, New Mexico Museum of
Natural History and Science, 1801 Mountain Road NW,
Albuquerque, NM 87104; Bednarski, Sheila, New Mexico
Friends of Paleontology, New Mexico Museum of Natural
History and Science, 1801 Mountain Road NW, Albuquerque,
NM 87104

The New Mexico Friends of Paleontology (NMFOP) is a
volunteer organization affiliated with the New Mexico
Museum of Natural History and Science (NMMNHS) in
Albuquerque, New Mexico. NMFOP has a membership of 85
people from a wide range of backgrounds. Most members
live in the Albuquerque area. A substantial number of
NMFOP members are retired professionals from a variety of
fields, including geology, physics, engineering, medicine,
computer science, education, liberal arts, and business.
NMFOP holds monthly meetings in the NMMNHS from
January to May and September to December, taking a three-
month hiatus during the busy summer field and travel season.
All meetings are open to members and the general public,
and include a business meeting and an invited speaker who
presents a non-technical lecture relating to New Mexico
palontology. The overall mission of the NMFOP is to
promote activities that aid in the knowledge, understanding,
and public awareness of paleontology in New Mexico.

Another important purpose of the organization is to provide
assistance to the NMMNHS in the form of volunteer labor in
palontology. A portion of the annual NMFOP membership
dues is used to support the NMMNHS paleontology program,
including the preparation lab, field work, and research. In the
past several years, monies have been allocated to purchase
plaster for field work, glues and consolidants for the field and
lab, and air scribes and replacement tips for preparators.
Many NMFOP members are highly trained volunteers and
have taken the rigorous Docent Training Program at the
NMMNHS (two days a week for two months, consisting of
lectures covering scientific fields represented by public
exhibits in the NMMNHS, including biology, geology,
palontology, space science, and computer technology).
Many NMFOP members also have participated in an
additional six-week fossil preparation training program.
Many volunteer in one or more of the paleontology programs
at the NMMNHS, including the fossil preparation lab, fossil
collection, docent-led tours in the museum exhibits, and field
work. Several NMFOP members participate in research
projects with NMMNHS paleontologists, and have been
coauthors on scientific papers.

Session 25-15: Monday, 2:30 PM
Presenter: David Clark

ENGAGING PROFESSIONALS AND THE PUBLIC:
OUTREACH EFFORTS OF THE FRIENDS OF THE
UNIVERSITY OF MICHIGAN MUSEUM OF
PALEONTOLOGY

Clark, David R., The Friends of the University of Michigan
Museum of Paleontology, The University of Michigan, 1109
Geddes Avenue, Ann Arbor, MI 48109

The Friends of the University of Michigan Museum of
Paleontology (“The Friends”) is an active group of
individuals passionate about paleontology, focused on
charitable, educational, and scientific work. “The Friends”
support the activities, research and study of fossils at the
University of Michigan Museum of Paleontology. The
members have embraced multiple projects and activities to
support the museum and engage the public. Among these are:
1) the development of a web-accessible Michigan Basin
Photo database; 2) the reprinting of the classic Strata and
Megafossils of the Middle Devonian Silica Formation by
Robert V. Kesling and Ruth B. Chilman that was originally
published in 1975; 3) designing and maintaining a “Friends” display case in the University of Michigan Museum of Natural History; 4) volunteering for Museum activities geared around fossils, such as ID day, Dino day, etc.; 5) specimen donations; 6) fieldwork support; and 7) financial support for research and scholarly activities. These projects and activities are reviewed in detail. Collaborating with professional paleontologists, the group has thrived and contributed to the advancement of paleontology, especially paleontology of the Michigan Basin.

Session 25-16: Monday, 3:15 PM
Presenter: Aaron A. Alford

**SHARKFINDER: ADVANCING THE UNDERSTANDING OF EVOLUTION AND DIVERSITY OF PREHISTORIC ELASMOBRANCHES (SHARKS, SKATES, AND RAYS) THROUGH AN INNOVATIVE CITIZEN-SCIENCE PROGRAM**

Alford, Aaron A., Vice President, Paleo Quest, Gainesville, VA 20155; Osborne, Jason E., President, Paleo Quest, Gainesville, VA 20155

Science education in America is thirsting for novel approaches that increase science literacy. Citizen-science projects can offer the opportunity for participants to become explorers, help unlock Earth’s mysteries, and potentially make significant contributions to the advancement of science. SharkFinder is a self-funded citizen-science/STEM education program aimed at finding fossil elasmobranch (sharks, skates, and rays) remains along the Atlantic coastal plain of the United States. To date, elasmobranches from this region are incompletely characterized despite the fact that shark fossils from this region have been a favorite of collectors and paleontologists for more than a century. SharkFinder is now providing the opportunity for schools and citizen scientists at all academic levels to search through highly concentrated fossil-bearing media to find and report shark, skate, and ray fossils. These fossils are then sent to the University of Maryland where undergraduates and their advisors identify and publish on noteworthy discoveries. In addition to experiencing the thrill of the hunt and knowing that their efforts are actually contributing to paleontology, participating classrooms and citizen scientists will be acknowledged in resulting professional publications. These collections will be donated and curated in public museums. Not only is this educational module structured so that it can be applied to the study of fossil elasmobranchs globally, but it can also be used to investigate other large collections of comparably-sized vertebrate or invertebrate fossils.

Session 25-17: Monday, 3:30 PM
Presenter: Robert M. Ross

**PARTICIPATION OF K–12 TEACHERS AND STUDENTS IN PALEONTOLOGY: FACTORS IMPACTING EFFECTIVENESS AND SUSTAINABILITY**

Ross, Robert M., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850; Buckler, Carolyn S., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850; Capps, Daniel K., College of Education and Human Development, University of Maine, 324 Shibles Hall, Orono, ME 04469; Cronin, Kelly E., Department of Geography and Geology, University of North Carolina Wilmington, 601 South College Road, Wilmington, NC 28403; Crawford, Barbara A., College of Education, University of Georgia, Athens, GA 30602; Smrecak, Trisha A., Department of Geological Science, Michigan State University, 288 Farm Lane, Room 206 NS, East Lansing, MI 48824; Wall, Alexander F., Paleontological Research Institution, 1259 Trumansburg Road, Ithaca, NY 14850

K–12 teacher and student participation in paleontology merges several goals of paleontology and science education. Such participation can: 1) provide opportunities for students to learn science through doing science; 2) increase engagement via intrinsic student interest in fossils and the history of life; 3) increase human resources for the data-intensive needs of some kinds of paleontological research; 4) improve student motivation through the perception that they are helping scientists to do real research; (5) provide teacher experiences that foster complex science teaching skills; 6) offer opportunities for education research on the relationship between authentic science experiences and improved classroom teaching and learning; and 7) increase public understanding of the nature of paleontological science and its relevance to Earth systems issues. Because different goals are important to different stakeholders, lack of attention to any one goal may endanger project success and sustainability. For example, teachers must feel the project satisfies their curricular needs more effectively than other potential activities. Students must learn more than they would using more traditional approaches. Paleontologists must care about the data, trust it was collected carefully, and be able to use data with a certain amount of error. Teachers and scientists count on timely feedback from one another. It takes substantial effort to create effective communication among stakeholders, offer teacher professional development, monitor data quality, transfer and curate samples and data, and give regular feedback to classrooms; thus, other stakeholders are generally essential, e.g., teacher professional developers and paleontologist educators. Education researchers and evaluators are essential to helping determine whether teaching practices and learning outcomes improve. The Paleontological Research Institute (PRI) has run several kinds of citizen-science projects since about 2000, involving tens of thousands of students from around the USA and elsewhere. Highly structured projects include extensive teacher professional development, education research, a curriculum into which the study is embedded, and student data submission and analysis using an online database. Such projects include Devonian Seas and Fossil Finders (NSF 0733223), which used Devonian Hamilton Group samples from central NY. The less structured Mastodon Matrix Project ships samples to groups who sort fossils from sediment and return them to PRI; generally only information and suggested activities are provided. It is run with late Pleistocene post-glacial pond sediments from several mastodon excavations. Each approach has different strengths and weaknesses.

Session 25-18: Monday, 3:45 PM
Presenter: Austin J. W. Hendy
DIGITIZING PALEONTOLOGICAL COLLECTIONS FOR NEW AUDIENCES: PAST PRACTICES AND THE POTENTIAL FOR PUBLIC PARTICIPATION

Hendy, Austin J.W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; MacFadden, Bruce J., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Among U.S. natural history museums, fewer than 1% of fossil specimens are on display to the public, and less than 10% of those museums maintain an online database. The vast majority of fossil collections are therefore inaccessible to the public, including non-professional paleontologists. These collections are a tremendous source of information, and a vehicle for education outside of the academic institution. As digitization in paleontological collections becomes increasingly important as a component of the curatorial process, imaged paleontological collections can easily be adapted for education and outreach usage by downstream users, who may include teachers, students, fossil club members, families, and other lifelong learners. A content analysis of more than 25 paleontological collection websites in U.S. natural history museums was undertaken to understand the extent to which digital images are used, the ways in which they are presented, and the extent to which existing digitization workflows result in products for downstream users. Aspects considered in the content analysis include: 1) the efficiency with which information can be searched, 2) consistency with which it is presented, 3) ease of interpreting data, 4) their richness, 5) clarity, 6) use of multimedia, and 7) accessibility of information to non-English-speaking audiences. In general, U.S. natural history museums still have challenges in reaching diverse public audiences who may access their online paleontological collections. Content provided for downstream users is often spotty in coverage and composition, and digital images are presented via a wide range of design approaches. Furthermore, very few websites assessed have apparently planned their content with K–12 curricular or science-education standards in mind. Traditional museum search engines, while useful to researchers, do not provide easy access among non-professional audiences, and can't be effectively paired with education content. More effective tools for sharing education content include image galleries, text pages with embedded images, or slideshows. Natural history museums could more effectively share their collections, especially those that are valuable to education initiatives or of local importance, by working directly with downstream users (teachers, students, fossil clubs) in the design of thses online resources. In this talk, we provide examples of how one might engage more amateur paleontologists in the digitization of museum collections, thereby enhancing the resources available to them as part of ongoing national digitization efforts.

Session 25-19: Monday, 4:00 PM
Presenter: Bruce MacFadden

CLUBS AND PROFESSIONAL PALEONTOLOGISTS IN THE U.S.

MacFadden, Bruce J., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Crippen, Kent, College of Education, University of Florida, Gainesville, FL 32611; Duncekl, Betty, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Ellis, Shari, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

FOSSIL (Fostering Opportunities for Synergistic STEM with Informal Learners) is a recently established four-year project that brings together two primary target audiences in the U.S. —fossil clubs and professional paleontologists—into a cyberenabled learning community of practice (CoP). Although other amateur interest groups such as star-gazers (e.g., Astronomy from the Ground UP) and bird-watchers (e.g., Audubon, e-Bird) have well-established national networks, no such organization currently exists in paleontology. Our front-end research has identified more than 50 active fossil clubs in the U.S., and we also have developed a database of professional paleontologists working with these clubs. The fossil clubs typically consist of tens to hundreds of members ranging in age from primary school students to retirees, embodying the concept of lifelong learners. Fossil clubs usually have a monthly meeting, oftentimes with a speaker, and support other activites such as a newsletter, fossil fairs, field trips, and outreach to formal K–12 education. Although our background research has revealed a high interest in the FOSSIL network, currently, most fossil clubs act independently with little interactions with other similar clubs. Within this cyberenabled CoP, FOSSIL will bring together the fossil clubs and professional paleontologists in activities of mutual interest, including training ("amateur development"), annual meetings, joint field trips, cyberenabled joint presentations, and participation in the national effort to digitize fossils into a Cloud-based database. FOSSIL activities, collaborations, and learning will be mediated by the myFOSSIL web portal, related social media, and a monthly e-newsletter. We intend to broaden the reach of FOSSIL through K–12 outreach, particular focusing on topics relevant to paleontology and aligned with the new national science standards (NGSS). FOSSIL is in the development phase; we are therefore seeking ideas and input from our clubs and professionals, as well as encouraging participation from new stakeholders. Activities, deliverables, and outcomes will be optimized and tracked by formative and summative project evaluation. Another goal of FOSSIL is to conduct related-learning research. Using a design-based approach, our research questions focus on strategies for developing a networked CoP and how involvement might influence the capacity of participating members to learn science, contribute to the science of paleontology, and promote informal science education. FOSSIL builds on the goals of the 21st Century Learning in Natural History Settings conference, and contributes to our understanding of the roles and impact of public participation in scientific research (PPSR).
Session No. 26 (continued): Critical paleobiological transitions in Earth history: The value of multidisciplinary approaches

Chairs: Sandra J. Carlson and Philip D. Gingerich

Monday Afternoon 1:30 PM to 4:15 PM

Session 26-10: Monday, 1:30 PM
Presenter: Lisa Park Boush


Park Boush, Lisa E., Geosciences, The University of Akron, Akron, OH 44325; Motz, Gary J., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

The timing and mechanisms of how faunas established themselves within the continental realm is critical to our understanding of clade origination, radiation, and derivation throughout time. In addition, determining the conditions and physiological traits necessary for clades to invade continents allows us to better characterize the nature of these invasions and understand the requirements for survival in non-marine environments as well as informing on the possible cause of diversity disparity across the tree of life. The early history of lake faunas is one of opportunity and amelioration. Feedback loops created by the establishment of vascular land plants altered the terrestrial nutrient cycle and impacted lacustrine regimes as a result. All trophic levels within lake systems were established early, but became increasingly complex throughout the Paleozoic. Groups invading the continents via the ‘estuary effect’ did so numerous times via the episodic establishment of marine-freshwater connections along these continental margins. The invasion occurrences and subsequent diversification demonstrate a dramatically different diversification pattern on continents than in the marine realm. Continental faunas established themselves through estuarine gateways by multiple invasions during maximum flooding events when ecosystem space expanded on the shelf margin. Characterizing the clades that were subsequently successfully established on land reveals a diversity disparity between exclusively marine clades and those that are both marine and continental in distribution. With the exception of the echinoderms, clades on continents are more diverse than those metazoans occurring exclusively in the marine realm. In general, diversification patterns of lacustrine faunas appear different than those from exclusively marine taxa. The global tectonic and geochemical cycling that has occurred throughout the Phanerozoic may have influenced continental colonization and subsequent diversification of those clades through time.

Session 26-11: Monday, 1:45 PM
Presenter: William A. DiMichele

TROPICAL BIOME DYNAMICS DURING THE PENNSylvANIAN ICE AGES

DiMichele, William A., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013
Cecil, Blaine, US Geological Survey (ret.), Rockbridge Baths, VA 24473; Montañez, Isabel P., Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616

Characterized as the “Coal Age”, the tropics of the terrestrial Pennsylvanian Subperiod are often visualized as one vast wetland forest growing under an unchanging, humid climate. Many lines of evidence, however, indicate that these same tropics also regularly hosted different kinds of vegetation characteristic of seasonally dry environments. During the Late Paleozoic Ice Age, the Euramerican tropics experienced periodic oscillations in climate, sea level, and sedimentation patterns linked to polar ice volume fluctuations and atmospheric CO₂ concentration. The shortest fluctuations occurred on temporal scales approximating Milankovitch-band orbital frequencies. In the broad, flat, continental interior of west-central Pangea, the resulting sedimentary patterns are referred to as “cyclothems.” With humid-to-perhumid climates prevailing during glacial maxima and early transgression, and dry, subhumid-to-semiarid climates during interglacials and early regressive stages of sea level, wet-dry floras oscillated with the same rhythm. Evidence and models suggest that in dry-subhumid to semiarid tropical climate stages, no large areas of humid climate were found in the tropics or paratropics, requiring wetland flora survival in dispersed refugia. In contrast, during intervals of widespread humid climate, the seasonally dry flora survived in areas of western Pangea and in microhabitats in the Central Pangean Mountains. Thus these biomes had different dynamic patterns of expansion and contraction. The wetland flora appears to have undergone sufficient contraction that reemergence during wet intervals involved ‘reassembly.’ In contrast, the seasonally dry biome simply underwent large-scale range contractions and expansions. Evolutionarily, both biome types are persistently of low diversity. Wetland biodiversity, at the scale of thousands of square kilometers, is estimated to be up to 120 species. Seasonally dry floras are of considerably lower diversity, though accurate estimates of how low are lacking. Regular contraction into multiple refugia might be expected to promote speciation among the wetland taxa, but the highly dispersed microspores of most taxa may have suppressed differentiation; the one exception to this generality is the seed ferns, in which both low dispersibility seeds and pollen grains combined to lead to high diversity and species turnover. Wind pollination, wind-water dispersed seeds, and large population sizes may have strongly contributed to conservatism of the seasonally dry flora. During environmental crises, mainly reflective of the long-term trend of drying and warming in the late Paleozoic tropics, the two biomes responded differently. The wetlands appear to have had lower thresholds to major reorganization
of dominance-diversity patterns, whereas the seasonally dry environments saw gradual spatio-temporal compositional changes and in the areal extent of landscape covered by any of the several different seasonally dry species pool.

Session 26-12: Monday, 2:00 PM
Presenter: Christian A. Sidor

**RESTRICTURING OF TERRESTRIAL ENVIRONMENTS IN SOUTHERN PANGEA FOLLOWING THE PERMIAN–TRIASSIC MASS EXTINCTION**

Sidor, Christian A., Burke Museum of Natural History & Culture, University of Washington, Box 353010, Seattle, WA 98195; Angielczyk, Kenneth D., Department of Geology, Field Museum of Natural History, 1400 S. Lake Shore Drive, Chicago, IL 60605; Roopnarine, Peter D., Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA 94118; Tabor, Neil J., Roy M. Huffington Department of Earth Sciences, Southern Methodist University, 3225 Daniel Ave., Dallas, TX 75275; Nesbitt, Sterling J., Department of Geosciences, Virginia Tech, Blacksburg, VA 24061; Peccei, Brandon R., Burke Museum of Natural History & Culture, University of Washington, Box 353010, Seattle, WA 98195; Smith, Roger M.H., Karoo Palaeontology, Iziko, South African Museum, Cape Town, South Africa; Huttenlocker, Adam K., Department of Biology, University of Utah, 57 South 1400 East, Salt Lake City, UT 84112; Glasspool, Ian J., Department of Geology, Field Museum of Natural History, 1400 S. Lake Shore Dr, Chicago, IL 60605

The Permian–Triassic (PT) mass extinction generated a major discontinuity in the evolution of life on Earth. In the marine realm, numerous studies have shown that many abundant and diverse invertebrate groups were decimated, whereas other, previously marginal taxa flourished in the extinction's aftermath. Accompanying these changes was a major ecological restructuring of marine communities whose effects can still be seen today. In contrast to the marine realm, the effect of the PT extinction on terrestrial communities is less well understood, with most data coming from the southern Urals of Russia or the Karoo Basin of South Africa. These two areas contain the most complete and well-studied terrestrial sections spanning the PT boundary, and both provide evidence for Early Triassic aridification. Since 2007, our research group has undertaken fieldwork in PT beds in Tanzania and Zambia (collectively, TZAM). When compared to the ‘traditional’ data from the Karoo, our work has yielded surprising results, namely that: 1) a homogeneous and broadly distributed fauna in the late Permian was replaced by a more provincial and biogeographically fragmented fauna by early Middle Triassic times; and 2) TZAM basins include dinosaur predecessors and other archosaurs unknown elsewhere, foreshadowing the archosaur-dominated ecosystems common throughout the remainder of the Mesozoic. The fact that divergent faunal assemblages were established within the same basins that previously hosted broadly similar pre-extinction communities provides a measure of taphonomic control and indicates a biological origin. Moreover, these results cast doubt on the utility of the Karoo as a model for a global terrestrial PT recovery, and suggest unexpectedly complex geographical patterns of post-extinction diversification. To date, our research group has focused on the vertebrate paleontology, sedimentology, and taphonomy of TZAM. A recent award from the National Science Foundation's Earth-Life Transitions (ELT) program will allow us to apply a multi-analytical approach to further address relationships between environmental change, faunal composition, ecological community structure, and biogeographic patterns in the context of the PT mass extinction and its subsequent recovery. We will use multiple types of data to assess global and local signals for paleoenvironment, including: 1) paleosol morphology, 2) paleosol geochemistry, 3) pedogenic organic matter, 4) coal petrography, and 5) fossil wood chronology and stable isotopes. Finally, we will integrate our empirical results with two modeling approaches to further assess changes in biogeographic structure and terrestrial community dynamics from the middle Permian to Middle Triassic.

Session 26-13: Monday, 2:15 PM
Presenter: Gregory P. Wilson

**DIVERSITY, EXTINCTION, AND RECOVERY IN TERRESTRIAL ECOSYSTEMS ACROSS THE K/Pg BOUNDARY IN NORTH AMERICA AND INDIA**

Wilson, Gregory P., Department of Biology, University of Washington, Box 351800, Seattle, WA 98195; Renne, Paul, Berkeley Geochronology Center, 2455 Ridge Road, Berkeley, CA 94709; Wilson, Jeffrey A., Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI 48109

Mass extinctions have fundamentally shaped the history of life. Documenting the dynamics of ancient mass extinctions and ensuing biotic recoveries is vital for understanding and mitigating the mass extinction that we are currently in. The Cretaceous–Paleogene (K/Pg) is a key interval for analyzing mass extinction and biotic recovery dynamics because it experienced substantial long-term environmental and biotic effects. Major advantages of studying the K/Pg transition as compared to more ancient extinction events is the greater quantity and quality of the geological and paleontological data, and the greater proportion of taxa with living descendants or modern analogs whose ecology is well understood. Biotic turnover during the K/Pg also had a profound influence on modern biodiversity, including the collapse of dinosaur-dominated terrestrial ecosystems and the radiation of modern mammalian lineages. Although the initial hypothesis of an extraterrestrial impact at the K/Pg boundary is now backed by strong evidence, a consensus has not been achieved regarding the relative importance of other potential K/Pg causal mechanisms, such as volcanism. Moreover, with research largely focused on the mass extinction, analysis of the ensuing biotic recovery has lagged behind. Perhaps most critically, our understanding of K/Pg dynamics in terrestrial ecosystems is largely based on data from a single geographic region (western North America [NA]), and the resultant regional hypotheses need to be thoroughly evaluated in a global context. Even in the relatively well-studied NA record, there are unrealized opportunities to dramatically increase the temporal resolution of extinction and recovery and correlate them with critical abiotic changes. We are engaged in a collaborative project to...
investigate the K/Pg in the Williston Basin of NA and Deccan Volcanic Province of India. Our team integrates expertise across diverse fields in earth and life sciences to produce 1) a high-resolution, three-dimensional chronostratigraphic framework for the K/Pg of our two study areas that will allow temporal correlation with regional and global abiotic and biotic events; 2) a detailed paleoenvironmentally and taphonomically constrained investigation of the evolutionary and paleoecological changes in vertebrate and plant paleocommunities leading up to, across, and following the K/Pg; and 3) a robust test of current models of extinction and recovery dynamics. More broadly, we hope that our findings will uncover environment-specific commonalities among K/Pg survivors that will help prioritize the limited funds and efforts available for mitigating the current human-engineered biodiversity crisis.

Session 26-14: Monday, 2:30 PM
Presenter: Philip D. Gingerich

PALEOCENE–EOCENE CORING PROJECT IN THE BIGHORN BASIN: MULTIDISCIPLINARY APPROACH TO A CRITICAL EARTH-LIFE TRANSITION

Gingerich, Philip D., Department of Earth and Environmental Sciences, University of Michigan, 2534 CC Little Building, Ann Arbor, MI 48109; Clyde, William C., Earth Sciences, University of New Hampshire, Durham, NH 03824; Wing, Scott L., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013

The Paleocene–Eocene boundary in the deep sea is marked paleontologically by a major benthic marine foraminiferal extinction event. The Paleocene–Eocene boundary on land is marked paleontologically by a major continental mammalian origination event. The two are tied together by a carbon isotope excursion (CIE) and coincident 5–8°C event of global warming (Paleocene–Eocene thermal maximum or PETM). We are concerned about global warming today. What caused global warming at the Paleocene–Eocene boundary, and what were the consequences? One consequence of PETM warming was acidification of the marine environment and dissolution of many carbonate-rich stratigraphic sections recording the event in the world’s oceans. Continental sections avoid the acidification problem and in favorable circumstances have the temporal resolution we associate with marine sections. The Paleocene–Eocene CIE is recorded at Polecat Bench and other localities round the Bighorn Basin in northwestern Wyoming. Polecat Bench preserves the most complete and richly fossiliferous early Paleogene continental sequence in the world, with approximately 40 meters in the PETM interval. The CIE is recorded in pedogenic carbonate and dispersed organic matter. PETM mammals, soil development, trace fossils, carbon isotopes, and orbital cyclicity have all been studied in stratigraphic sections exposed at the surface at Polecat Bench. During the summer of 2011, our NSF-sponsored Bighorn Basin Coring Project (BBCP) recovered more than 900 meters of core in parallel holes spanning the PETM at two sites and spanning the slightly younger hyperthermals ETM2 and H2 at a third site. High depositional rates at all three sites (30–50 cm/thousand years) permit resolution of events on a millennial time scale.

The BBCP science team has put together a detailed correlation of surface and core sections for Polecat Bench that enable much higher resolution of the Paleocene–Eocene CIE and direct correlation with physical properties used in orbital tuning. The result is a better understanding of the timing of PETM warming relative to Earth’s orbital eccentricity of and axial precession. Critical transitions in Earth’s environment and biotic responses to these transitions are recorded geological strata of Earth’s crust. These can only be investigated adequately by multidisciplinary teams studying sedimentary geology, time, environments, paleontology, paleoclimate, and energy in the past. All have consequences for Earth’s climate, environments, and life in the future.

Session 26-15: Monday, 3:15 PM
Presenter: Scott L. Wing

EFFECTS OF THE PALEOCENE-EOCENE THERMAL MAXIMUM ON TERRESTRIAL PLANTS AND CARBON STORAGE

Baczynski, Allie A., Department of Earth and Planetary Sciences, Northwestern University, Technological Institute, 2145 Sheridan Road, Evanston, IL 60208; Barclay, Richard S., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013; Bowen, Gabriel J., Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112; Denis, Elizabeth H., Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; Freeman, Katherine H., Department of Geosciences, 503 Deike Building, Pennsylvania State University, University Park, PA, 16802; Harrington, Guy J., School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK; Jardine, Phillip E., Department of Environment, Earth and Ecosystems, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK; Maibauer, Bianca, Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112; McLnerney, Francesca A., Sprigg Geobiology Centre, Environment Institute and School of Earth and Environmental Sciences, University of Adelaide, Adelaide, SA, Australia; Wing, Scott L., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013

The Paleocene–Eocene Thermal Maximum (PETM) was a massive perturbation of the global carbon cycle with far-reaching effects on climate and ecosystems. Thousands of petagrams of carbon were released in a few millennia at the onset of the PETM and global temperature increased 5–8 °C. Similarity of the PETM to extreme scenarios for anthropogenic global warming has made it a focal interval for integrated earth-life studies. In 2011, the Bighorn Basin Coring Project (BBCP) recovered hundreds of meters of core spanning the PETM. We describe early results from the Basin Substation site in the eastern Bighorn Basin, where the Paleocene–Eocene transition occurs in fluvial rocks with drab paleosols lacking carbonate nodules, features indicating poor drainage on the ancient floodplains that inhibited microbial decay and increased preservation of organic matter. Organic matter is better preserved in the core than in
The emergence of grassland biome, which today covers ~40% of Earth's land surface, constituted a critical ecological transition that involved major changes in faunas and climate, as well as silica and carbon cycling. Documenting this fundamental ecosystem change has preoccupied paleontologists and evolutionary biologists for nearly 140 years. The superb Cenozoic terrestrial record on many continents has allowed high-resolution study of functional morphology of animals and stable isotopes, documenting broad patterns of grassland evolution. In contrast, paleobotanical data have historically been scarce; however, in recent years, plant silica (phytoliths) has emerged as a highly suitable tool for tracking diversification of Poaceae lineages and the spread of grassland vegetation. Unlike pollen and most macrofossils, grass phytoliths are diagnostic of ecologically distinct grass subclades. Plant silica can also be found in a wide range of sediments that do not preserve other types of plant fossils, such as many Cenozoic deposits. Combined with other lines of evidence, phytolith data collected so far in North and South America, Europe, Asia, and Africa have revealed that the evolutionary history of the grassland biome was substantially more complex than previously assumed. For instance, it now appears that open-habitat grasses diversified long before becoming ecologically dominant in both North and South America, indicating that different environmental factors triggered these events. Comparison between faunal and plant silica-based floral data also shows that grazers did not evolve in tight coevolution with grasslands in North America and Eurasia, and in South America, grazer-like morphology originated independently of grasslands. These results suggest that region-by-region studies that integrate multiple lines of evidence are necessary to fully understand the factors that shaped and continue to shape grass-dominated ecosystems.

Session 26-17: Monday, 3:45 PM
Presenter: Carlos Jaramillo

EXPANSION OF THE PANAMA CANAL AND THE RISE OF THE ISTHMUS

Jaramillo, Carlos, Smithsonian Tropical Research Institute, Unit 0948, APO AA 34002, Balboa, Ancon, 0843-03092, Panama; MacFadden, Bruce J., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Bloch, Jonathan, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Jones, Douglas, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Morgan, Gary, New Mexico Museum of Natural History, NM

Even though the uplift of the Panamanian isthmus was a small-scale geological event, it separated two oceans and joined two continents, producing large-scale biological, climatic, and paleocenographic changes. It has been traditionally accepted that the rise of the isthmus happened ~3.5 Ma ago. Over the past four years, given the Panama Canal expansion, we have had access to a vast amount of fresh rocks, otherwise covered by tropical rainforest, and the opportunity to collect more evidence about the timing and consequences of Panamanian isthmus uplift. Paleontology, thermochronology, provenance, geochemistry, petrography, magnetostratigraphy, global circulation/Neodymium modeling, and structural analyses indicate three major exhumation events that occurred during the late Eocene (~38 Ma), the earliest Miocene (~20 Ma), and the late Miocene (~10 Ma) intervals. There is no record of strong exhumation at ~3.5 Ma. Furthermore, the Central American Seaway (CAS, that we define as the ocean corridor along the tectonic boundary between the South American plate and the Panama microplate) shut down by the late Miocene (12–10 Ma ago), and an active exchange of sediments between both blocks was initiated. Neodymium modeling suggests also that this 10 Ma CAS shut-down interrupted the flow of Pacific deep-water into the Caribbean and only shallow waters (~200 m deep) could mix across the isthmus. This 12–10 Ma event could be associated with the onset of AMOC circulation.
Fossil evidence and genetic analyses of a number of clades including monkeys, bats, snakes, crocodiles, bees, frogs, salamanders, hummingbirds, some fresh-water fishes, and plants indicate that migration of terrestrial elements across the isthmus started ~2.1 Ma ago, and became more frequent by 10 Ma ago. Shallow-water communication between Pacific and Caribbean, albeit intermittent, continued until 3.5 Ma, as evidenced by a variety of records including fossil marine molluscan faunas. Mammalian migration is very limited, only increasing until around 2.7 Ma, suggesting that a barrier, other than a physical connection, did not allow a large mammalian exchange both continents. Migration also varied along latitude, with North American taxa reaching temperate areas of South America earlier than tropical areas. Perhaps the onset of the Northern Hemisphere glaciation at 2.7 Ma and the vast climatic changes that it produced had more influence on mammalian and other migrations (e.g., fresh-water fishes) across the isthmus, rather than the establishment of a continuous land bridge.

Session 26-18: Monday, 4:00 PM
Presenter: Federico Moreno

LATE PLEISTOCENE–PLEISTOCENE CLIMATE CHANGE FROM LA GUIAJIRA PENINSULA (COLOMBIA)

Moreno, Federico, Center for Tropical Paleoeocology and Archaeology, Smithsonian Tropical Research Institute, Panama City, 9100, Panama; Martinez, Camila, Plant Biology, Cornell University, 412 Mann Library Building, Ithaca, NY, 14853; Jaramillo, Carlos, Smithsonian Tropical Research Institute, Unit 0948, APO AA 34002, Balboa, Ancon, 0843-03092, Panama

The Guajira Peninsula physiography is comprised of a northerly vast land portion connected to the continent through a narrow bottleneck. Lowlands are extended from the continent to the north part of the peninsula, where they are interrupted by three major ranges: Macuira, Jarara, and Cocinas. This physiographic configuration makes the connection with the continent susceptible to any important sea-level fluctuation. Therefore, provenance analysis in sedimentary rocks will be a useful tool for identifying those fluctuations. Stratigraphic work in the Castilletes Formation shows major sea-level oscillations by lithological and sedimentological changes. In this manner, it is possible to identify any major drop in global sea-level related to the onset of the Northern Hemisphere glaciation. To understand the Guajira Peninsula desertification, it is important to consider the global and local context. As part of the local landscape, the Macuira Range has the highest elevation in the Guajira Peninsula, 864 meters above sea level. Due to its localization in the northermost portion of the peninsula, and to its southeast-northwest trend, it constitutes an important physiographic barrier for the humid winds coming from the northeast to South America. As a consequence, an amazing humid ecosystem has developed in the Macuira Range. The impact of the Macuira Range is a shadow effect of humidity that could be responsible of the dominating dry climate conditions in the peninsula. Hence, the Macuira Range could be also responsible for the past drastic climate change that Castilletes Formation records. As a consequence, ages of exhumation and desertification should be correlated. To address this possible explanation, I plan to study the exhumation of the Macuira Range using thermochronology. Invertebrate biostratigraphy, vertebrate paleontology, paleobotany, and palynology studies are being conducted by paleontologists. Putting together their upcoming results with the stratigraphy, sedimentology, provenance, and thermochronology analyses will allow the better understanding of the dramatic ecological changes that took place during the last few millions years in the Guajira Peninsula.

Session No. 27 (continued): The Cenozoic assembly of the grassland biome: pattern and process in ecosystem evolution

Chairs: Caroline Strömberg and Bonnie Jacobs

Monday Afternoon 1:30 PM to 4:30 PM

Session 27-10: Monday, 1:30 PM
Presenter: Christine Janis

PALEOGENE SURFACE UPLIFT AND ITS IMPACT ON TERRESTRIAL PALEOENVIRONMENTS AND MAMMALIAN COMMUNITIES IN WESTERN NORTH AMERICA

Janis, Christine M., Ecology and Evolutionary Biology, Brown University, 80 Waterman Street, Providence, RI 02912; Eronen, Jussi T., Department of Geosciences and Geology, University of Helsinki, Helsinki, Finland; Chamberlain, C. Page, Department of Environmental and Earth System Science, 473 Via Ortega, Rm 140, Stanford University, Stanford, CA 94305; Mulch, Andreas, Biodiversität und Klima Forschungszentrum (BiK-F), Senckenberganlage 25, 60325 Frankfurt/Main, Germany

The early Cenozoic North American environments were primarily paratropical forests and woodlands: prior to the initial radiation of the grassland biome in the late Oligocene/early Miocene, Northern Hemisphere climatic change had resulted in a mammalian fauna that was no longer tropical in aspect, but which was in many ways already adapted to colder and drier environmental conditions. Yet this change preceded the dramatic cooling recorded in the oxygen isotope record of deep sea foraminifera at the Eocene–Oligocene boundary. Here we investigate the origins of this pre-grassland biome fauna considering the role of the uplift of the western North American Cordillera on late Paleogene environmental change, both in changes in precipitation due to rain-shadow effect, and changes in temperature due to altitude. We use dental morphology data from large herbivorous mammals to spatially analyze the development
Eocene. It is hypothesized that increased volcanic output in early Cenozoic led to a sustained high during the North America. Analysis of rock-type distributions show the large-scale changes in sediment throughout the Cenozoic of grit rather than the grasses themselves; unfortunately the grit are too often examined out of geologic context. In this impact the organisms involved. However, fossil organisms of habitats and paleoenvironments during the Eocene and Oligocene in western North America. We combine the fossil record with a compilation of pedogenic and lacustrine long-term oxygen isotope data that allows us to infer the first-order paleotopographic history of western North America. Collectively, these biotic and abiotic paleoenvironmental records are key to investigating the role of surface uplift in the development of Paleogene paleoenvironment and habitat structure of western North America. In particular, we combine oxygen isotope-based reconstructions of regional precipitation patterns with results from transfer function analysis of herbivorous mammal data, and suggest that for extensive regions of western North America, middle Eocene drying rather than cooling characterized an important global climatic event. The uplift started around 50 Ma, and took place mainly before the Oligocene. We see large changes in mammalian community dynamics that reflect changes in precipitation regime during the Eocene, especially between Wasatchian–Bridgerian (50 Ma), Bridgerian–Uintan (46 Ma), and in particular Duchesnean–Chadronian (37 Ma). While the Duchesnean is uniformly less humid than previous time periods, the Chadronian faunas reflect considerably drier environments. We suggest that the lack of change around the Eocene–Oligocene boundary at the end of the Chadronian is because mammalian faunas were already pre-adapted to cooler and drier conditions before this transition, resulting from the effects of the surface uplift. Comparison with Europe shows that these changes were not global, or at the very least, they were enhanced by the North American tectonic development.

Session 27-11: Monday, 1:45 PM
Presenter: Deborah L. Rook

THE NITTY GRITTY OF US WESTERN PLAINS: PALEONTOLOGICAL AND GEOLOGICAL IMPLICATIONS FOR THE EVOLUTION OF GRAZERS AND GRASSLANDS

Rook, Deborah L., Department of Geosciences, University of Wisconsin-Madison, Madison, WI 53706

Long has a debate raged about the circumstances of the coevolutionary processes that led to the incredibly interconnected grazer and grassland ecosystem. Although new discoveries further our understanding of these processes, a critical piece of the puzzle is overlooked. Grass macrofossils, pollen, mammal teeth, and body fossils are the foundation of most arguments, but geological processes that might affect organism evolution are not always considered. Plants grow in—and mammals live and eat on—sediment, and any significant changes in surface sediment would impact the organisms involved. However, fossil organisms are too often examined out of geologic context. In this particular debate, it has been suggested that changes in mammal teeth were likely caused by some sort of ingested grit rather than the grasses themselves; unfortunately the grit has not been well studied. The Macrostrat Database and its sedimentological and stratigraphic data allow examination of large-scale changes in sediment throughout the Cenozoic of North America. Analysis of rock-type distributions show the quantity of volcanic rock dramatically increased across the early Cenozoic leading to a sustained high during the Eocene. It is hypothesized that increased volcanic output in the form of ash and particulates may have greatly contributed to the coevolutionary cycle of the North American grassland ecosystems. Active volcanoes and volcanic dust in the sediment will change the soil chemistry for plants and could be the grit previously described that drove tooth evolution in grazing mammals. Fieldwork has begun that will test this hypothesis at sites in the western Wind River Basin of Wyoming, including distinguishable pre- and post-volcanic contributions to the stratigraphic and sedimentologic records.

Session 27-12: Monday, 2:00 PM
Presenter: Jay O’Sullivan

A NEW PARAHIPPINE EQUID FROM THE EARLY MIocene OF FLORIDA AND THE ORIGIN OF CEMENTUM-COVERED CHEEKTEETH IN HORSES

O’Sullivan, Jay, Department of Health Sciences and Human Performance, University of Tampa, 401 W. Kennedy Blvd., Tampa, FL 33606; Hubert Jr., Richard C., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Parahippine equids are the evolutionary intermediaries between brachydont taxa, such as Miohippus and Anchitherium, and hypsodont taxa, such as Merychippus, hippocriones, and advanced equines. They were relatively abundant for only a short period of time in the early Miocene (~22–17 Ma) of North America. Evolutionary innovations first observed in parahippines (often enhanced in later equines) include a fully unguligrade foot, higher-crowned teeth with a coating of cementum and increased enamel complexity, and a complete postorbital bar. These are classically thought to be responses to living in more open habitats with an increased amount of grass in the diet. Understanding of this critical interval of equid evolution is hindered by the absence of a modern systematic revision or phylogenetic analysis at the species level. We are currently working on resolving these shortcomings. Here we describe the dental morphology of a previously unknown parahippine taxon from the Miller local fauna of Florida (~19 Ma, very early Hemingfordian Land Mammal Age). It is of moderate size (toothrow lengths 90–100 mm) and its unworn cheekteeth are 12–14 mm tall, both equal to the observed ranges found in Parahippus paviensis of Colorado and Nebraska (~18–19 Ma) and Parahippus leonensis of Florida (~17.5–18 Ma). The cheekteeth of P. paviensis lack cementum, as do all known Arickareean parahippines. All permanent cheekteeth of P. leonensis have an external coating of cementum, of varying thickness. In the Miller parahippine, a thin coating of cementum is observed on some cheekteeth, most frequently on third molars (37.5% of uppers and lowers; N=40). Cementum occurs on only 12.5% of second molars (N=24), and less frequently on first molars (3.6%, N=28) or permanent premolars (8%, N=101). If present, the cementum only coats the walls of the crown, most often the buccal side of upper teeth and the lingual side of lowers. It does not fill areas between lophs on the occlusal surface, nor is it present in the fossettes of the upper teeth. No cementum is found on the crowns of deciduous premolars. The Miller parahippine is the first known instance of such variation for this character within a population of equids, and implies that evolutionary acquisition of cementum on horse teeth was not related to a major increase
in crown height, although it played an important role in allowing greatly increased hypsodonty in later species.

Session 27-13: Monday, 2:15 PM
Presenter: Alice Novello

NEW INSIGHTS ON THE EXPANSION OF GRASSES IN CENTRAL AFRICA DURING THE MIO-PLIOCENE: EVIDENCES FROM THE PHYTOLITHS PRESERVED AT PALEONTOLOGICAL SITES IN NORTHERN CHAD

Novello, Alice, iPHEP, UMR 7262 INEE, Université de Poitiers, 86000 Poitiers, France; Barboni, Doris, CEREGE, Aix Marseille Université UM34, CNRS, IRD, 13545 Aix en Provence, France; Blondel, Cécile, iPHEP, UMR 7262 INEE, Université de Poitiers, 86000 Poitiers, France; Abderamane, Moussa, Université N'Djamena, Department of Paleontology, N'djamena, Chad; Mackaye, Hassane Taisso, Université N'Djamena, Department of Paleontology, N'djamena, Chad; Likius, Andossa, Université N'Djamena, Department of Paleontology, N'djamena, Chad; Vignaud, Patrick, iPHEP, UMR 7262 INEE, Université de Poitiers, 86000 Poitiers, France; Brunet, Michel, iPHEP, UMR 7262 INEE, Université de Poitiers, 86000 Poitiers, France.

Earliest paleobotanical evidences of grasses in Africa are associated with 70 million-year-old deposits, suggesting that the current distribution of African grasses results from a long past history. In East Africa, paleobotanical and carbon isotope data indicate that C4 grasses became dominant from the early Pliocene (~5–4 million years ago, Ma), although they were present in the vegetation as early as the early Miocene (~16 Ma). It also appears that some East African mammals abundantly consumed C4 grasses almost three million years before C4 grasses became dominant in the environment. To better understand how C4 grasses and then grass-dominated biomes expanded over the African continent during the Cenozoic, we investigated the phytolith content of Mio–Pliocene sediments from the Lake Chad Basin, Central Africa. Two hominin species, Australopithecus bahrelghazali (~3.6 Ma) and the earliest hominin species known thus far, Sahelanthropus tchadensis (~7 Ma), were recovered from this region. Mio–Pliocene deposits of the Djurab desert. We analyzed the phytolith content of about 50 paleontological levels from the Djurub area (16°N/17°E) and of 25 sedimentological levels from Lake Chad (Bol core, 13°N/14°E), which were absolutely dated using cosmogenic isotopes and provide a paleoenvironmental record for the last 7 Ma. Calibration work, including 98 grass species and 57 soil samples from modern Chad, was carried out to assess the environmental significance of the phytolith signal in the fossil record. Our results show that, as far north as 17°N, mosaic environments occurred around 7 Ma, including aquatic vegetated areas (herbaceous swamps), forested patches, and C4 savannas. The existence of diversified vegetation is consistent with vertebrate diversity, tooth-wear pattern, and enamel iso- tope data for mammalian fossil taxa, which show a large variety of dietary preferences including pure C3 diet, intermediate C3-C4 diet, and pure C4 diet. Yet, the dietary preference of S. tchadensis is unknown. At ~3.5 Ma, the phytolith signal from the Djurub area is essentially that of C4 savannas, which is in agreement with a dominant C4 dietary preference (>90%) among the fossil specimens of mammal herbivores studied from the same area. Isotope analyses also revealed that A. bahrelghazali mostly depended on C4 plants. Grass-dominated biomes, therefore, were expanded ~3.5 Ma at 17°N. By comparison, in the south (13°N), the phytolith record indicates that grass-dominated biomes were already well-established ~6.5 Ma. We conclude that C4 grasses were already present in Central Africa ~7 Ma. Yet, it is most likely that the expansion of grass-dominated biomes did not occur later than ~6.5 Ma, although their spread out may have differed from northern to southern Chad in relation to the importance of aquatic areas.

Session 27-14: Monday, 2:30 PM
Presenter: Bonnie F. Jacobs

A MIOCENE PHAROID GRASS (POACEAE: PHAROIDIEAE) FROM KENYA AND IMPLICATIONS FOR MID-MIOCENE PALEOECOLOGY

Jacobs, Bonnie F., Roy M. Huffington Department of Earth Sciences, Southern Methodist University, 3225 Daniel Ave., Dallas, TX 75275; Judziewicz, Emmet, Department of Biology and Museum of Natural History, University of Wisconsin-Stevens Point, Stevens Point, WI 54481; Kabuye, Christine H.S., Biology Department, Makerere University, Kampala, Uganda

The Pharoideae are forest grasses and are the second- to basalt-most clade in the Poaceae (Judziewicz and Clark, 2007). Fossil pistillate spikelets of the Neotropical genus Pharus are known from Dominican Republic amber, dated late Eocene to early Miocene (Poinar and Judziewicz, 2006). Here we report a well-preserved impression of the abaxial leaf-blade surface (functionally the upper surface in this subfamily) of a pharoid grass from 12.6 Ma Miocene volcanic ash at Kabarsero, in the type section of the Ngororora Formation, Tugen Hills, Kenya. The impression preserves the oblique lateral veins and even the intercostal sclerenchymatous bands characteristic of pharoid grasses (Judziewicz, 1987), as confirmed by scanning electron microscopy. There is one extant pharoid grass genus in Africa (Leptaspis), and the single extant widespread species, L. zeylanica, occurs geographically closest to the fossil site in Kakamega forest of western Kenya, only 118 km away, and at approximately the same elevation (1300–1600 m) today. The environment represented by the fossil assemblage in which Leptaspis occurs is likely to have been similar to the Kakamega forest, based upon the taxonomy of the plant assemblage and its physiognomic characteristics. Interestingly, the fossil leaf impression does not differ appreciably from the extant species. The grass fossil from the Kabarsero locality, and its associated plant fossils, demonstrate that while open habitats were occurring in West Africa (evident from pollen assemblages), and mixed C3/C4 communities were present in the Tugen Hills (evident from carbon isotopic studies of paleosols and mammalian tooth enamel), parts of the Tugen Hills during the early formation of the Kenyan Rift Valley were occupied by forest and forest grasses.

Session 27-15: Monday, 3:15 PM
Presenter: Stephanie Pau
ORIGINS OF C₄ GRASSLANDS: INTEGRATING MODELING AND PALEO DATA TO SHED LIGHT ON NEOGENE VEGETATION CHANGE

Pau, Stephanie, Department of Geography, Florida State University,113 Collegiate Loop, PO Box 3062190, Tallahassee, FL 32306; Strömberg, Caroline A.E., Department of Biology, University of Washington, 24 Kincaid Hall, Box 351800, Seattle, WA 98195; Fox, David L., Department of Earth Sciences, University of Minnesota, Minneapolis, MN 55455; Still, Christopher, Forest Ecosystems and Society, Oregon State University, 321 Richardson Hall, Corvallis, OR 97331; Osborne, Colin P., Department of Animal and Plant Sciences, The University of Sheffield, Western Bank, Sheffield S10 2TN, UK; Lehmann, Caroline, School of Geosciences, Edinburgh EH9 9YL, UK; Taylor, Lyla L., Department of Animal and Plant Sciences, The University of Sheffield, Western Bank, Sheffield S10 2TN, UK; Beerling, David J., Department of Animal and Plant Sciences, The University of Sheffield, Western Bank, Sheffield S10 2TN, UK

The rapid ecological expansion of grasses with C₄ photosynthesis at low- to mid latitudes at the end of the Neogene (8–2 Ma) was one of the most dramatic vegetation changes in recent geologic time, paving the way for modern tropical grassland ecosystems. This broadly synchronous shift to C₄-dominated vegetation, long after the evolutionary origin of the C₄ pathway in grasses, is well documented in the fossil record of stable carbon isotopes. However, it is less well understood in terms of driving mechanisms. Today’s distinct distribution of C₄-dominated grasslands has been linked to differences in the ecophysiology between C₃ and C₄ grasses, with C₃ grasses being favored in hot, dry climates with summer precipitation and at low CO₂. It has therefore been assumed that changes in global climate condition and/or atmospheric composition (e.g., a late Miocene drop in CO₂) may have triggered the rise to ecological dominance of C₄ grasses. To test whether the physiology of C₄ grasses can explain the distribution of C₄-dominated grasslands also in the geologic past, we compare modeled C₄ grass(land) distribution with observed (paleontological) data. Specifically, we used climate models of increasing complexity (e.g., modern climate, Global Circulation Models), coupled with different models for the distribution of C₄ grasses (e.g., Sheffield Dynamic Global Vegetation Model) to produce global maps of fractional C₄ cover and biomass for the Miocene and Pliocene under different levels of atmospheric CO₂. These model predictions were compared statistically to stable carbon isotopic data from paleosol carbonates and tooth enamel to evaluate how well the models explain actual data on past distribution of C₄ grasslands. Paleobotanical information also permitted a separate test of the models’ ability to reconstruct openness. These comparisons allow us to evaluate different abiotic factors that may have contributed fundamentally to the late Neogene C₄ revolution.

Session 27-16: Monday, 3:30 PM
Presenter: Richard Madden

THE ROLE OF EARTH SURFACE PROCESSES IN THE EVOLUTION OF MAMMALIAN TOOTH SHAPE

Madden, Richard H., Organismal Biology and Anatomy, University of Chicago, 1027 E 57th St, Chicago, IL 60637

The Cenozoic fossil record of terrestrial mammals documents innumerable examples of the evolution of tooth structures for resisting abrasive wear, including hypodonty. The most conspicuous examples come from tectonically active areas of Andean and Patagonian South America, the western interior of North America, the rift system of East Africa, and islands in the western Mediterranean. This pervasive pattern has been understood to relate to the rigors of herbivory, and much focus has been placed on herbivore grazing behavior. Coincidentally, the evolutionary pattern is often associated with silicic volcanism and earth-surface processes that mobilize mineral abrasives into, through, and beyond the herbivore environment. This suggests a working hypothesis that accumulations of readily eroded sediment (e.g., volcanic ash), where accessible to erosion, plus the properties of mineral particles (e.g., volcanic glass) that make them abrasives of industrial significance, plus the active role of surface processes that mobilize these mineral particles, may conspire to drive the evolutionary increase in hypsodonty. At ecological timescales, annual tooth-wear rates are positively
correlated with soil loss when expressed as mineral particle flux. Both direct soil ingestion and the soil load on plants may be significant, but are rarely distinguished. On islands, where rates of morphological evolution are high and the selection pressure imposed by the environment is unavoidable, variation in tooth wear rates appears to reflect the type and amount of soil exposed at the surface and surface processes that mobilize it. At evolutionary timescales, the intensity of tectonism and topographic complexity have high positive correlations with species richness, and origination and extinction rates. Erosion rates are high in tectonically active areas with high relief, but are still higher in volcanic landscapes. Where fossil mammals are recovered from volcanic sediments, and where a downwind record of erosion intensity is preserved in marine sediments, we find a remarkable correlation between rates of dental evolution and the intensity of erosion. The production and accumulation of volcanic ash provides a potential long-term source of mineral particle abrasives. Where orbital time-scale variation in earth-surface processes that deliver these abrasives into and through the herbivore environment can be documented, we find evidence of evolutionary response. Relating sediment accumulation on the sea floor to the earth-surface processes operating where herbivores lived and evolved requires following mineral particles from their source to their ultimate sink.

Session 27-18: Monday, 4:00 PM
Presenter: Matthew C. Mihlbachler

**ITS NOT EASY BEIN’ GREEN: GRASSLANDS AND THE DENTAL ECOLOGY OF NORTH AMERICANUNGULATES OF THE NORTH AMERICAN CENOZOIC**

Mihlbachler, Matthew C., Anatomy, New York Institute of Technology College of Osteopathic Medicine, Old Westbury, NY 11568; Solounias, Nikos, Anatomy, New York Institute of Technology College of Osteopathic Medicine, Old Westbury, NY 11568; Beatty, Brian L., Anatomy, New York Institute of Technology College of Osteopathic Medicine, Old Westbury, NY 11568; Barron-Oritz, Christian, University of Calgary, Calgary, AB, T2N 1N4, Canada

Mammals that feed in open environments experience higher rates of dental wear than closed habitat feeders because they ingest higher concentrations of dietary (phytoliths) and non-dietary (sand, dust, soil) abrasives. Therefore, hypotheses about the ecological responses of extinct ungulates to the spread of open-grassland ecosystems are testable via dental wear observed in the rich record of North American fossil ungulates. Dental mesowear surveys involving thousands of specimens of the three most abundant North American ungulate families—Camelidae, Merycoidodontidae, and Equidae—all indicate a consistent trend for increasing dietary abrasion through the Oligocene, Miocene, Pliocene, and Pleistocene. However, these groups provide conflicting results regarding the coevolution of diet and dental hypsodonty, rendering it difficult to understand the role that grazing diets had in the adaptive radiations of these mammal clades, particularly with regard to the evolution of hypsodonty. Most studies of unglulate dental wear have sought to associate microscopic wear features (microwear) or macroscopic wear facet development (mesowear) with grazing, browsing, and mixed-feeding diets. We suggest that this approach may be oversimplified for two reasons: it is unclear 1) how ingestion of non-dietary abrasive particles contributes to dental wear, and 2) how intrinsic phylogenetic differences between different mammal species influence dental-wear patterns. Comparisons of the dental microwear patterns of extant ruminants and perissodactyls suggest that the dental wear of ruminants are more highly correlated to browsing and grazing diets, whereas less selective, hind-gut-fermenting perissodactyls have wear patterns that are only weakly associated with diet but are more strongly associated with feeding environment. Dental microwear and mesowear of hypsodont and brachydont perissodactyls (horses and rhinos) from the Miocene of North America are often inconsistent with dietary predictions made from published stable isotope data or crown height data. We suggest these peculiar dental-wear patterns may ultimately reveal less about diet and more about feeding environments. Because North America, in contrast to the modern world, was dominated by non-ruminating ungulates, we are a far from being able to generate robust paleoecological conclusions from dental-wear data. Recent efforts have focused on increasing precision and minimizing observer error in dental-wear analyses (e.g., confocal texture analysis, outline-based morphometric analysis of dental mesowear). Future research needs to focus not just on precise quantification of dental wear, but on understanding the physical causes of how dental wear occurs, at what rate, and what factors are involved, including diet, other aspects of the environment, and the intrinsic influence of phylogeny.

Session 27-19: Monday, 4:15 PM
Presenter: Lars Werdelin

**THE ROLE OF CARNIVORES IN GRASSLAND ECOSYSTEM EVOLUTION AND COMMUNITYREGULATION**

Werdelin, Lars, Department of Palaeobiology, Swedish Museum of Natural History, Box 50007, SE-10405, Stockholm, Sweden

That grassland formation is dependent on a combination of climatic factors (temperature, precipitation) is a given. This bottom-up regulation has effects upwards in the food web and generates a characteristic spectrum of primary and secondary consumer species. However, perturbations to these trophic levels will, in turn, affect the structure of grassland communities. In particular, changes to the composition of the top predator guild may have drastic consequences for lower trophic levels through trophic cascades moving downwards though the food web. An often-cited example of this process in the modern world is the reintroduction of wolves to Yellowstone National Park. In modern grasslands, it has been shown through natural exclusion experiments in Serengeti National Park that loss of key predators strongly affected the structure of parts of the grazer (prey) community. Furthermore, loss of certain grazer species changed the composition of the primary producer community, in some cases leading to a marked reduction in grasslands, trending toward woodland. In this presentation, I will consider the possibility of the existence and identification of top-down regulation of grassland ecosystems in the past. I suggest some avenues for detecting top-down regulation based on
changes to the structure of carnivore communities. Key global events include the origin and spread of large sabertooth felids in the late middle Miocene–early late Miocene and the massive turnover in carnivore communities near the Miocene–Pliocene boundary. Other events that may be implicated in top-down regulation include the replacement of hyaenodontid creodonts by carnivorans in the mid-Oligocene of North America and middle Miocene of Africa, the origin of bone-cracking hyenas in the late Miocene of Eurasia, and the extinction events that have followed the appearance of genus Homo at different times on different continents. Some of the events listed above have co-occurred with climatic changes. Such events can be expected to be especially severe, and the challenge then remains to tease apart the effects of bottom-up and top-down regulation.

Session No. 28 (continued): Exceptional Records: Evolution and ecology of microfossils

Chairs: Gene Hunt and Pincelli Hull

Monday Afternoon 1:30 PM to 4:15 PM

Session 28-10: Monday, 1:30 PM
Presenter: Richard D. Norris

FISH LIKE ANOXIA: ICHTHYOLITH PRODUCTION REPEATEDLY INCREASES DURING MEDITERRANEAN SAPROPEL EVENTS

Norris, Richard D., Scripps Institution of Oceanography, La Jolla, CA 92093

It has long been noted that anoxic periods in Earth history are associated with mass extinctions, leading to speculation that anoxia itself is the extinction driver. The repeated development of 'Black Sea'-like anoxia in the Mediterranean basin offers a series of natural experiments for the impact of basin-scale anoxia on marine vertebrates. The Mediterranean oscillated on an orbital time scale between having a well-oxygenated water column with deposition of calcareous oozes and periods of basin-wide photic-zone anoxia associated with deposition of black, organic-rich sapropels. Anoxic conditions were brought on by climate-driven increases in regional rainfall that led to the development of low salinity surface waters and ocean stratification. Analysis of six late Pliocene sapropel layers and intervening calcareous oozes in Ocean Drilling Program Site 967B, Core 9H, shows that both fish bones and teeth are rare in normal marine conditions but spike 10–100× above background in each of the sapropels. Sapropels are well known to have "burn-down" zones at their tops, where organic carbon has been oxidized upon return of an oxygenated water column. Teeth and bones are well preserved in these burn-down zones at abundances typical of the fully-preserved sapropels. Therefore, it appears that the abundance of ichthyoliths in the sapropels, relative to the calcareous oozes, is not a preservation artifact. Furthermore, there is a repeated cycle in the composition of the tooth assemblage between the normal oxygenated calcareous oozes and the sapropel beds. Calcareous oozes are associated with flattened triangular teeth typical of large predatory fishes whereas those in the sapropels include a more diverse fish community including forms that belong to mid-water lantern fishes (Myctophids). These ichthyolith results suggest that anoxia was associated with generally higher fish productivity than non-sapropel periods. Other proxy evidence such as fluxes of biogenic barium and diatoms also suggest that ocean productivity was higher during sapropel climates than non-sapropel climates. While these results do not comment directly upon the potential of anoxic periods to induce extinction, they do show unequivocally that Black Sea-style anoxia promotes fish production, probably by increasing the overall phytoplankton production, offering a low-oxygen mid-water daytime refuge for fish and invertebrates against predation, and increasing the overall nighttime activity of the deep-scattering layer of mid-water communities. Therefore, it seems unlikely that anoxia, per se, is the extinction driver in past oceanic anoxic events, which may instead owe more to changes in the composition of phytoplankton communities with knock-on effects in food-chain structure.

Session 28-11: Monday, 1:45 PM
Presenter: Lana G. Graves

FISHY INCREASE OF ICHTHYOLITHS THROUGHOUT THE OLIGOCENE SUGGESTS MARINE COOLING FACILITATED BONY FISH POPULATION EXPANSION

Graves, Lana G., Scripps Institution of Oceanography, La Jolla, CA 92093; Sibert, Elizabeth C., Scripps Institution of Oceanography, La Jolla, CA 92093; Norris, Richard D., Scripps Institution of Oceanography, La Jolla, CA 92093

The Oligocene records the widespread development of polar glaciers, a marked change in Southern Ocean ecosystems, and the radiations of top marine predators, including the great whales. While most biological proxies focus on the response of primary producers or microzooplankton, fish and shark scales, called ichthyoliths, are an under-utilized microfossil resource for reconstruction of the production and composition of consumer-level communities. The extensive presence of ichthyoliths in marine sediments, including otherwise non-fossiliferous red clays, provides a means of assessing the response of consumer-level marine organisms to global change, such as that associated with the Oligocene marine transition. Here we report changes in mass accumulation rate (MAR) of ichthyoliths at Ocean Drilling Program (ODP) Site 886, a red-clay site in the North Pacific Ocean from the latest Eocene through the Oligocene and into the earliest Miocene. In the 20 million years represented by our record, ODP 886 drifts roughly from latitude 35°N to 40°N. We find that there is an overall increase in ichthyolith accumulation from the E/O boundary through the Oligocene/Miocene boundary. Mass accumulation rate of ichthyoliths in the latest Eocene is about 40 ichthyoliths/cm²/my and rises to an average of 150 ichthyoliths/cm²/my through the middle Oligocene. In the latest Oligocene and earliest Miocene, we find as many as
420 ichthyoliths/cm²/my. This overall pattern suggests that global cooling during the Oligocene improved conditions for fish production in the North Pacific. Part of the pattern may also reflect the northward tectonic drift of ODP Site 886 into the productive temperate ocean north of the North Pacific subtropical gyre. The relative balance of bony fish and sharks, however, varies considerably throughout the record, suggesting that while the overall fish production increased through the O/M boundary, the composition and structure of the fish community is decoupled from the overall fish productivity levels.

Session 28-12: Monday, 2:00 PM
Presenter: Elizabeth C. Sibert

AN INCREASE IN COMPLEXITY OF PELAGIC FISH COMMUNITY STRUCTURE FOLLOWING THE CRETACEOUS-PALEOGENE MASS EXTINCTION
Sibert, Elizabeth C., Scripps Institution of Oceanography, La Jolla, CA 92039; Norris, Richard D., Scripps Institution of Oceanography, La Jolla, CA 92039

The Cretaceous-Paleogene (K–Pg) mass extinction had profound effects on marine ecosystems, causing >90% extinction among planktonic calcifiers. Using ichthyoliths—microfossil fish teeth and shark dermal scales—we assess the response of fishes to the mass extinction. Our prior research has shown that in the North Pacific Ocean, fish productivity was unaffected by the mass extinction, with accumulation of ichthyoliths remaining at, or in some cases, above Cretaceous levels in the earliest Danian and into the later Paleocene. These results suggest that the productivity of some upper trophic level consumers was not adversely affected by the mass extinction in the North Pacific. Here we report new results for DSDP Site 596, a red-clay site in the South Pacific Ocean that reveals a drastic and permanent change in fish community composition at the K–Pg mass extinction despite having a relatively constant accumulation rate of ichthyoliths across the boundary. Cretaceous ichthyolith assemblages typically have approximately equal numbers of shark denticles and fish teeth. However, at the boundary, this ratio falls by a factor of two, with fish teeth increasing considerably, while denticles decrease slightly (≠, two-sample t-test, p<0.0001). This change is maintained throughout the entire Paleocene, and continues into the Eocene. In addition to an overall composition change, the size structure of the ichthyolith tooth assemblage becomes considerably more complex following the extinction. Cretaceous samples have a small range of tooth sizes, with the majority of ichthyoliths approximately 150–200 µm in length. Paleocene assemblages have a much wider range of sizes, both larger and smaller (100–500 µm), and have a sustained higher quantity of large teeth compared to their Cretaceous counterparts. We interpret this as a shift to a more complex fish community structure with increased numbers of larger predatory fishes driven by the changes in the marine ecosystem at the K–Pg boundary. The increase in Paleocene ichthyolith size and diversity suggests that fish were able to take advantage of newly opened ecological niche space vacated by predators that did not survive the mass extinction. The K–Pg mass extinction, therefore, was likely not a disaster for all upper trophic level organisms, and instead, provided an opportunity for rapid, post-extinction ecological diversification for open-ocean fishes.

Session 28-13: Monday, 2:15 PM
Presenter: Regan Dunn

SEEING THE LIGHT THROUGH CELL MORPHOLOGY. A NEW PROXY FOR ESTIMATING LEAF AREA INDEX (LAI) FROM ANTICLINAL EPIDERMAL PHYTOLITHS
Dunn, Regan E., Department of Biology and Burke Museum of Natural History & Culture, University of Washington, Box 353010, Seattle, WA 98195; Strömberg, Caroline A.E., Department of Biology, University of Washington, 24 Kincaid Hall, Box 351800, Seattle, WA 98195

Vegetation is the context in which all terrestrial biota exist and evolve, and the structure of vegetation dictates many important aspects of ecosystem processes including productivity, photosynthetic rates, atmospheric gas concentrations, hydrological regimes, fire frequency, soil temperature and erosion, animal diets, and habitats. Yet, in paleoecological studies, we do not have a way to reliably measure vegetation structure. This study presents a novel proxy for estimating Leaf Area Index (LAI), a measure of habitat openness and canopy complexity, from the fossil record using plant silica, or phytoliths. It uses the well-known relationship between irradiance and epidermal plant-cell morphology whereby cells of leaves growing in shade are larger and more undulated than those growing in full sun. Leaf epidermis is often a site of silica deposition in plants. Silica-filled epidermal cells are casts of the original cells that faithfully preserve cell-wall outline, cell size and shape, and are often preserved as phytoliths in soils and microfossil in paleosols. We hypothesized that overall, anticlinal epidermal cells, and hence phytoliths contained in soils under closed habitats, would be larger and more undulated due to diffuse levels of irradiance under a forest canopy as compared to those from open habitats receiving higher amounts of direct light. To test this hypothesis, we collected assemblages of modern phytoliths from soils under various canopy light environments in Costa Rica (savanna, shrubland, deciduous tropical forest, flooded savanna, and multi-tiered rainforest). From each site, eLAI (effective LAI) was measured using hemispherical photography. Anticlinal epidermal cells, presumably from dicots, ferns, and non-herbaceous monocots, were photographed and measured. Consistent with expectations from theory, we found significant correlations between eLAI and both mean anticlinal phytolith area (r²=0.45, p<0.0001) and mean undulation (Undulation Index; r²=0.48, p<0.0001) from ~50 sites studied. We developed a multiple linear regression model that strongly correlates cell area and cell undulation with eLAI (r²=0.57, p<0.0001). Using the model created from the modern Costa Rica dataset, we present a record of significant change in forest structure (eLAI) linked to climate change during the middle Cenozoic (50–14 Ma) in Patagonia, Argentina. As an example of model application, this new method adds an important new tool to paleoecological studies previously unattainable via other paleobotanical archives (pollen or macrofloras), and fills a major gap in paleoenvironmental reconstruction. The method has the advantage of being taxon-independent, therefore it can be applied to strata of any age so long as phytoliths are preserved. LAI is an important
Teeth and jaws are the most common mammal fossils found in latest Cretaceous and earliest Paleocene assemblages of North America, and therefore our understanding of this seminal time in mammalian history is almost entirely based on the dental material. Although postcranial bones from the Western Interior at this time are relatively rare and usually found as isolated elements, this material can supplement patterns derived from the dental record and can provide powerful and novel insight into body-size patterns and locomotor ecologies of Cretaceous–Paleogene (K–Pg) mammals. This study describes proximal limb elements (femora and humeri) from K–Pg deposits in northeastern Montana from the Hell Creek (Upper Cretaceous) and Tullock formations (lower Paleogene), representing the Lancial and Puercan North American Land Mammal Ages. This area contains some of the best-sampled and stratigraphically well-constrained terrestrial deposits in the world, and is ideal for studying causes of the K–Pg mass extinction and characteristics of the subsequent recovery. We assigned 61 humerus specimens to morphotypes, then quantitatively and qualitatively assessed taxonomic and body-size diversity through time. We find several key results. Taxonomically, our Lancial and Puercan samples record each of the major groups of mammals alive at that time (multituberculates, metatherians, and eutherians), but multituberculate postcrania predominate the samples. The Lancial sample has the most diverse multituberculate assemblage, and, among other taxa, includes a humerus of the largest Cretaceous metatherian, *Didelphodon vorax*. Eutherians, despite being known from the Lancial, are largely absent from our samples until the Puercan. Among these eutherians, we identified archaic ungulates (likely representing periphyctids and multiple arctocyonids, e.g., *Pratungulatum*), much larger mammals (possibly representing taeniodonts, trisodontids, or pantodonts), and a possible “plesiadapiform” primate. Additionally, the size of femur and humerus specimens implies a decrease in mean body size following the K–Pg mass extinction, and a subsequent increase in the mid-late Puercan (Pu2/3), a trend that is supported by the dental record. Maximum size for both elements is small for Lancial and early Puercan (Pu1) samples, but greatly increases in the mid-late Puercan, with multiple specimens suggestive of body sizes an order of magnitude larger than the next largest specimens in the study. However, mean specimen size in the Pu2/3 is smaller than in the Lancial due to a preponderance of very small multituberculate specimens and a lack of mid-sized mammal postcrania. Future work will continue to analyze these and other elements to compare taxonomic and body-size diversity patterns to those derived from the dental record, and to assess locomotor inferences for these mammal communities before and after the K–Pg mass extinction.

### Modern North American Benthic Foraminifera Feel the Heat

Keating-Bitonti, Caitlin, Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305; Payne, Jonathan L., Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305

Organism size within and among species commonly varies systematically across depth and latitude within the ocean, but the limiting environmental parameter or combination of parameters controlling these size gradients remain poorly understood. A particular challenge is the covariation among many potentially controlling parameters, such as temperature, dissolved oxygen concentration, and particulate organic carbon (POC) flux. Benthic foraminifera, a diverse group of amoeboid protists possessing reticulose pseudopods, are an ideal study group for identifying the controls on organism size. They occur in all marine environments, from coastal estuarine settings to the deepest ocean trenches, thereby providing an unparalleled opportunity to study the controls on organism size across multiple environmental regimes.

### Deep-Sea Biodiversity Response to Abrupt Climate Changes for the Last 20,000 Years

Yasuhara, Moriaki, School of Biological Sciences, Swire Institute of Marine Science, and Department of Earth Environmental Sciences, University of Hong Kong, Hong Kong SAR, China 94305; Payne, Jonathan L., Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305

High-resolution records of microfossil assemblages from deep-sea sediment cores covering the last 20,000 years in the North Atlantic Ocean were investigated to understand biodiversity dynamics over decadal–centennial timescales. The results show pervasive control of deep-sea benthic species diversity by rapidly changing climate. Species diversity rapidly increased during abrupt stadial events during the last glacial and the Holocene interglacial periods. These included the well-known Heinrich 1, the Younger Dryas, and the 8.2 ka events when the strength of Atlantic Meridional Overturning Circulation (AMOC) decreased. In addition, there is evidence for quasi-cyclic changes in biodiversity at a ~1500-year periodicity. Statistical analyses revealed that AMOC-driven bottom-water temperature variability is a primary influence on deep-sea biodiversity. Our results based on the exceptionally highly resolved fossil records highlight possible pervasive, synchronous, and sudden ecosystem response to human-induced climate and ocean-circulation changes in this century.
gradients. Here we explore the oceanographic controls on cell size using test (shell) volumes measured from holotype illustrations in the Ellis and Messina Catalogue of Foraminifera. Biogeographic data come from Culver and Buzas’ compilation of foraminiferal occurrences along the North American continental margins of the Pacific and Atlantic Oceans, including the Caribbean Sea and Arctic Ocean. We compile environmental data on mean annual temperature, dissolved oxygen, salinity, and temperature seasonality from the National Oceanographic Data Center World Ocean Atlas 2009, calculate seawater carbonate saturation state of calcite from the Global Ocean Data Analysis Project and Carbon Dioxide in the Atlantic Ocean, and estimate POC flux from Lutz et al. (2007) primary productivity model. In total, we are able to match the water depth and geographic coordinates of over 12,000 low-Mg calcareous benthic foraminiferal occurrences spanning 80 degrees of latitude to test size and environmental data. In multiple regression analyses, we find that temperature is the best predictor of (log-transformed) test volume for calcareous benthic foraminifera, and that the strength of this inverse association is consistent across ocean basins. Based on AIC and BIC model selection criteria, the best model does not include any other environmental predictors. Larger size may be associated with lower temperatures due to a reduction in the relative costs of maintenance metabolism or the biomechanical benefits of larger size in colder, more viscous water. However, the majority of size variation within and among localities is unexplained by the six environmental parameters included in this study even though they are the parameters most widely hypothesized to influence size. The vast majority of cell-size variation in foraminifera must reflect other aspects of the local physical and biological environment that remain difficult to quantify.

Session 28-17: Monday, 3:45 PM
Presenter: Kirsty Edgar
‘BLEACHING’ OF PHOTOSYMBIONTS IN PLANKTIC FORAMINIFERA DURING THE MIDDLE EOCENE CLIMATIC OPTIMUM
Edgar, Kirsty M., School of Earth and Ocean Sciences, Cardiff University, CF10 3AT, UK; Bohaty, Stephen M., Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14 3ZH, UK; Gibbs, Samantha J., Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14 3ZH, UK; Sexton, Philip F., Centre for Earth, Planetary, Space and Astronomical Research, The Open University, MK7 6AA, UK; Norris, Richard D., Scripps Institution of Oceanography, University of California, San Diego, CA 92093; Wilson, Paul A., Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14 3ZH, UK
Planktic foraminifera are abundant and prolific producers of pelagic calcium carbonate in the modern oceans. Many genera are adapted to nutrient-poor (oligotrophic) surface waters by hosting photosynthetic symbionts, but it is unknown how they will respond to future changes in surface-ocean temperature, nutrient availability, and acidity. In a previous study, we showed that one of the dominant Eocene surface-dwelling genera, Acarinina, was temporarily (~100 kyr) ‘bleached’ during a transient global warming event—the Middle Eocene Climatic Optimum (MECO) approximately 40 million years ago (Ma). However, the pervasiveness of this phenomenon (spatially and between species) and the driving mechanism(s) remain uncertain. Here we utilize a suite of biological and geochemical tools from multiple deep-sea sites to evaluate the global response of multiple photosymbiont-bearing genera of planktic foraminifera to the MECO. Our data shed new light on the stability of host-symbiont interactions through geological time, the driving mechanisms of ecological change, and the implications of these changes on the reliability of geochemical proxy records generated from symbiont-bearing planktic foraminifera across short-lived environmental perturbations.

Session 28-18: Monday, 4:00 PM
Presenter: Samantha Gibbs
EXQUISITELY PRESERVED FOSSIL COCCOLITHOPHORES: A DAY IN THE LIFE OF ANCIENT PLANKTON
Gibbs, Samantha J., Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14 3ZH, UK; Bown, Paul R., Department of Earth Sciences, University College London, London, WC1E 6BT, UK
Coccolithophores are major pelagic carbonate producers and a critical component of oceanic ecosystems and biogeochemical cycles. The geological record contains a rich archive of exported coccolithophore populations that can inform our predictions of their response to current and near-future environmental change. However, to maximize the application of this record requires a shift towards a more cellular-level focus that allows closer comparison of fossils with living populations. Finding fossils that allow us to do this is challenging, but there are exceptional situations where the usual preservation bias is greatly reduced and we gain glimpses of more complete populations and their biological associations. This has been exemplified recently by a growing body of research emerging from drilling of Tanzanian sediments where calcifying plankton fossils are revealing hitherto unknown diversity, biological associations, and new environmental proxy records. The search for similar ‘exceptional’ microfossils has now extended our records to Bass River in New Jersey (onshore Ocean Drilling Program core), central California, and the Gulf Coast. We will present highlights from recent research that utilize these hemipelagic Paleogene sediments, targeting exquisitely preserved intact coccospheres that facilitate direct comparison between modern and fossil cells.
How do different preservational pathways influence the taphonomic bias of soft-bodied fossil deposits? Studying such questions can be difficult because it is unusual to find instances in the geologic record where the same original population of soft-bodied organisms is preserved by two different preservational pathways. It is rarer still for their numbers to be great enough to allow for robust and statistically sound comparisons. However, the Green River Formation of the Piceance Creek Basin in western Colorado provides a rare opportunity to study the exceptionally preserved, recalcitrant soft-bodied components of insects, such as their carapaces, wings, hairs, and even eye facets. Most fossiliferous beds throughout the basin contain insects preserved as carbonaceous compressions, as is seen at the Anvil Points site; however, at the Paleoburn site, insects are preserved as iron oxides. To investigate how differing preservational pathways affect the soft-bodied preservation of insect specimens, we studied insects from the Paleoburn and Anvil Points sites. Both the Paleoburn and Anvil Points sites are located within authigenic carbonate ‘marlstones’ of the Parachute Creek Member of the Green River Formation. Approximately 230 insects from the Paleoburn site and 400 insects from the Anvil Points site were taxonomically identified, measured for size, and scored for preservational quality. Quality was measured by counting the number of preserved legs and antennae, and by assigning ranks to the preservation state of the eyes, antennae, wings, heads, thorax, and abdomen. The majority of preserved insects at the Paleoburn are beetles (Coleoptera), whereas at Anvil Points there are approximately equal numbers of beetles and flies (Diptera). Although beetle elytra and insect abdomens are well-preserved at both sites, on the whole, carbonaceous compression insects show better preservational quality. At the Anvil Points site, for example, fine and delicate features, such as wing venation, leg and antennae segmentation, and body hairs are preserved much more frequently than at the Paleoburn. This difference in taphonomy is likely the result of secondary overgrowth of the Paleoburn insects by diagenetic iron oxides, as well as a primary taphonomic bias imparted by the mineralization process. Compared to the relatively direct translation of living organic matter to kerogen seen in carbonaceous compressions, the accumulation of sufficient ferrous iron and reduced sulfur (assuming a pyrite precursor for the iron oxide insects) should entail relatively extensive microbial activity, enough to begin degradation even of recalcitrant soft-bodied tissue.
Taphonomic processes distort patterns of variability that exist in living assemblages. For skeletal fossils, this most frequently involves fragmentation, pre-burial sorting, and time-averaging; for soft-bodied fossils, post-burial compression and secondary mineralization reduce morphological resolution. A strategy for identifying taphonomic lenses and their effects involves comparing specimens with various levels of preservational fidelity. We applied this strategy to study the ontogenetic allometry of the problematic Sphenothallus, which has been compared to cnidarians, algae, and worms. Sphenothallus consists of a lamellar, phosphatic tube with a pair of oppositely-situated longitudinal thickenings separated by weakly mineralized (if not entirely organic) membranes that are rarely preserved. In the Cambrian (Series 2) Shujingtou Formation of South China, beds with densely-packed Sphenothallus contain both skeletal and organic types of preservation. Organic parts were preserved through carbonaceous compression and early mineralization pathways. The frequency of specimens (>50%) conserving delicate features indicates that, while the organisms were transported a short distance before burial, they likely did not undergo significant reworking. The distribution of tube length was positively skewed, but longer specimens more often possessed their labile membranes, suggesting that rapid post-mortem burial was a prerequisite for large tubes and delicate features. Alternatively, the delicate membranes of larger specimens may have been more significantly biomineralized than in smaller specimens. Differential degrees of compression in and between specimens biased most measurements of Sphenothallus. Nonetheless, by combining the data sets obtained from both low- and high-fidelity specimens, we distinguished several overlooked trends in the growth of Sphenothallus relevant to interpretations of its affinities.
The rise of eukaryotes signifies one of the most evolutionarily influential transitions in the history of life, profoundly changing the biological landscape and paving the evolutionary road for the origin of complex multicellularity. Unfortunately, the reliable interpretation of the early fossil record of eukaryotes has been met by numerous roadblocks. Foremost of which is that distinguishable cytological characters of eukaryotic cells, such as membrane-bound organelles, may not demonstrate a high preservation potential, although numerous fossils exhibit cellular- and potentially subcellular-scale preservation. In such cases, debates on the nature and origin of intracellular inclusions (ICIs) have resulted largely in unsatisfying resolutions. Revisitation of discussions regarding the interpretation of nucleus-like features within phosphatized animal embryole-like fossils from the Ediacaran Doushantuo Formation have prompted a critical and comprehensive investigation of ICIs in some of the oldest indisputable eukaryote microfossils—the ornamented acritarchs Dictyosphaera delicata and Shuiyousphaeridium macroreticulatum from the Paleoproterozoic Ruyang Group of North China. Using a combination of electron microbeam characterization and quantitative approaches, our data suggest that, although the Ruyang acritarchs must have had nuclei when alive, their ICIs represent neither fossilized nuclei nor taphonomically condensed cytoplasm. We instead propose that these ICIs likely represent biologically contracted eukaryotic protoplasts, i.e., the consolidation of the nucleus, surrounding cytoplasm, and plasma membrane. There exists an important distinction between this model and the degradational contraction of prokaryotic cells within a mucoidal sheath, as was previously invoked to explain ICIs in the Neoproterozoic Bitter Springs microfossils. That is, our model instead implies that the contraction and consolidation of protoplasts, preserved as ICIs in the Ruyang acritarchs, were biologically programmed in vivo, likely as a response to adverse conditions in preparation for encystment. While the discovery of bona fide nuclei in ancient single-celled fossils would be a substantial landmark in our understanding of eukaryote evolution, processes that are capable of producing nuclei-mimicking structures necessitate comprehensive investigations to corroborate or invalidate organellic interpretations.

Session 29-15: Monday, 3:15 PM
Presenter: James R. Thomka

**TAPHONOMIC IMPLICATIONS OF GEOPETAL STRUCTURES AND PLATE DISRUPTION PATTERNS IN DIPLOPORITE ‘CYSTOIDS’ (ECHINODERMATA) FROM THE SILURIAN MASSIE FORMATION OF SOUTHEASTERN INDIANA**

**Thomka, James R.**, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; **Young, Allison L.**, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; **Bantel, Thomas E.**, Dry Dredgers, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; **Carlton E.**, University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Diploporite ‘cystoid’ echinoderms are locally abundant in the lower decimeter of the middle Silurian (Wenlock: Shenwoodian) Massie Formation at the New Point Stone quarry near Napoleon, southeastern Indiana. At this locality, diploporites are exceptionally preserved, typically occurring as uncrushed, articulated thecae with well-preserved surface details of thecal plates and diplopore morphologies. Nevertheless, few specimens are truly pristine; most display differential preservation of opposite sides of the theca, with one side (the ‘good side’) characterized by intact and undisturbed plating and the other side (the ‘bad side’) characterized by loss of plates, disruptions to plate circlets, or shifting along plate contacts. This has historically been interpreted as representing partial burial of thecae, allowing the upward-facing bad side to be damaged by biostratinomic processes, while the downward-facing good side was protected. Careful investigation of the distribution of postmortem encrusters, the characteristics of theca-filling sediment, and the nature of specific plate disruption patterns, however, revealed a more complex taphonomic history, in some cases directly contradicting the partial burial model. 41% of specimens are encrusted, with 32% having encrusters on the good side only. This indicates that the good side was not always, if ever, downward-facing. 36% of thecae contain internal geopetal structures, and there is only a 1% difference between good-side up and bad-side up preservation. 73% of specimens display plate disruption to only one side of the theca; however, two distinct types of disruptions can be recognized. Plate loss and jumbling of plates is associated with the upward-facing side of the theca, whereas shifting along plate contacts while maintaining proper position relative to other plates in the circlct is associated with the downward-facing side of the theca and appears to be compaction-related. Summarily, the taphonomic variability observed within the Napoleon quarry diploporite assemblage is not simply the result of differential exposure time in between partial burial and final burial. Rather, it is an expression of varying taphonomic pathways ranging from simple (death, then minor decay, then final burial) for the best-preserved specimens to variable and complex pathways involving death, minor decay, encrustation, reorientation, initial burial, cementation of theca-filling sediment, exhumation, partial burial, and final burial for more poorly preserved specimens. This study demonstrates the taphonomic complexity shown by a seemingly taphonomically uniform assemblage, highlights the significance of noting agreement or disagreement between internal and external geopetal indicators, stresses the value of documenting and interpreting specific plate disruption patterns in multi-element skeletons, and represents one of the first taphonomic studies of blastozoan echinoderms.

Session 29-16: Monday, 3:30 PM
Presenter: Dhurjati Prasad Sengupta

**TAPHONOMY OF MIDDLE TRIASSIC VERTEBRATE ACCUMULATION OF SAHAVAN, CENTRAL INDIA**

**Sengupta, Dhurjati Pr.**, Geological Studies Unit, Indian Statistical Institute, 203 Barrackpore Trunk Road, Kolkata,
An exceptionally fossil-rich site has been identified from the upper part of the Middle Triassic, fluvial and mud-dominated Denwa Formation of the Satpura Gondwana basin of Central India where at least 15 individuals of temnospondyl amphibians, mostly represented by their skulls, interclavicle, clavicle, mandibles, and postcranials, have been noted to occur in a jumbled-up situation forming stacks of fossil bones in a small area that is nearly 50 m long. 25 m wide and 8 m thick near a village called Sahavan. These fossils occur within sheet-like heterolithics, with fine sands and mud or silt forming millimeter to centimeter thick strata parallel to the basal bounding surfaces encased within thick, red, extrachannel mudstones. The vertebrate bone-bearing mud and heterolithics also have unionsids, and are nearly 5 to 7 m thick. They have intermittent calcareous layers at the bottom. There are at least three such layers, nearly 5 cm thick, and are charged with diamond-shaped scales and fish bones of uncertain biological affinities. In between, the fish-scale layers have 10 to 20 cm of heterolithics. The heterolithic sheet bodies are interpreted as crevasse splays, and the typical association of amphibians, fishes, and unionsids with wavy laminations in silstones indicate the presence of floodbasin ponds that acted as local watering holes for the aquatic to amphibious vertebrates. The presence of peloidal calcirudites of doral origin, and the rich layers of disintegrated fish skeletons and scales reflect periodic drying of the water holes. X-ray diffraction of the red mudstones shows the presence of montmorillonite, illite, mica, calcite, and kaolinite, which indicates a wide range of paleoclimate. Among the major oxides, sodium, potassium, and calcium oxides, and among the trace elements, lead, thorium, and uranium show slightly higher values in Sahavan fossil site compared to the other Triassic mudstones of different Gondwana basins of India. However, these results are minor aberrations, and overall the Triassic red mudstones and heterolithics of the major Gondwana basins of India show marked similarity of major oxides and trace elements proportions. Therefore, there is no geochemical anomaly responsible for the death of those animals. The presence of many juveniles in the Sahavan site indicates that the death events were not natural either. Hence periodic drying up of the water holes and death of the amphibians, fishes, and bivalves in time of arid spells could be a possible interpretation of the Sahavan fossil accumulation. There are reports from Amazon River where countless fishes and few crocodiles having superficial similarity with the temnospondyl body plans, are found to be dead and stacked in piles at the flood plains during successive droughts of 2005 and 2010. The Sahavan fossil site is a local and miniature analog of periodic aridity affecting the biota of a small waterhole present in the flood plain.

Session 29-17: Monday, 3:45 PM
Presenter: Christine A.M. France

**RAMAN SPECTROSCOPY AS A NON-DESTRUCTIVE METHOD FOR SCREENING COLLAGEN DIAGENESIS IN BONE**

France, Christine A.M., Smithsonian Museum Conservation Institute, Museum Support Center, 4210 Silver Hill Road, Suitland, MD 20746; Thomas, Daniel B., Smithsonian Institution, Department of Vertebrate Zoology, Division of Birds, PO Box 37012, MRC 116, Washington, DC 20013; Madden, Odile, Smithsonian Museum Conservation Institute, Museum Support Center, 4210 Silver Hill Road, Suitland, MD 20746

Obtaining well-preserved collagen from fossil bones is crucial for paleontological applications such as carbon-dating, stable isotope analyses, and proteomics. To date, determining collagen quality typically requires lengthy chemical procedures involving destruction of fossil bones, which ultimately may indicate a poorly preserved specimen that is unusable for additional analyses. This study examined Fourier transform (FT) Raman spectroscopy as a non-destructive method for determining collagen quality in bone. Collagen from several historic mammal bones was extracted and examined for preservation quality based on the well-established parameters of C:N ratios, weight % nitrogen yields, and total collagen yield. Bones categorized as well- and poorly-preserved using these elemental abundance criteria were examined with FT-Raman on outer surfaces and freshly cut cross-sections. Raman spectra were examined visually and using bivariate and multivariate statistics in an effort to produce an unambiguous numerical indicator distinguishing well- and poorly preserved collagen. A ratio of the 960 cm⁻¹ and 1636 cm⁻¹ peak heights from freshly cut cross-sections provided the most unambiguous distinction. FT-Raman spectra from bones with well-preserved collagen produced a 960 cm⁻¹:1636 cm⁻¹ ratio of 19.4 or less (after baseline correction). Changes in this ratio provide information regarding the relationship between the phosphate mineral and amino acid backbone of the collagen as the bone degrades. This mineral-to-collagen peak-height ratio was typically greater in poorly preserved samples because organic material is preferentially degraded during diagenesis. These criteria now can be used to accurately determine collagen quality in bones before sacrificing samples to further destructive chemical extractions. This method is especially valuable for isolating subsets of rare and valuable specimens likely to yield high quality results during carbon-dating and other organic chemical analyses.

Session 29-18: Monday, 4:00 PM
Presenter: Kelsey T. Stilson

**A NEW RESAMPLING METHOD FOR NORMALIZING SIZE-BASED TAPHONOMIC BIAS ACROSS FOSSIL ASSEMBLAGES**

Stilson, Kelsey T., The University of Texas at Austin, Jackson School of Geosciences, 2225 Speedway, Stop C1160, Austin, TX 78712; Davis, Edward Byrd, Geology Department, University of Oregon, Eugene, OR 97403; Hopkins, Samantha S.B., Geology Department, University of Oregon, Eugene, OR 97403

Recent paleocommunity studies have focused on building increasingly complex models to statistically separate biological signals from taphonomic bias. We were interested in developing a way to instead normalize samples with differing taphonomic biases, at least in terms of hydraulic sorting. We measured the greatest first three dimensions of every fossil in three Hemphillian-age Oregon localities...
(McKay Reservoir, Krebs Ranch II, and Westend Blowout; total n=4492). Each is a fluvial depositional system, so we treated the fossils as hydrodynamic particles. A principle-components analysis revealed that maximum length alone controlled the vast majority of the variance of the shape data. We also assigned each fossil a basic 3D shape and identified each fossil to the lowest taxon possible. These data gave us two ways to compare the three assemblages in terms of both particle shape dominance and relative abundance of taxa. Westend Blowout is the smallest of these samples, so we imposed the frequency distribution of lengths from this site onto the other two localities, using resampling methods to ‘fill’ and ‘cut’ the distributions until they were equivalent to Westend Blowout. Through both direct comparisons of relative abundances and chord-distance analysis, we found that the other two localities, when constrained by the smallest distribution, were less similar than would be expected by chance. This result is consistent with Shotwell’s paleoecological conclusions about differences between these sites, but exciting because we use an approach that explicitly considers the physical properties of the fossils, rather than only their preservational associations.
The Paratethyan basins were a chain of only partly connected basins extending from the western Alpine foreland through the Alpine-Carpathian to the Caspian area. The Paratethyan basins were formed by the orogenic movements in Oligocene, and resulted in changing of marine, brackish, and freshwater sedimentation depending on local conditions and global sea-level changes (Rögl and Steininger, 1983; Rögl, 1998; Popov et al., 2004). The Badenian Carpathian Foredeep was a peripheral foreland basin in the northwest Central Paratethys developed at the European plate margin due to Carpathian accretionary wedge overthrusting and deep subsurface loading. The Badenian oyster samples analyzed come from the Badenian Carpathian Foredeep in Moravia their comparison with other types of Badenian organic buildups (algal or bryozoan bioherms). The Carpathian Foredeep belonged to the Paratethys, a large intracontinental sea transformed from the northern branch of Western Tethys due to the orogenic movements in Oligocene, and formed by a chain of only partly connected basins extending from western Alpine foreland through the Alpine-Carpathian region up to the Caspian area. The Paratethyan basins were frequently connected with the Mediterranean, the Indo-Pacific, and the Atlantic, but periodically also isolated, which resulted in changing of marine, brackish, and freshwater sedimentation depending on local conditions and global sea-level changes (Rögl and Steininger, 1983; Rögl, 1998; Popov et al., 2004). The Badenian Carpathian Foredeep was a peripheral foreland basin in the northwest Central Paratethys developed at the European plate margin due to Carpathian accretionary wedge overthrusting and deep subsurface loading. The Badenian oyster samples analyzed come from different Olomouc region localities (Czech Republic) and adjacent areas, the most important being Hluchov, Laškov, Lulec, Myslejovice, and the historical Slatinky. The most common oysters assemblage is represented by: Crassostrea gryphoides, Hyotissa squarrosa, Neopycnodonte navicularis, Ostrea edulis, Ostrea gingensis, Ostrea lamellosa, Ostrea cf. fimbriata, Ostrea sp. Practically all the studied specimens manifest intensive bioerosion and bioencrustation traces caused typically by barnacles, sponges, bryozoans, worms, gastropods, and bivalves. These organisms have affected the oysters, highlighting structures and furrows along the entire extension of their shells. We can observe reticular, channel-shaped and punctate structures, referable to Entobia, Gastrochaenolites, and Maaenedriopolydora.
taphonomic point of view, these phenomena often indicate, especially in Slatinky sandpit, the life positions of the valves. For the Neogene outcrops, very abundant oyster accumulations with large shells of *Crassostrea gryphoides* are mentioned in the literature (Harzhauser et al., 2003; Hosgör, 2008; Gramigna et al., 2008; Schultz and Piller, 2005). After Jimenez et al. (1991), in the past, *Crassostrea* banks developed basinward of coral reefs, very different from actual style of life, in shallow-intertidal to shallow seawater with lowered salinity. These communities are generally relatively very poor in species in dependence on environmental conditions (water depth, water dynamics, light, aeration, salinity).

In recent years, interest in avian paleontology has increased substantially, with a large number of articles being published on phylogenetic relationships, taxonomic classification, and discoveries of new species. In contrast, relatively little inquiry has addressed avian taphonomy and paleoecology, even though understanding the roles of depositional environment, paleoclimate, and other ecological factors in the preservation of avian bones is central to developing proper interpretations of the fossil record. In 2010, we undertook a review of 128 peer-reviewed publications in an effort to identify taphonomic trends affecting the avian fossil record. We have recently reviewed an additional 119 publications from reference lists generated by the Paleobiology Database and report here the updated findings. The compiled 247 publications describe avian fossils dating from the Early Cretaceous to the Recent, and indicate that the majority of specimens (53%) represent siliciclastic depositional environments, particularly shallow marine and lacustrine settings. Loose wing bones (40.7%) and leg bones (33.5%) are the most commonly preserved skeletal elements. Articulated skeletons comprise only 1.0% of the total number of reported bone fossils, and are found significantly more frequently (Chi-Square Test, P=0.001) in siliciclastic environments than in carbonate, mixed carbonate-siliciclastic, or environments of unknown lithology. The majority of avian fossils are recovered from formations that were deposited during warm-temperate (43%) and subtropical (20%) climatic conditions, although climate was rarely considered as a taphonomic factor by authors of the publications. Also, the age and sex of fossil specimens were considered in only 7.8% of the papers. The reports noting age and/or sex did not relate either factor to quality of bone preservation. Based on experimental studies we have conducted, the results of which are published elsewhere, it appears that age and sex may strongly impact the preservation potential of some avian bones. Although the most famous bird fossil, *Archaeopteryx*, was found in the tropical carbonate lagoon environment of the Jurassic Solnhofen limestone, this review indicates that the real avian fossil record is archived in warm-temperate to subtropical siliciclastic localities, chiefly of shallow-marine and lacustrine settings. Only a small percentage of the specimens are articulated; most of the record is based on wing and leg bones, suggesting a taphonomic bias against the preservation of avian remains. Several taphonomic factors, from predation to hydrologic sorting to metabolic and reproductive aspects unique to birds, may be responsible for this trend. Our review highlights the need for more detailed taphonomic analyses of avian specimens in both fossil assemblages and in modern experimental investigations to identify sources of preservation bias.

**Session 31-Poster 54: Monday, 4:45 PM**

**Presenter: Eleanor E. Gardner**

**PRESERVATION BIAS IN THE AVIAN FOSSIL RECORD: A REVIEW AND UPDATE**

**Gardner, Eleanor E.,** Department of Agriculture, Geosciences, and Natural Resources, University of Tennessee at Martin, 256 Brehm Hall, Martin, TN 38238; **Walker, Sally E.,** Department of Geology, University of Georgia, 210 Field Street, Athens, GA 30602

In recent years, interest in avian paleontology has increased substantially, with a large number of articles being published on phylogenetic relationships, taxonomic classification, and discoveries of new species. In contrast, relatively little inquiry has addressed avian taphonomy and paleoecology, even though understanding the roles of depositional environment, paleoclimate, and other ecological factors in the preservation of avian bones is central to developing proper interpretations of the fossil record. In 2010, we undertook a review of 128 peer-reviewed publications in an effort to identify taphonomic trends affecting the avian fossil record. We have recently reviewed an additional 119 publications from reference lists generated by the Paleobiology Database and report here the updated findings. The compiled 247 publications describe avian fossils dating from the Early Cretaceous to the Recent, and indicate that the majority of specimens (53%) represent siliciclastic depositional environments, particularly shallow marine and lacustrine settings. Loose wing bones (40.7%) and leg bones (33.5%) are the most commonly preserved skeletal elements. Articulated skeletons comprise only 1.0% of the total number of reported bone fossils, and are found significantly more frequently (Chi-Square Test, P=0.001) in siliciclastic environments than in carbonate, mixed carbonate-siliciclastic, or environments of unknown lithology. The majority of avian fossils are recovered from formations that were deposited during warm-temperate (43%) and subtropical (20%) climatic conditions, although climate was rarely considered as a taphonomic factor by authors of the publications. Also, the age and sex of fossil specimens were considered in only 7.8% of the papers. The reports noting age and/or sex did not relate either factor to quality of bone preservation. Based on experimental studies we have conducted, the results of which are published elsewhere, it appears that age and sex may strongly impact the preservation potential of some avian bones. Although the most famous bird fossil, *Archaeopteryx*, was found in the tropical carbonate lagoon environment of the Jurassic Solnhofen limestone, this review indicates that the real avian fossil record is archived in warm-temperate to subtropical siliciclastic localities, chiefly of shallow-marine and lacustrine settings. Only a small percentage of the specimens are articulated; most of the record is based on wing and leg bones, suggesting a taphonomic bias against the preservation of avian remains. Several taphonomic factors, from predation to hydrologic sorting to metabolic and reproductive aspects unique to birds, may be responsible for this trend. Our review highlights the need for more detailed taphonomic analyses of avian specimens in both fossil assemblages and in modern experimental investigations to identify sources of preservation bias.

**Session 31-Poster 55: Monday, 4:45 PM**

**Presenter: Victoria E. McCoy**

**DISTRIBUTION OF FOSSILIFEROUS CONCRETIONS AT THE MAZON CREEK FOSSIL SITE**

**McCoy, Victoria E.,** Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, CT 06511; **Dolak, David,** Science and Mathematics, Columbia College, 600 S. Michigan Ave., Chicago, IL 60605; **Briggs, Derek E.G.,** Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, CT 06511

The Mazon Creek (Illinois, USA) fossil site has been widely studied as an example of a well-preserved record of a Late Carboniferous deltaic ecosystem encompassing freshwater to brackish environments. The fossils are typically preserved inside sideritic concretions, most commonly collected as float from coal mine spoil piles and along riverbeds after weathering out of the primary outcrop, the Francis Creek Shale member of the Carbondale Formation. The biota preserved in the fossiliferous concretions have studied extensively for over 150 years, leading to a strong understanding of the Carboniferous paleoenvironment of the area. However, little work has been done to document the spatial and temporal distribution of concretions within the outcrops. For this study three sites with exposed Mazon Creek outcrops (Higgins, Kodat, and Kost farms) were visited. At each site, the composition, contents, and importantly, the position of each in-situ concretion was mapped and correlated within the (up to) four distinct horizons spaced between 5–30 cm vertically, visible at each outcrop (max. 8–10m of shale with inter-bedded sandstone lenses). Each of the three outcrop sites exhibit a different pattern of fossil abundance and preservation quality. The freshwater biota sites range from approximately 25% of concretions containing only poorly preserved plant fossils (Higgins) to nearly 70% of concretions at the Kodat site containing primarily well preserved plants and soft-bodied animals such as insects and arachnids. The Kost site, representing a brackish deposit, had the lowest percentage of fossiliferous concretions (12%) preserving mostly amorphous blobs, remnants of soft-bodied organisms. In addition, within each site, the fossil abundance and mineral composition (percentage of siderite and pyrite as cementation agents) of the concretions varied between the concretion horizons. To obtain a better understanding of regional fossil abundance in Mazon Creek concretions, specimens collected from two
proximate mine-spoil sites (the brackish Pit 11 and the freshwater Cooper’s Pit) are also considered, as these sites yielded much larger numbers of specimens providing a basis for statistical comparison, even though, as non in-situ locations, they cannot contribute data to correlate concretionary horizons. The patterns represented by the data suggest that: 1) in general, the closer a site is to the zone of the assumed paleoenvironment salinity transition, fossils are more abundant and better preserved; 2) concretion formation and fossilization appear to result from discrete, isolated depositional events that provided an influx of mineral-rich precursor fluids to the deposited sediments, which then interact with a source of organic material; and 3) fossil abundance and preservation quality can vary greatly across a small temporal range even when concretions may not appear to be significantly different.

Session 31-Poster 56: Monday, 4:45 PM
Presenter: Robert Salazar

PREPARATION OF SUBFOSSIL IVORY: CASE STUDY OF MAMMUT-AMERICANUM

Salazar, Robert, Earth and Planetary Sciences, Santa Barbara City College, 721 Cliff Dr, Santa Barbara, CA 93109; Maybee, Michele, Earth and Planetary Sciences, Santa Barbara City College, 721 Cliff Dr, Santa Barbara, CA 93109

Ivory’s high organic content and hygroscopic nature renders it especially vulnerable to fragmentation in arid environments. In particular, subfossil ivory from Mammuthus columbi, Mammuthus exilis, and Mammut americanum from the marine terraces of southwest California and the Channel Islands are often fragmented beyond current preparatory efforts. Through the development of novel preparatory techniques, we strive to restore structural integrity to subfossil ivory tusks so they may become available for researchers, artists, and exhibition. Subfossil ivory is different from permineralized bone in how it is worked and the unique physical properties it exhibits. Properties unique to subfossil ivory include its light-sensitive coloration, luster, relative softness, and sensitivity to temperature and humidity. While durable and homogenous in life, tusks fracture in three differing anatomies. These analyses allow for comparison of preservation between differing Anomalocaris anatomies.

CAN STABLE ISOTOPES IN FOSSIL MARINE ARTHROPODS SERVE AS PALEOECOLOGICAL INDICATORS?

Vrazo, Matthew B., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Crowley, Brooke E., Departments of Geology and Anthropology, University of Cincinnati, Cincinnati, OH; 45221; Dieffenb, Aaron E., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Brett, Carlton E., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

Modern arthropod chitin yields stable isotopic signatures of carbon and nitrogen that reflect diet source (i.e., marine vs. terrestrial) and trophic level. Chitin has been shown to be resistant to degradation in experiments on freshwater and marine arthropods, and can remain relatively unaltered in
Cenozoic-age material. This biomolecule therefore has great potential as a tool for understanding paleoecological conditions in fossil arthropods from both marine and terrestrial settings, but chitin isotope geochemistry has yet to be utilized fully in paleoecological studies. Stable isotope values from insect cuticle have been used to a limited extent in terrestrial paleoenvironment and fossil ecosystem reconstruction; however, no equivalent studies have been carried out on fossil marine arthropods. Here, we present the first study to test the presence of biogenic stable isotope signatures from a variety of marine decapods ranging in age from Cretaceous to sub-Recent. Modern congeners or confamilials of the fossil taxa were chosen for comparison based on inhabitance of similar environments and trophic levels. Prior to stable isotope analysis, we purified samples by removing all inorganic carbonates and most proteins from both modern and fossil exoskeletons. Preliminary results indicate that most fossils have undergone a significant loss of organic exoskeletal carbon and nitrogen, and contain only fractional quantities in comparison to their modern counterparts (as seen in previous studies). This loss appears to occur relatively quickly in normal marine settings as non-lithified subfossil material (less than a few hundred years old) contains little or no original organic carbon, and only minimal amounts of nitrogen, despite appearing pristine in many cases. Carbon and nitrogen stable isotope values for many fossil specimens also indicate alteration, presumably due to bacterial fractionation or diagenesis. However, somewhat surprisingly, specimens of Pleistocene, Miocene, and even Cretaceous age yield carbon and nitrogen stable isotope values that are directly comparable to those in their modern counterparts from similar depositional environments. Multiple fossil individuals from the same taxa and locality also yield similar stable isotope values, with a degree of variability similar to that seen in modern conspecifics. We discuss the possibility that these are biogenic rather than diageneric signatures, and consider that stable C and N isotopes values in fossil cuticle may be a viable source of paleoecological information. Further testing of specimens from single localities will aid in determining whether or not isotopic signatures in fossil arthropods can be used in marine ecosystem reconstruction.

Session 31-Poster 59: Monday, 4:45 PM
Presenter: Lane A. Wallett

CHRONIC LAMINITIS: PALEOPATHOLOGY OF THE UNGUAL PHALANX OF *Equus* AS A TAPHONOMIC CONSIDERATION

---

Session No. 32: Stratigraphic paleobiology: Integrating sedimentary and fossil records (poster session)

Monday Afternoon 4:45 PM to 5:45 PM

Session 32-Poster 60: Monday, 4:45 PM
Presenter: Garett M. Brown

UNDERSTANDING THE MARINE BIODIVERSITY AND PALEOECOLOGY OF THE EARLY MIocene CHIPOLA FORMATION OF NORTHERN FLORIDA
The lower Miocene Chipola Formation (~18.9 Ma) is a fossiliferous, near-shore marine unit exposed in Calhoun and Liberty counties, Florida. Previous studies of the Chipola Formation have identified over 1000 species making this unit one of the most biologically diverse fossil assemblages found along the Gulf Coastal Plain. In spite of this, relatively little attention has been given to examining this unit’s faunal distribution patterns, its paleoenvironmental setting, or how its fauna compares to similar, younger fossil assemblages in Florida in terms of paleoecology and diversity. Therefore, this study examines the faunal and paleoecological composition of the lower Miocene Chipola Formation using samples collected from reef-associated localities (i.e., Cooter Bluff and the Cooter Bluff Reef Site) and more open-shelf facies (i.e., Alum Bluff and Farley Creek). Bulk samples from each locality were screened using -2.0 and 0.0 phi sieve sizes. Specimens were identified to species level and assigned to their respective ecological guilds. Faunal data were statistically analyzed in PAST 2.17c using rarefaction and detrended correspondence analysis (DCA). These data are then compared with younger Pliocene and Pleistocene molluscan faunal data from peninsular Florida to understand how the diversity of shallow-marine settings in the Gulf of Mexico changed throughout this interval. Our results show that the lowest diversity levels are affiliated with the reef-associated fauna at the Cooter Bluff Reef Site, moderate diversity is associated with the open-shelf sites, and the highest diversity is found at the back-reef deposits of Cooter Bluff. The high diversity of the back-reef deposits may be the result of taphonomy as the bulk samples collected from there had a greater ratio of shelly material to matrix than the other localities. All of the localities had comparable evenness, with the exception of the Cooter Bluff Reef Site. Species richness and evenness of the Chipola Formation was compared to that of the Pliocene Pinecrest Beds (its closest analogue in terms of overall diversity in regards to number of species) and the Pleistocene Bermond Formation. These comparisons show that the Chipola Formation fauna had a moderate diversity with high species evenness.

**Session 32-Poster 61: Monday, 4:45 PM**

**Presenter: Katherine V. Bulinski**

**Evaluating the Use of Ecospace Utilization Analysis in Fine-Scale Paleoecological Studies**

Bulinski, Katherine V., School of Environmental Studies, Bellarmine College, 2001 Newburg Rd, Louisville KY 40205

In some cases, paleoecological studies are conducted using a very fine-scale stratigraphic resolution, occasionally on as small as a decimeter or centimeter scale. When attempting to characterize the biodiversity structure within such fine-scale sampling, it is common to use multiple analytical techniques to fully illustrate patterns of ecological change through time. Calculations of evenness or richness are useful and straightforward measurements of biodiversity. These metrics work well in fine-scaled studies, but only measure a singular aspect of diversity. Detrended Correspondence Analysis is also useful for examining how communities vary according to ecological gradients over a fine stratigraphic scale, but this kind of analysis involves summarizing a stratigraphic layer or sample with a singular value along an axis of variation, thus not retaining information about the nature of the community structure. The use of assessments of ecospace utilization allows for a measure of how the number and diversity of the paleoecological roles of organisms (i.e., modes of life: tiering, feeding, and motility) change through time or through space (Bush et al., 2007). In this way, ecospace utilization analysis generates a fuller picture of how the organisms present are distributed and what the functional diversity of the community is according to the occupied modes of life. This study investigates the degree to which ecospace utilization varies across a range of stratigraphic scales. These analyses involve determining whether the total number of modes of life exhibit direct or predictable relationships with other assessments of biodiversity, such as richness and evenness, even at a fine scale. Alternatively, these analyses may reveal that patchiness or taphonomic biases may dampen or even remove any meaningful ecological pattern at very fine stratigraphic scales. The data used to examine these relationships originates from the extensively studied Late Ordovician (type Cincinnatian) fossil communities of Kentucky, Indiana, and Ohio. The use of highly fossiliferous and finely sampled stratigraphic intervals provides an idealized dataset for this kind of analysis. This study will test the limitations of ecospace utilization analysis for fine-scale ecological analysis and provide recommendations of the sampling scale necessary for characterizing a full ecological signal.

**Session 32-Poster 62: Monday, 4:45 PM**

**Presenter: Chelsea Jenkins**

**Initiation of Provincality Across Laurentia During the Ordovician**

Jenkins, Chelsea E., Department of Geology, University of Georgia, 210 Field Street, Athens, GA 30602; Holland, Steven M., Department of Geology, University of Georgia, 210 Field Street, Athens, GA 30602

Biogeographic provinces are well-developed in the Late Ordovician of Laurentia, and have been documented previously for several groups, including conodonts, corals, and bryozoans. Four provinces have been recognized: Appalachian, Southern (Cincinnati Arch and Nashville), Midcontinent (Missouri, upper Mississippi valley, Michigan, to western Pennsylvania and New York), and Western (New Mexico, Colorado, Wyoming, Alaska, and most of Canada). These provinces correspond to geochemically distinct water masses based on carbon and neodymium isotopic analysis of carbonates and phosphates. They also have distinct relative abundance distributions as indicated by analyses of Hubbell’s theta. The geographic distribution of these provinces suggests a causal connection to the Taconic Orogeny, and we test whether the origination of these provinces is consistent with a Taconic trigger. Specifically, we test whether these four provincial areas can be recognized during three divisions of the Ordovician (Early, Middle, and Late), with the Late Ordovician corresponding to the Taconic Orogeny. We use data for all phyla from the Paleobiology Database. We limit our analyses to the shallow subtidal, one of the most widely represented environments, to avoid differences in available sedimentary environments from complicating the signal of provinciality. We contrast intraprovence and interprovence
similarity by mean pairwise Jaccard coefficient of collections converted to presence-absence data. We also use cluster analysis (agglomerative nesting, Ward's method) to identify spatial patterns in similarity of collections. Through the Ordovician, values of intraprovince (Jaccard coefficients of .02 to .17, with one province at .42 in the Late Ordovician), and interprovince (.02 to .16) similarity overlap, indicating little support for these provinces. Cluster analyses of the Early and Middle Ordovician support a lack of provinciality, with most collections in North America belonging to one large cluster. A few isolated regions have distinctive compositions, but these appear to be largely driven by monographic effects. In the Late Ordovician, collections from one large cluster are also distributed broadly across Laurentia, but many collections from the Southern Province form a separate cluster. These results are consistent with the Taconic Orogeny and its regional environmental effects being a primary cause for the formation of biogeographic provinces in the Ordovician of Laurentia. It appears that the overlap of intraprovince and intraprovience similarity values, even in the Late Ordovician, is driven partly by the use of presence-absence data, and that relative abundance data would better show the distinctiveness of Late Ordovician provinces and might reveal more subtle faunal differentiation across Laurentia in the Early and Middle Ordovician.

Session 32-Poster 63: Monday, 4:45 PM
Presenter: Sharon K. McMullen

**CONTROLS ON THE STRATIGRAPHIC DISTRIBUTION OF NON-MARINE FOSSILS: A CASE STUDY IN THE UPPER JURASSIC MORRISON FORMATION, WESTERN USA**

McMullen, Sharon K., Department of Geosciences, University of Wisconsin-Madison, Madison, WI 53706

Sequence stratigraphic architecture is known to influence the spatiotemporal distribution and quality of fossil preservation in shallow-marine settings. The extent to which stratigraphic architecture influences distribution and preservation of fossils in non-marine settings has not been well-studied. This study combines stratigraphic analyses of a large foreland-basin alluvial system with paleontological and taphonomic data to determine relative importance of rate of accommodation-space formation, base-level change, sediment supply, fluvial geomorphology, and architectural element preservation in governing fossil preservation. Fossil occurrences include invertebrates, vertebrates, and plant material, and are analyzed at both the outcrop and basin scale to determine relationships. The non-marine Late Jurassic Morrison Formation is well-exposed in the western United States, has been well-studied in many regards, and is renowned for well-preserved and abundant vertebrates. The Morrison Formation also contains a distinctive trend of increasing fossil abundance throughout time. Along the Colorado Plateau, three stratigraphic members characterize the roughly 10 m.y. of deposition for the Morrison: the Tidwell, Salt Wash, and Brushy Basin. In the Paleobiology Database, the basal member, Tidwell, contains one fossil occurrence, the middle member, Salt Wash, contains 25 fossil occurrences, and the uppermost member, Brushy Basin, has 140 recorded fossil collections. This trend is echoed throughout the Morrison Formation, including areas where the Morrison is informally divided into a lower and upper member. Seven stratigraphic sections were measured and described from the Morrison Formation: four along the Colorado Plateau in southwestern Colorado and southeastern Utah and three in north-central Wyoming. Sites targeted areas near or at known vertebrate fossil localities, with the exception of one site on the Colorado Plateau that has been prospected with little to no success. This latter locality is meant to act as a possible explanation for the lack of fossils in some areas to help understand spatial distribution of fossils. These data are combined with previously published stratigraphic sections and fossil data from the PaleoBiology database to characterize large-scale temporal and spatial changes in fossil distribution in an alluvial setting. Additional stratigraphic sections will be measured and described for this study as needed.

Session 32-Poster 64: Monday, 4:45 PM
Presenter: Mostafa Hamad

**PLANKTOMATIC FORAMINIFERAL BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE MIOCENE SEQUENCE IN THE AREA BETWEEN WADI GHARANDAL AND BIR HALEFIYA, GULF OF SUEZ REGION, EGYPT**

Hamad, Mostafa, Geology Department, Cairo University, Cairo, Egypt

An integrated biostratigraphical analysis based on the planktonic and larger foraminifera from three surface sections in the area between Gharandal and Bir Halefiya, Gulf of Suez region, Egypt, namely Wadi Gharandal, Gebel Zeita, and Bir Halefiya sections, provides a well-defined zonal scheme of the Miocene successions in the study area. Lithostratigraphically, the Miocene sequence could be differentiated into four rock units representing shallow- and deep-marine facies. These are from base to top as follows: Nukhul, Rudeis, Kareem formations (Gharandal Group), and Belayim Formation (Ras Malaab Group). The examination of the studied samples has led to the identification of 44 planktonic foraminiferal species belonging to 12 genera. The preserved planktonic foraminifera through the studied sections range from good to moderately well diversified, and enabled biostratigraphic zonation of the Miocene sequence. On the basis of the vertical stratigraphic distribution of the planktonic foraminiferal species, the studied sections could be subdivided into six planktonic foraminiferal biozones following the Mediterranean (MMi) zonal schemes, from base to top as follows: 1) Globigerinoides primordius Zone (MMi 1; early Miocene, Aquitanian); 2) Globigerinoides altiaperturus–Catapsydrax dissimilis Zone (MMi 2b); 3) Globigerinoides tribobus Zone (MMi 3; early Miocene, Burdigalian); 4) Preorbivalina glomerosa s.l. Zone (MMi 4); 5) Orbulina suturalis–Globorotalia folki peripheroronda Zone (MMi 5; middle Miocene, Langhian); and 6) Globoratalia siakensis Zone (MMi 6; middle Miocene Serravallian). The lower/middle Miocene boundary is defined by the first occurrence (FO) of Preorbivalina glomerosa and is discussed within the text. Two larger foraminiferal zones were recognized in the studied successions (Wadi Gharandal and Bir Halefiya sections), from base to top, SB 24 Zone in the Aquitanian and SB 25
Zone in the Burdigalian, according to the European shallow benthic foraminiferal zonation (SBZ). By integrating the established foraminiferal zonal schemes, the stratigraphical ranges of some larger foraminifers with planktonic foraminiferal zones have been calibrated. According to the integrated zonation, Miogypsina burdigalensis, Miogypsina intermedia, and Borelis curdica first occur in the MMi 2b Subzone, whereas Nephrolepidina spp. last occurs within the same subzone. Two chronostatigraphic units are detected. The older unit is represented by the early Miocene, and the overlying unit is middle Miocene.

Session No. 33: Digitization in vertebrate paleobiology (poster session)
Monday Afternoon 4:45 PM to 5:45 PM

Presenter: Johanset Orihuela

**ENDOCRANIAL MORPHOLOGY OF THE EXTINCT ANTILEAN SHREW NESOPHONTES (LIPOTYPHLA: NESOPHONTIDAE) FROM NATURAL AND DIGITAL ENDOCASTS OF CUBAN TAXA**

Orihuela, Johanset, Department of Earth and Environment, Florida International University, Miami, FL 33199

The behavior of the extinct Antillean shrew Nesophontes was investigated in several species with endocranial casts. Its endocranial morphology was based on natural and digital endocranial casts extracted from Cuban specimens. The casts show developed olfactory lobes without accessory bulbs, an exposed tectum with visible superior colliculi, a large cerebellum and vermis, and a smooth neocortex. The body mass was estimated from the skull size to be between 97 and 114 g, yielding encephalization quotients between 0.52 and 0.57. Endocranial casts of Nesophontes are morphologically similar to those of Solenodon (a much larger Caribbean shrew), more so than to other lipotyphlans such as Sorex, Blarina, Erinaceus, or the African Tenrec. The morphological similarity of Nesophontes to Solenodon, not only in endocranial structures but also in the rest of the skeleton, suggests analogous behaviors and ecologies. The marked superior colliculi, prominent olfactory lobes, and facial musculoskeletal anatomy suggest that Nesophontes was most likely nocturnal and fossorial, relying on hearing, smell, and tactualy to forage. Future analysis of the appendicular skeleton can help determine if this genus was solely terrestrial, or if it exploited arboreal habitats as well. The sum of the morphological features in these species can help us understand the behavior with respect to the great morphological variation that is observed in the genus.

Session No. 34: Celebrating public participation in paleontology (poster session)
Monday Afternoon 4:45 PM to 5:45 PM

Presenter: Daniel Snyder

**‘HORSE COLLARS’ ARE FOR BALANCING? THE FUNCTION OF AN ENIGMATIC DEVONIAN FOSSIL REEXAMINED WITH 3D VISUALIZATION**

Hegna, Thomas A., Department of Geology, Western Illinois University, 115A Tillman Hall, 1 University Circle, Macomb, IL 61455; Snyder, Daniel, Department of Science and Engineering, Middle Georgia State College, Dublin, GA, 31021

Gluteus minimus is a small, enigmatic fossil with a composition largely of apatite. Descriptively referred to as “Horse Collars”, they are known only from the Devonian of Iowa. The type specimen was reexamined using micro-CT scan technology. Internal visualization revealed a high degree of ordered layering and a lack of vascularization. The fossils have a high degree of bilateral similarity, but are not truly bilaterally symmetrical. We suggest that Gluteus was part of a balancing organ (i.e., otolith or statolith) in some as yet unidentified free-swimming animal, based on the presence of a single lateral primordium, or core, and nonsymmetric growth layers. The homology of the primordium cannot be resolved conclusively because a number of groups of modern animals have similar mineralized balancing organs. Living animals that have relatively large stato/otoliths (millimeter- to centimeter-scale) with ordered layering include fish and cephalopods. However, ‘balancing stones’ in these taxa are usually calcium carbonate and show strong lateralization. The observed presence of phosphate and fluorine in Gluteus is explained by diagenetic replacing—the same pattern is exhibited in gastropods from the same locality. Additionally, there are living counter-examples to bilateral symmetry between lateralized otoliths, notably in pleurodontiform flatfish (i.e., flounders) and deepwater lanternfish (i.e., anglerfish).

Session 33-Poster 66: Monday, 4:45 PM

Presenter: Daniel Snyder

**FUNCTION OF AN ENIGMATIC DEVONIAN FOSSIL REEXAMINED WITH 3D VISUALIZATION**

Hegna, Thomas A., Department of Geology, Western Illinois University, 115A Tillman Hall, 1 University Circle, Macomb, IL 61455; Snyder, Daniel, Department of Science and Engineering, Middle Georgia State College, Dublin, GA, 31021

Gluteus minimus is a small, enigmatic fossil with a composition largely of apatite. Descriptively referred to as “Horse Collars”, they are known only from the Devonian of Iowa. The type specimen was reexamined using micro-CT scan technology. Internal visualization revealed a high degree of ordered layering and a lack of vascularization. The fossils have a high degree of bilateral similarity, but are not truly bilaterally symmetrical. We suggest that Gluteus was part of a balancing organ (i.e., otolith or statolith) in some as yet unidentified free-swimming animal, based on the presence of a single lateral primordium, or core, and nonsymmetric growth layers. The homology of the primordium cannot be resolved conclusively because a number of groups of modern animals have similar mineralized balancing organs. Living animals that have relatively large stato/otoliths (millimeter- to centimeter-scale) with ordered layering include fish and cephalopods. However, ‘balancing stones’ in these taxa are usually calcium carbonate and show strong lateralization. The observed presence of phosphate and fluorine in Gluteus is explained by diagenetic replacing—the same pattern is exhibited in gastropods from the same locality. Additionally, there are living counter-examples to bilateral symmetry between lateralized otoliths, notably in pleurodontiform flatfish (i.e., flounders) and deepwater lanternfish (i.e., anglerfish).

Session 34-Poster 67: Monday, 4:45 PM

Presenter: Michael Guberek

**THE ANZA BORREGO DESERT STATE PARK PALEONTOLOGY SOCIETY: FORTY YEARS OF VOLUNTEER SUPPORT IN FIELD, PREPARATION, AND CURATION ACTIVITIES.**

Guberek, Michael P., Anza Borrego Desert State Park, Paleontology Society, 200 Palm Canyon Drive, Borrego Springs, CA 92004; Jefferson, George T., Anza Borrego Desert State Park, Paleontologist Emeritus, 200 Palm Canyon Drive, Borrego Springs, CA 92004; Murray, Lyndon K.,
Anza Borrego Desert State Park, District Paleontologist, 200 Palm Canyon Drive, Borrego Springs, CA 92004

The Anza Borrego Desert State Park Paleontology Society is a local organization of volunteers dedicated since 1993 to support the State Park’s activities in education, field collection of fossils, laboratory preparation, collection curation, and educational outreach under the direction of the Park’s District Paleontologist. Its membership of one hundred amateur paleontologists contribute 11,000 hours per year to survey the fossiliferous beds within the 600,000 acre park, and to prepare and curate the recovered specimens. Membership is very diverse, including elementary-school students and nonagenarians, the struggling underemployed and the comfortably retired, the self-taught jack-of-all-trades and the academic or professional specialist. Members are required to complete a certification process under the guidance of the Park’s professional staff to insure proper handling of the fossils. The mandatory Certification Program is a varied, comprehensive, and constantly improving curriculum, including 160 hours of instruction. Many other educational opportunities exist for interested volunteers, such as attending local and international meetings and workshops, field trips and expeditions, membership in professional organizations, participation in research projects, and formal and informal course work at colleges and universities. Additionally, the members contribute in a variety of ancillary activities including database management, GPS mapping, comparative specimen preparation, website maintenance, newsletter production, mineralogical analysis, photography, fundraising, publication preparation, and public outreach. The Park’s badlands contain a record of changing environments and habitats extending from the Miocene into the Pleistocene Epoch and from the Hemphillian through the Rancholabrean NALMAs. More than 550 types of now-extinct fossil plants and animals are present in the collections, which contain over 16,000 vertebrate and 14,000 invertebrate specimens. In addition to the collections, the Park operates a laboratory, offices, and a library in the Stout Research Center, where the Paleontology Society carries out its tasks.

Session 34-Poster 68: Monday, 4:45 PM
Presenter: Jack Kallmeyer

HEIRS TO THE ‘CINCINNATI SCHOOL OF PALEONTOLOGY’: OVER 70 YEARS OF SCIENTIFIC CONTRIBUTIONS FROM THE CINCINNATI DRY DREDGERS

Hartshorn, Kyle R., Dry Dredgers, Inc., Department of Geology, University of Cincinnati, Cincinnati, OH 45221; Kallmeyer, Jack W., Dry Dredgers, Inc., Department of Geology, University of Cincinnati, Cincinnati, OH 45221; Heimbrock, William P., Dry Dredgers, Inc., Department of Geology, University of Cincinnati, Cincinnati, OH 45221; Bantel, Thomas E., Dry Dredgers, Inc., Department of Geology, University of Cincinnati, Cincinnati, OH 45221

The highly fossiliferous Late Ordovician rocks of the Cincinnati Arch have long inspired geologists, professional and amateur alike. The Cincinnati Dry Dredgers was officially established in 1942 as an association of amateur paleontologists. The group was formed following a series of public lectures and field trips held by the University of Cincinnati in the late 1930s, and maintains close ties with the University Of Cincinnati Department Of Geology. This long and mutually beneficial relationship has resulted in important contributions to the Late Ordovician and lower Silurian paleontology of Ohio, Kentucky, and Indiana, reviewed herein. Dry Dredgers members have coauthored papers involving trilobite paleoecology, crinoid morphology and systematics, mollusk taphonomy, and cornulitid paleoecology. The group has provided important specimens, locality recommendations, and field assistance for numerous researchers, both within and beyond Cincinnati, and the Dry Dredgers Paleontological Research Award has provided monetary support for over 20 research projects. Counted among our members are two recipients of the Paleontological Society’s Strimple Award, and one recipient of the Paleontological Research Institution’s Katherine Palmer Award. In addition, Dry Dredgers take an active role in promoting good practices in amateur paleontology, and the organization provides educational outreach through regular meetings, field trips, fossil identification events, museum exhibits, school visits, and an informative website. The group is a crucial middle ground between the lay public and the earth-science professional, ideally placed for introducing concepts of deep time, evolution, extinction, stratigraphy, and taxonomy. Paleontologists associated with the Dry Dredgers recognize the positive impact amateur collectors can have on public education and advanced research.

Session 34-Poster 69: Monday, 4:45 PM
Presenter: Daniel Krisher

ROCHESTER ACADEMY OF SCIENCE FOSSIL SECTION—AN EXAMPLE OF CITIZEN SCIENTISTS AND THEIR ROLE IN PALEONTOLOGY

Krisher, Daniel L., Rochester Academy of Science, Fossil Section, P.O. Box 92642, Rochester, NY 14692

Amateurs have always had an important place in the field of paleontology. Before paleontology existed as a recognized profession, amateurs and naturalists were responsible for many significant finds. The amateur’s role continues today in the form of fossil clubs. The Rochester Academy of Science is a professional society that has been promoting interest and education in the natural sciences since 1881. In 1984, the Genesee Valley Fossil Club merged with the Academy to become the Fossil Section. Members of the Section range from arm-chair enthusiasts to professional paleontologists and geologists, with the bulk of the membership falling in the middle. Several of our members are active and published researchers who collaborate with professionals. A major goal for the Section is community education and outreach, which includes participation in the Rochester Museum and Science Center’s Science Saturdays, Science Education Days at St. John Fisher College, and presence at other public events. Section members also lead numerous field trips for interested members of the public as well as for classes from local school systems. In most cases, the activities and trips hosted by the Section represent the closest the public gets to fossils and the field of paleontology. Over the years, the Section has built good relations with paleontology professors and graduate students within New York State and in the region. Section members are also active participants in the New York State Geological Association, and activities hosted by the
Paleontological Research Institution in Ithaca. Access to collecting sites is problematical owing to our current litigation-prone environment. The Section strives to build good relationships with those responsible for a specific locality, whether they are the landowner or an organization responsible for the care of the site. All too often, the landowner or organization has had bad experiences with irresponsible and undisciplined collectors. The Section has actively tried to repair these relationships so a site is not lost to future researchers and amateurs. In the end, educated, responsible amateurs can contribute greatly to the field of paleontology. In today's era of tight budgets and funding restrictions, the amateur is likely to spend considerably more time in the field than many paleontology professionals. A dedicated, educated amateur can serve as the eyes for the professional who cannot make it into the field. The amateur can also serve as an educator so the importance and relevancy of paleontology is conveyed to the public.

Session 34-Poster 70: Monday, 4:45 PM
Presenter: Paul R. Roth III

EDUCATIONAL OUTREACH BY AVOCATIONAL PALEONTOLOGISTS AND CITIZEN SCIENTIST FOR NATIONAL FOSSIL DAY - JUNIOR PALEONTOLOGIST EDUCATIONAL KITS
Roth III, Paul R., Florida Paleontological Society, P.O. Box 117800, University of Florida, Gainesville, FL 32611; Kittle, Talk Brown, Russell D., Florida Fossil Hunters, P.O. Box 540404, Orlando, FL 32854

In the summer of 2012, members of the Florida Paleontological Society (FPS) and Florida Geological Foundation (FGF) assembled two Junior Paleontologist Kits for the National Park Service. The kits were first used by the Castillo de San Marcos National Monument during their celebration of National Fossil Day, “Fossils at the Fort,” October 17, 2012. The two kits were then sent to the National Park Service Washington Bureau, where the kits have been used in local school programs in Washington, D.C., and surrounding states. Each kit is designed to complement the Junior Paleontologist Program and to showcase the many paleontological resources in our National Parks. Contributions by FPS, FGF, and the Florida Fossil Hunters (FFH) show how avocational paleontologists and citizen scientists can make contributions to public education through collaboration and outreach. This has enabled three new kits to be assembled in 2013. These kits will be distributed to the Castillo de San Marcos National Monument, the Timucuan Ecological and Historic Preserve, and the Canaveral National Seashore, to be utilized in their Junior Ranger programs on National Fossil Day and throughout the year. The ultimate goal is to distribute a kit to all of the National Park units (current total 10) within the state of Florida.

Session No. 35: Critical paleobiological transitions in Earth history: The value of multidisciplinary approaches (poster session)

Monday Afternoon 4:45 PM to 5:45 PM

Session 35-Poster 71: Monday, 4:45 PM
Presenter: Sarah Carmichael

ISLAND ARCS IN THE CENTRAL ASIAN OROGENIC BELT: IMPLICATIONS FOR LATE DEVONIAN OCEAN ANOXIA
Carmichael, Sarah K., Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Waters, Johnny A., Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; DeReuil, Aubry A., Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112; Moore, L. McCain, Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Batchelor, Cameron J., Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Sanchez, Sonia, Department of Geology, Appalachian State University, ASU Box 32067, Boone, NC 28608; Suttner, Thomas J., Department of Geology, University of Graz, 8010 Graz, Heinrichstraße 26, Austria; Kido, Erika, Department of Geology, University of Graz, 8010 Graz, Heinrichstraße 26, Austria

The Late Devonian Zhulumute, Hongguleleng and Heishantou Formations in northwestern Xinjiang, China, contain the Frasnian–Famennian (F–F) boundary and the Devonian–Carboniferous (D–C) boundary in a highly fossiliferous shallow marine setting. The Kellwasser Ocean Anoxia Event below the F–F boundary is present in the Hongguleleng and underlying Zhulumute Formations, and the Hangenberg Ocean Anoxia Event is present at the D–C boundary in the Heishantou Formation. Both the Kellwasser and Hangenberg Events are evident via multiproxy geochemical evidence rather than the visible black shales commonly associated with these intervals. The source of the sediments that comprise these units and the continuity of sedimentation across the boundary intervals have long been debated for these units. The lowermost Zhulumute Formation is a poorly cemented, poorly sorted sandstone with trachytic basalt pebbles and subbedal albite grains in an illite or illite/chlorite matrix. The cements are variable in composition and amount, and are composed of calcite, quartz, or tianite. The Hongguleleng Formation represents a deepening sequence, and grades into intercalated siltstones and limestones containing storm deposits. There is no evidence for an unconformity at the Zhulumute–Hongguleleng contact or at the F–F boundary. The Heishantou Formation is primarily composed of siltstones with a base of intercalated siltstones and limestones. There is likewise no evidence for an unconformity at the D–C boundary. The lack of significant detrital quartz in the Zhulumute Formation, in combination with the lack of luminescence in the quartz silt in the Hongguleleng Formation, indicates that the silt is not derived from mature continental material but is authigenic in origin,
which is consistent with increases in primary productivity during and immediately after anoxia events. 87Sr/86Sr isotope data are consistent with models for groundwater interaction with immature basalts. Regional tectonic models place the Zhulumute, Hongguleleng, and Heishantou Formations on a Late Devonian island arc, indicating deposition in an open ocean. This interpretation is confirmed by U/Th ratios, petrologic, sedimentological, and 87Sr/86Sr isotope data, which are consistent with a juvenile island-arc basalt as a detrital sediment source for the Zhulumute, Hongguleleng, and Heishantou Formations. The presence of the Kellwasser and Hangenberg Events in these sequences indicates that ocean anoxia occurred in the shallow open ocean of the Paleotethys, and not only along the shallow continental margins of the closing Rheic Ocean. This suggests that the Kellwasser and Hangenberg Events are inconsistent with the model of deep-water spillover onto continental shelves during sea-level rise, calling into question the basic model of deep-water spillover onto continental shelves.

Session 35-Poster 72: Monday, 4:45 PM
Presenter: Roger W. Cooper

A MULTIDISCIPLINARY ANALYSIS OF THE UNIQUE IRON-RICH TURONIAN–CONIACIAN BOUNDARY INTERVAL (~3.16M THICK) WITHIN THE BOQUILLAS FORMATION, BIG BEND REGION, TX, THAT INCLUDES THE ALLOCRIOCERAS HAZZARDI ZONE

Cooper, Dee A., Non-vertebrate Paleontology, Jackson School of Geosciences, The University of Texas at Austin, 225 Speedway, Stop C1160, Austin, TX 78712 Cooper, Roger W., Department of Earth and Space Science, Lamar University, Beaumont, TX, 77710

The Turonian–Coniacian boundary interval in the southern Big Bend region of Texas is defined by a distinctive iron-bearing lithostratigraphic interval (~3.16m thick) that includes the unique ~1.27m biostratigraphic interval formally recognized as the Allocriceras hazzardi Zone (so named for the diagnostic, loosely coiled, slightly helical heteromorph ammonite exclusive to this Zone). This Late Cretaceous isochronous stratigraphic marker unit was mapped, described, analyzed, and sampled throughout the eastern part of Big Bend National Park and near Terlingua/Study Butte and Lajitas, TX. The iron-rich interval is easily recognized as a distinctive brown-colored stripe within the otherwise pale gray-to-buff Boquillas Formation. It consists of quartz-bearing calcarenites and red clay. The four indurated ledges of the A. hazzardi Zone (~1.27m thick) are included within this iron-rich interval, and are characterized by a macrofauna assemblage zone dominated by heteromorph ammonites (Baculites sp; A. hazzardi; and Scaphites semicostatus, in order of abundance). Other identified macrofauna within the zone include Cremnoceramus deformis erectus, For sterea sp., Belemnite sp.; Didymotis variabilis; Cerithiid sp.; Laminospindylus transversus; and Teleost sp. The ledges of the A. hazzardi Zone consist of shells and shell fragments, disseminated quartz, disseminated pyrite and pyrite nodules, silt and clay-size particles of quartz and calcium carbonate with intervening brownish carbonate mud layers. The iron-rich interval and associated macrofauna represent the environment that developed at the peak regression in the Big Bend region prior to the transgression associated with OAE3. Overlying stratigraphic rock units (alternating massive limestone/chalk/maar and carbonate mud) are related to OAE3 (~88.6–83.5 Ma) in the Western Interior Seaway. Underlying rock units (alternating massive limestone and carbonate mud) within the Boquillas Formation represent the overall regression in the region after OAE2 (~93.5 Ma). Analysis of both the iron-bearing lithostratigraphic interval and the fauna of the Allocriceras hazzardi Zone encompassing an area of more than 1,800 sq. km (~700 sq. miles) has resulted in a regional reinterpretation of the paleoenviromental conditions and geographical constraints present in the southern Big Bend region of Texas ~88.6Ma.

Session 35-Poster 73: Monday, 4:45 PM
Presenter: Katherine Cummings

EVIDENCE FOR A DIVERSE TERRESTRIAL ECOSYSTEM IN THE 1.1 GA MIDCONTINENT RIFT

Cummings, Katherine E., Interdisciplinary Ecology, University of Florida, Gainesville, FL 32611; Bjornrud, Marcia G., Geology, Lawrence University, Appleton, WI, 54911

The ~1.1 Ga Copper Harbor Formation includes conglomerates, sandstones, and some finer-grained rocks representing alluvial fan, braided stream, and ephemeral lake environments within the axial valley of the Midcontinent Rift. This high-energy terrestrial environment would seem an unlikely setting for Mesoproterozoic life, but calcified lacustrine stromatolites have long been recognized in the upper part of the Copper Harbor Fm. Recently, we have discovered other types of biogenic structures in the Copper Harbor Fm., including cm-scale sand domes and siltstone rip-up chips, both indicative of widespread microbial mats, as well as some enigmatic, geometrically distinctive macroscopic features that may represent eukaryotic body fossils. The features were found on the underside of bedding surfaces of a siltstone between two stromatolitic horizons at Horseshoe Harbor, Michigan. In plan view, the features are circular to elliptical and 0.3–1.0 cm in diameter. Many have a transecting lenticular element that creates a ‘theta’ geometry, laying at random orientations in the slabs. In cross-section, the features are funnel-shaped, narrowing upwards to a blunt tip marked in some specimens by a mm-scale crystal of calcite. Calcite also cements the fine-grained material inside the features. Petrographic and XRD analyses indicate that the rest of the interior material is fine quartz and feldspar plus minor clay (halloysite) and iron oxide, as found in the surrounding rock. SEM images of the material inside and outside the features show no obvious differences in grain size or texture. These features are unlikely any common sedimentary or diagenetic structures. They are too large to have been formed by single prokaryotes, and their consistent geometry seems improbable for colonies of individuals. If they are biogenic, they most likely represent either body or trace fossils of eukaryotes, perhaps heterotrophs that were living off the underlying buried and decomposing stromatolites. Marine eukaryotes were diverse by Mesoproterozoic time, but there are few reports of terrestrial eukaryotes of this age. The Copper Harbor stromatolites indicate that in spite of a high-energy environment, there was an active lacustrine ecosystem in the valley of the
Midcontinent Rift at 1.1 Ga. The stromatolites, sand domes, mat chips, and body fossils considered together may point to a greater degree of terrestrial biodiversity than previously recognized in the Midcontinent Rift during the Mesoproterozoic.

Session 35-Poster 74: Monday, 4:45 PM
Presenter: Dennis R. Ruez, Jr.

ECOLOGICAL STRESS IN THE EVOLUTION OF FOSSIL HOMINIDS IN SOUTH AFRICA

Ruez, Jr., Dennis R., Environmental Studies, University of Illinois at Springfield, Springfield, IL 62703

The hominid fossils of Die Kelders Cave 1, South Africa, are of great interest to paleoanthropologists because they occur in discrete stratigraphic intervals and include the transition into anatomically-modern humans. Moreover, the deposits contain several hundred thousand identified mammalian fossils that yield insights to the interaction of fossil hominids and their environments. The entire mammalian fauna from Die Kelders Cave 1 was analyzed to determine whether the ecological position (based on body mass) of fossil hominids shifted with the derived behavioral change associated with the transition into anatomically-modern humans. Body-masses of mammals in an ecosystem are distributed discontinuously in clumps (Holling's textural discontinuity hypothesis), rather than spread evenly. The gaps between body-mass clusters were calculated using a split moving-window analysis. The body-mass clusters for the Die Kelders Cave 1 faunas changed in number, boundary values, and taxonomic composition. However, the positions of the fossil hominids were static, consistently occurring near the upper boundary of a cluster. Modern herptiles, birds, and mammals that fall on the edges of these clusters have been suggested as more subject to extirpation. If similar conclusions are applicable to Die Kelders Cave 1, southern African hominids may have evolved into anatomically modern humans in response to this ecological stress.
Ediacaran environments and ecosystems

Chairs: Lidya Tarhan and Marc Laflamme
Tuesday Morning 8:00 AM to 12:15 PM

Session 36-1: Tuesday, 8:00 AM

Presenter: Paul Myrow (Invited Keynote)

ROLE OF PALEOENVIRONMENTAL INTERPRETATION FOR ANALYSIS OF EDIACARAN FAUNAS

Myrow, Paul M., Geology, Colorado College, 14 East Cache La Poudre St., Colorado Springs, CO 80903

The stratigraphic distribution, biological affinities, and paleoecology of Ediacaran faunas have been a subject of considerable debate, in part due to the status of these faunas as the first metazoan organisms. Both the timing and nature of processes that led to the appearance and disappearance of these biotas is controversial. The role of preservational processes, specifically the opening and closing of a taphonomic window, is an important parameter to explain their stratigraphic distribution. Taphonomic factors include a number of biological aspects of a changing biosphere during the terminal Proterozoic to Cambrian transition. These include the material properties of Ediacaran bodies, their acoelomate body plans, and the timing of onset of typical Phanerozoic processes such as bioturbation, scavenging, and predation. Taphonomic processes, biological evolution, and ethological changes all took place within a rapidly evolving Earth surface environment. This included significant changes within the atmosphere and ocean surface waters, particularly increased oxygenation, as well as a global plate-tectonic reorganization. Feedbacks between these various biological, geological, atmospheric, and oceanic processes are poorly understood. Paleoenvironmental controls were certainly of paramount importance, yet high-resolution process-oriented sedimentological interpretations are generally lacking in Ediacaran-fossil-bearing strata. In any particular location, biological and taphonomic processes were affected by environmental conditions, which limited the spatial distribution of organisms, controlled the diversity and paleoecology of the fauna, determined whether the fauna were preserved, and led to a wide array of preservation styles. Work to date indicates that even within specific field areas (e.g., Australia), Ediacaran fossils are preserved in multiple facies and sequence-stratigraphic settings. Fossils are found in a wide variety of siliciclastic lithologies, including a wide range of grain sizes up to coarse-grained sandstone. In most cases, the presence of a microbial mat is inferred, although the diagenetic pathways that led to preservation, including possible precipitation of iron compounds, are not fully understood. Globally, the range of ancient depositional settings is broad, and includes shoreline to deep-sea paleoenvironments. Although terrestrial environments are invoked for Ediacaran faunas, there is little direct process-oriented sedimentological data to support non-marine paleoenvironmental interpretations.

Session 36-2: Tuesday, 8:30 AM

Presenter: Gregory J. Retallack

PALEOSOLS AND PALEOENVIRONMENTS OF THE EDIACARAN (565 MA) MISTAKEN POINT FORMATION, NEWFOUNDLAND

Retallack, Gregory J., Department of Geological Sciences, University of Oregon, Eugene, OR 97403

Ediacaran (565 Ma) fossils of Newfoundland, Canada, have been considered preserved by deep-sea turbidites and contourites. However, past geochemical analysis of their matrix has found high C/S ratios of freshwater and low highly reactive to total iron characteristic of soils and floodplains. Past geochronology and geological mapping have shown that the Mistaken Point Formation was deposited on granitic continental crust of an andesitic forearc basin. This study of polished slabs of individual fossiliferous beds was unable to find graded beds of turbidites or nodules and lags of contourites in the Mistaken Point Formation. A few unfossiliferous beds show soft-sediment deformation and large-clast shale breccia, and can be interpreted as seismites. Some other unfossiliferous beds show hummocky cross-stratification and shale lags, comparable with tempestites. Volcanic crystal and lapilli tuffs from subaerial eruptions onto the fossiliferous surfaces fail to show grading, and have oversize clasts scattered in fine-grained matrix. These, as well as block and ash flows, volcanic spindle bombs, and gas-escape structures, are evidence of tuffs deposited on land, not filtering down through several kilometers of deep ocean. Sandy beds of the Mistaken Point Formation have sharp tops, not grading into overlying purplish-red clayey siltstones, comparable with tsunamiite sands overlain by tidal flat and floodplain sediments of convergent continental margins. The purplish-red clayey siltstones with drab-mottled upper surfaces are interpreted as interseismic paleosols with concave grain size profiles due to limited surficial clay formation, top-down destruction of lamination by mottles, cracks and filaments, loessic textures (mainly silt grains from top to bottom), surface gleization, physical shrinkage, and base cation depletion characteristic of hydrolysis, and sessile frond fossils in life position on desiccated 'old-elephant-skin' textured surfaces. The Mistaken Point biota (565 Ma) was thus not a deep-sea community of suspension-feeding animals, but terrestrial to marginal-marine communities of lichens, other fungi, and microbial colonies in cool temperate humid coastal plains and tidal flats. Uncritical identification of turbidites in the Mistaken Point Formation has preempted consideration of alternative bed-scale models such as seismites, tempestites, tsunamiites, tuffs, and paleosols.
common in continental convergent-margin forearc basins.

Session 36-3: Tuesday, 8:45 AM  
Presenter: Jack J. Matthews  

**THE LATERAL CONTINUITY OF EDIACARAN FOSSIL SURFACES: IMPLICATIONS FOR TAPHONOMY AND PALEOECOLOGY**  
Matthews, Jack J., Department of Earth Sciences, University of Oxford, S. Parks Rd, Oxford, Oxfordshire, OX1 3AN, UK; Brasier, Martin D., Department of Earth Sciences, University of Cambridge, Downing St, Cambridge, Cambridgeshire, CB2 3EQ, UK; Liu, Alexander G., Department of Earth Sciences, University of Cambridge, Downing St, Cambridge, Cambridgeshire, CB2 3EQ, UK; DiMichele, W. A., Department of Earth Sciences, University of Oxford, S. Parks Rd, Oxford, Oxfordshire, OX1 3AN, UK; Narbonne, Guy M., Geological Sciences and Geological Engineering, Queen's University, Kingston, ON, Canada; Droser, Mary L., Geological Sciences and Geological Engineering, Queen's University, Kingston, ON, Canada; O'Brien, Sean J., Geological Survey of Newfoundland and Labrador, Newfoundland and Labrador Department of Natural Resources, St. John's, NL, Canada

The Mistaken Point Ecological Reserve (MPER) in Newfoundland records abundant macrofossils of late Ediacaran age, documenting the initial evolution of complex multicellular communities within a marine siliciclastic succession. Detailed sedimentological and stratigraphic mapping within the MPER demonstrates that several important fossil surfaces outcrop at multiple locations. The lateral extent of these surfaces, in excess of 8 km, indicates that deep marine Ediacaran macrofossil communities were not geographically restricted to localized habitats, as was predicted by some previous ecological models. Importantly, the observed paleontological assemblages at each locality can show considerable variation in taxonomic composition and fossil densities. We explain the extent to which these differences result from original ecological variability, and predicted by some previous ecological models. Importantly, the observed paleontological assemblages at each locality can show considerable variation in taxonomic composition and fossil densities. We explain the extent to which these differences result from original ecological variability, and later taphonomic processes. The insights gained from this study reveal several critical biases that influence interpretation of Ediacaran fossil assemblages. Consideration of these factors will lead to more rigorous and robust interpretation of paleobiology in the important Ediacaran–Cambrian transition.

Session 36-4: Tuesday, 9:00 AM  
Presenter: Sara J. Mason  

**DEEP-MARINE EDIACARAN FOSSIL-BEARING FORMATIONS OF THE BONA VISTA PENINSULA, NEWFOUNDLAND**  
Mason, Sara J., Chemical and Physical Sciences, University of Toronto Mississauga, Mississauga, ON, Canada; Narbonne, Guy M., Geological Sciences and Geological Engineering, Queen's University, Kingston, ON, Canada; Dalrymple, Robert W., Geological Sciences and Geological Engineering, Queen's University, Kingston, ON, Canada; O'Brien, Sean J., Geological Survey of Newfoundland and Labrador, Newfoundland and Labrador Department of Natural Resources, St. John's, NL, Canada

Within the last decade, Ediacaran fossils from Newfoundland's Bonavista Peninsula, exposed in a small dome (about 5 km diameter) near the town of Catalina, have been discovered and described. The strata in which these fossils are found have been correlated with the Conception and St. John's groups of the adjacent Avalon Peninsula, famous for the Mistaken Point assemblage of early complex macrofossils. Detailed sedimentological study of the Catalina Dome allows for comparison with previous paleoenvironmental analyses of correlative Avalon Peninsula stratigraphy to constrain further the nature of the basin in which the Ediacaran biota evolved. The absence of sedimentary structures indicating wave influence or exposure in a succession of hundreds of meters of stacked turbidites reaffirms previous interpretations that the succession formed in a deep-marine environment. It is dominated by mudstone-rich turbidites with abundant beds of volcanic ash. Soft-sediment deformation occurs throughout the succession, folded vertically due to seismicity lower in the succession, and folded horizontally by gravity-driven slumping toward the top. This change records a transition from a no-slope basin plane to a slope environment. Thick-bedded mudstone turbidites in the lower third of the succession are consistent with a previous interpretation that turbidite ponding may have occurred due to a topographic high to the east. A particularly sandstone-rich 94 m-thick interval not present in the Avalon succession may have been deposited in a turbidite channel. Compared to equivalent strata on the Avalon Peninsula, ash is more abundant in the Catalina Dome, with thicker beds and persistence of ash deposition to higher stratigraphic levels, likely due to a position closer to the volcanic arc to the west. Because the ash provides the mechanism for preservation of soft-bodied biota, and fossil assemblages are similar between the base and the top of the succession, it has previously been observed that this succession extends the stratigraphic range of the Mistaken Point biota. The occurrence of complex frond fossils beneath ash beds at this stratigraphic level, as well as surfaces with only the controversial discoid taxon *Aspidella*, which is similar to what is observed in equivalent strata on the Avalon Peninsula, supports interpretation of *Aspidella* as the holdfast of otherwise unpreserved frondose organisms. Previous workers studying the Conception and St. John's groups on the Avalon Peninsula recorded a shift in turbidite paleocurrent direction from roughly eastward to southward, consistent with the existing tectonic model for the basin: a transition from convergence to strike-slip. However, the paleocurrent change occurs at a different stratigraphic level in each area, which suggests significant diachronity in this transition.

Session 36-5: Tuesday, 9:15 AM  
Presenter: Mary Droser  

**UPSIDE-DOWN RIPPLES AND OTHER ANACTUALISTIC SEDIMENTARY STRUCTURES OF THE EDIACARAN**  
Droser, Mary L., Department of Earth Sciences, University of California, Riverside, Riverside, CA 92521; Gehling, James G., South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia; Dzaugis, Mary E., School of Oceanography, University of Rhode Island, Narragansett, RI 02882

It is generally recognized that microbial mats were widespread in the Precambrian. Preserved organic structures and surfaces on beds are relatively well-known; these are referred to as microbially induced sedimentary structures (MISS) for those structures which are definitively microbial in origin (Nofke, 2009), and textured organic surfaces (TOS) for surfaces with a diverse assemblage of structures that may have discrete morphological characters but commonly do not
have a defined shape or size that might enable taxonomic description. Typically, these structures either partially or completely cover bedding surfaces and include eukaryote and metazoan remains in addition to microbial mats (Gehling and Droser, 2009). However, the overall, commonly subtle, sedimentological and stratigraphic impact of these widespread mats has not been explored. The National Heritage Ediacara fossil site at Nilpena, in the Flinders Ranges of South Australia, holds the key for understanding the environmental relationships and taphonomic windows responsible for the Ediacara Biota. Well-known fossils of the Ediacara Member, including Dickinssonia, Spriggina, Parvancorina, Tribrichidium, and other taxa typical of the White Sea Association from Russia, occur abundantly on the base of rippled, thin-bedded medium-grained quartz sandstones representing deposition in shallow-marine settings between fairweather and storm wavebase. The rich fossil assemblages of these facies represent benthic communities typically smothered by sand deposited by waning storm surges. This facies is distributed throughout the spatial extent of the Rawnsley, and is the most common type of fossil preservation of within the Ediacara Member. Widespread mats had three main impacts on this sedimentological record. Most strikingly, not only are fossils cast on the base of beds, but ripples are also consistently cast on the base of beds. That is, as sand smothered the community and the mat surface, the rippled-topped substrate upon which the organisms were living was not only not destroyed, but was, in fact, commonly perfectly cast by the smothering sand. This is related to the second impact that is the lack of basal erosion surfaces. Thirdly, the Ediacara Member is replete with what are referred to as “shims.” These are extremely thin sand beds, ranging in thickness from a few sand grains to a few millimeters. They are discontinuous, but square meters of these shims can be excavated. In the case of shims, the organic surface served as a separator. The result of this is that within a two-centimeter thick section, up to 16 thin beds and shims (all of the same grain size) can be delineated and individually excavated. The nature of this sedimentological record is distinctly the result of mat-covered surfaces. The Phanerozoic equivalent would likely be a decimeter-thick amalgamated ripple-laminated sandstone with no recognizable breaks.

Session 36-6: Tuesday, 9:30 AM
Presenter: Alexander Liu

GIANT SULFUR BACTERIA AS A SIGNIFICANT COMPONENT OF LATE EDIACARAN BENTHIC ECOSYSTEMS

Liu, Alexander G., Department of Earth Sciences, University of Cambridge, Downing St, Cambridge, Cambridgeshire, CB2 3EQ, UK; Matthews, Jack J., Department of Earth Sciences, University of Oxford, S. Parks Rd, Oxford, Oxfordshire, OX1 3AN, UK

The biological affinities of late Ediacaran macrofossils have been the subject of much discussion in recent years, but a growing consensus amongst researchers is that they may include early stem- and crown-group metazoans. Testing such phylogenetic hypotheses via studies into the morphology and paleoecology of Ediacaran macrofossils has, at many localities, been hampered by the low preservational fidelity of the fossil surfaces. We describe a newly discovered assemblage of Ediacaran macrofossils from Newfoundland, Canada, which exhibits remarkable preservation of a diverse benthic marine ecosystem. The assemblage includes abundant specimens of ‘typical’ late Ediacaran macroorganisms, including rangeomorph taxa, many of which reveal exceptionally preserved morphological features. In addition to these, the preservational fidelity of the surface is high enough to record an extensive biogenic filamentous fabric, a feature not previously recognized in Avalonian depositional environments. The filamentous impressions have since been identified on numerous bedding planes in the region, and appear to have densely carpeted the deep marine seafloor during the late Ediacaran period. Observation of the bedding-plane relationships between macrofossils and filaments presents a rare opportunity to study the interactions between typical Ediacaran macroorganisms and contemporaneous biological components within their ecosystems. We demonstrate that the filamentous impressions are abundant and widespread within the late Ediacaran successions of Newfoundland, and that they possess strong morphological similarities to extant communities of giant sulfur bacteria. This finding has interesting implications for our views of the seawater chemistry of late Ediacaran deep-marine environments, and thus for the tolerance of Ediacaran macroorganisms to ambient environmental conditions.

Session 36-7: Tuesday, 9:45 AM
Presenter: Lidya Tarhan

TAPHONOMY AND MORPHOLOGY OF THE EDIACARAN FORM GENUS ASPIDELLA (EDIACARA MEMBER, RAWNSLEY QUARTZITE, SOUTH AUSTRALIA)

Tarhan, Lidya G., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521; Droser, Mary L., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521; Gehling, James G., South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia; Dragois, Matthew P., School of Marine Science, University of Texas Marine Science Institute, 750 Channel View Dr, Port Aransas, TX, 78373

Aspidella, the disk-like Ediacaran form genus, is a common and globally distributed member of the Ediacara Biota. In South Australia, it occurs prolifically (n>1000) in locally dense assemblages on the bases of siliciclastic beds in the eponymous Ediacara Member of the Rawnsley Quartzite. Association with stalks, fronds, and textured organic surfaces (TOS) has led to the interpretation of Aspidella as the holdfast of a frondose, Chariniodiscus-like organism that lived with its holdfast secured within or under a sandy microbial mat, and its stalk and frond protruding above the substrate and into the water column. Excavation and sequential reassembly of 26 fossiliferous beds (~300 m²) and bed-scale community analysis at Nilpena Station has revealed considerable variability in the composition of Ediacara fossil assemblages. As the dominant component of four fossiliferous beds and a minor component of most others, Aspidella exemplifies this heterogeneity. Aspidella itself, moreover, is characterized by strong morphological
variability. However, the distribution of morphological characters is unrelated to either specimen size or bed assemblage composition. This morphological diversity is therefore interpreted to reflect taphonomic variability. The morphological variability of Aspidella at Nilpena can be explained by four taphonomic pathways: 1) Internal mold: upon current-mediated severance of the stalk and frond, the hypomat holdfast may become filled in with sand. Following burial, compaction, and lithification, this internal mold of the pedal surface is preserved as a convex disk adhering to the base of the overlying bed. When viewed in cross-section, internal slumping and infill by sandy laminae are commonly visible. 2) Cast of external mold: in cases where the holdfast is enveloped in a thicker microbial mat, the pedal surface may be captured as an external mold, and subsequently cast following burial by the overlying veneer of sand. These two preservational morphotypes are especially prominent where Aspidella is preserved in association with Funisia-dominated TOS. In these cases, as viewed in hyporelief, Aspidella is always superimposed upon Funisia. 3) Top-surface cast: rapid burial (smothering) of a holdfast Aspidella in a thin microbial film may result in casting of the top surface of the collapsed structure on the epimat surface, at times including portions of the stalk entrained as a composite structure. 4) Mop: Dragging or plucking of the holdfast from the substrate may, in cases in which the substrate is characterized by a thin microbial film, result in casting of this perturbed epimat surface. Morphological variability of Aspidella is an expression of neither ontogenetic nor species-level anatomical differences, but rather appears to be controlled by differential taphonomy related to local substrate-related sedimentological and biogenic factors.

Session 36-8: Tuesday, 10:30 AM
Presenter: Charlotte Kenchington
TUFFS, TURBIDITES, AND TIERING: THE CONTROL OF SEDIMENTOLOGY ON BIOTIC ASSEMBLAGE IN THE EDIACARAN SUCCESSIONS OF CHARNWOOD FOREST (UK) AND NEWFOUNDLAND (CANADA).

Kenchington, Charlotte G., Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, UK; Wilby, Philip R., British Geological Survey, Nicker Hill, Keyworth, Nottingham, NG12 5GG, UK

The Avalon Assemblage of Charnwood Forest and Newfoundland comprises some of the oldest known occurrences of Ediacaran macrofossils. Although long considered the poor cousin of the Newfoundland succession, recent cleaning and silicone rubber molding of bedding surfaces in Charnwood Forest has uncovered a diverse and well-preserved biota, including at least seven previously undescribed taxa. All are preserved as low-relief impressions on upper bedding-plane surfaces. There are several key differences in biotic assemblage in sites both within and between Newfoundland and Charnwood Forest, although the depositional regime of both regions was broadly similar: both are deep-water, turbiditic, volcaniclastic successions with no indication of deposits formed above storm wave-base. The most notable differences in biotic assemblage include the dominance in certain successions of stalked forms such as Fractofusus, which are conspicuously common in other successions. Examples of the former assemblages are most common in Charnwood Forest and in the Port Union area of Newfoundland. In order to assess the causes for these differences, detailed sedimentological and petrographical studies of sections containing fossiliferous surfaces in Newfoundland were compared to each other and to surfaces in Charnwood Forest. Parts of the Port Union and Charnwood Forest successions share similar sedimentological as well as biotic assemblage characters: both are dominated by thin even bed, abundant soft-sediment deformation, and common ashy horizons, suggesting frequent but small-scale depositional pulses. In contrast, successions such as those in the Mistaken Point region are characterized by thicker event beds with rare soft sediment deformation, suggesting more substantial depositional events of presumed lower frequency. The former successions commonly contain stalked forms, and the latter flat-lying forms. The observed relationships suggest that, although the stalks may have originally evolved as a response to nutrient competition (tiering), they may also represent an adaptation to depositional environments such as those seen in Charnwood Forest and the Port Union area. The stalks would have held the frondose part of the organism free from sediment accumulating from small-scale, sub-lethal events that would have smothered flat-lying forms. The flat-lying forms may thus represent early colonizers that could thrive in depositional regimes that lacked frequent minor input of sediment, but which were instead characterized by sporadic events which felled or smothered all organisms in the community, frequently renewing the surface for recolonization. Given the influence of depositional nature on the composition of the faunal assemblage, the former must be taken into account together with biological factors when considering faunal successions and community composition.

Session 36-9: Tuesday, 10:45 AM
Presenter: Greg Burzynski
THE DISCS OF AVALON: RELATING DISCOID FOSSILS TO FRONDOSE ORGANISMS IN THE EDIACARAN OF NEWFOUNDLAND, CANADA

Burzynski, Greg, Dept. of Geological Science and Geological Engineering, Queen's University, Kingston, Ontario, Canada; Narbonne, Guy M., Dept. of Geological Science and Geological Engineering, Queen's University, Kingston, Ontario, Canada

The oldest members of the Ediacara biota in Newfoundland are fronds as well as discs of uncertain affinities. Strong current alignment of all fronds of the Mistaken Point assemblage implies that they were anchored to the substrate by a holdfast. Most charnid taxa lack a visible holdfast, supporting other evidence that their holdfast was located below the sediment-water interface. All other Ediacaran fronds are directly attached to their discoid holdfasts, implying that their holdfast was at least partly surficial on the sea bottom and facilitating comparisons with isolated discoid fossils such as Aspidella and Hemiolora. The construction and taxonomy of the fronds is well described, but little has been done to describe discs and holdfasts. Biometrical analyses of holdfast discs attached to fronds among all recorded specimens show a significant (p<0.01), positive
correlation between disc size and frond size, which is consistent with their function anchoring the frond to the sea bottom; the relationships between disc diameter and all other measured anatomical features were also significant (\(p<0.01\)). This trend continues among some lower taxonomic divisions, such as Charniodiscus and Primocanadelaebrium. Size-range box plots of the discs and plugs of Aspidella covers the ranges of all other taxa represented in this study; in particular, they show striking similarity to those of Charniodiscus. The morphology of holdfasts of Charniodiscus spp. shows a range that is closely similar to the spectrum of morphologies in Aspidella. Interestingly, a similar morphological continuum exists between Aspidella and Hiemalora. Taken together, this supports the notion that discoid fossils are indeed the holdfasts of frondose forms whose petalodia escaped preservation, and not whole organisms (e.g., jellyfish or polyp bases) or microbial colonies as inferred by some workers.

**Dickinsonia Lifts Off: Evidence of Current-Derived Morphologies**

Evans, Scott D., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521; Droser, Mary L., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521; Gehling, James G., South Australia Museum, North Terrace, Adelaide, South Australia 5000, Australia; Tarhan, Lidya G., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521

Excavation and examination of 26 medium-grained rippled sandstone beds of the Wave-Base Sands Facies in the Ediacara Member of the Rawsley Quartzite cropping out west of the Flinders Ranges (South Australia), reveals a diverse array of individual taxa as well as their preservational modes. The iconic taxa Dickinsonia occurs on all beds in varying abundances. On three of the beds, in addition to those that are well preserved, many specimens of Dickinsonia exhibit an unusual range of morphologies. These specimens, clearly not transported, have an appearance ranging from a ‘Pacman’ morphology to examples where up to half of the Dickinsonia is not preserved. Orientation measurements from these specimens exhibit strong evidence for current-mediated morphology and orientation resulting from the lifting of a portion of the Dickinsonia off the seafloor. Data from two of the beds are limited due to lack of total (9 and 38) and deformed (4 and 7) specimens; however, they show clear alignment of deformed features. A third bed contains more than 400 preserved fossils, including more than 200 Dickinsonia, 70 of which exhibit ‘Pacman’ or partial preservation. These specimens exhibit a non-random orientation, distributed over an approximately 180° range. A majority of these features are oriented within 80° of each other, suggesting current alignment. This orientation is also consistent with previously known current indicators, ‘MOP’ and ‘weave’. However, crosscutting relationships between Dickinsonia and ‘weave’ suggest more than one event has affected these beds, but that current direction remains constant.

**Modeling the Growth and Morphology of Ediacaran Organisms**

Hoekzema, Renee S., Department of Earth Sciences, University of Oxford, S. Parks Rd, Oxford, Oxfordshire, OX1 3AN, UK; Brasier, Martin D., Department of Earth Sciences, University of Oxford, S. Parks Rd, Oxford, Oxfordshire, OX1 3AN, UK

The Ediacara biota (575–542 Ma) marks the arrival of macroscopic life on the planet. It must have played an important role as precursor of the Cambrian Explosion and all complexity beyond, yet little is known about the biology of this period. A systematic approach to the growth and morphology of Ediacaran organisms might provide a way forward. In this study, we present a growth model that aims to capture the main variation in the shapes of the Ediacaran Dickinsoniomorphs and Rangeomorphs. This model is straightforwardly constrained with measurements from well-preserved fossils, which help us to map out the different growth plans of different species. Animations will be shown during the talk that demonstrate the growth of several modeled organisms. These allow us to reconstruct intermediate stages so that one can explore the relationship between specimens in a different stage of growth, and thus separate genetic and ontogenetic differences. In this talk, we also plan to relate differences in morphology to differences in paleoenvironment between the species. Such studies will help us to analyze the possible physical constraints on the mode of life of these elusive organisms.
Charniordiscus, Mawsonites) are found in both above-mentioned types of preservation in the Khatyspyt Fm., usually each type of preservation is characterized by distinct fossil genera. Therefore, it is possible to see that preservation was selective. However, the presence of some organisms in both assemblages is leading to the fact that during the Khatyspyt time, Ediacaria-like organisms and macroalgae lived together and were parts of one biota. The reason for selective preservation is hidden in different types of organism’s tissues, difference in ecology of these organisms, and way of preservation. Due to preservation of organic matter of macroalgae, it is detected that they had decomposers on their surface such as different types of bacteria and even some trichomes. However, the early silicification of carbonate material was a reason for preservation of macroalgae fossils, which had an effect like mumification. The Ediacara-like organisms also had an early cementation, but it was induced by decaying of organic matter, not by silica. This Khatyspyt-type taphonomic-window assemblage mostly consists of holdfast fossils (like Aspidella). It means that during cementation, they were already buried into sediment. This fact saved these fossils from completely decaying without preservation. Consequently, there are two different preservation-type assemblages in one Khatyspyt biota. Although macroalgae usually fully decayed before preservation in condition of early carbonate cementation induced by decaying. Vice-versa, the Ediacara-like organisms were not preserved in silicified cement because input of silica limited the required cycle of chemical elements.

Session 36-13: Tuesday, 11:45 AM
Presenter: Joseph Meert

RAPID CHANGES IN MAGNETIC FIELD POLARITY DURING THE LATE EDIACARAN: TRIGGER FOR THE AGRONOMIC REVOLUTION AND THE DEMISE OF THE EDIACARAN FAUNA?

Meert, Joseph G., Geological Sciences, University of Florida, 355 Williamson Hall, Gainesville, FL 32611;

Bazhenov, Mikhail, Geological Institute, Russian Academy of Sciences, 7 Pyzhevsky Lane, Moscow, Russia;
Levashova, Natalia M., Geological Institute, Russian Academy of Sciences, 7 Pyzhevsky Lane, Moscow, Russia

During the latter part of the Ediacaran Period and into the early part of the Cambrian (550–529 mya), many of the enigmatic soft-bodied Ediacaran fauna went extinct. In their place, organisms with hard parts, complex body plans, and the ability to burrow vertically through the sedimentary column appear in the fossil record. There are numerous and varied explanations as to both the cause of extinction and the subsequent Cambrian radiation. Here we speculate about a possible link between a low dipole magnetic-field intensity (and rapid field reversals), the destruction of a young ozone layer, and the biological changes that took place during this interval. Evidence for extremely rapid polarity changes in the Ediacaran is derived from new paleomagnetic studies on the Late Ediacaran (~548 Ma) Zigan Formation of the southern Urals. Estimates for reversal frequency in these strata is conservatively estimated at 24R/Ma compared to a maximum of 10–12R/Ma in the Phanerozoic. Low dipole intensity is a feature of a rapidly reversing dynamo (models), and also finds support from paleointensity measurements. A low dipole intensity can cause a decrease in shielding of incoming charged particles from the Sun or other galactic source. Interactions of charged particles with the upper atmosphere can cause destruction of the ozone layer and an increase in incident UV-A and UV-B radiation on Earth’s surface and shallow-marine environments. Numerous studies on extant biological organisms show that they exhibit a number of evolutionary and behavioral responses to increasing UV radiation, including, genetic repair from UV damage, diel vertical migration, and masking behavior. We postulate that the mostly sessile Ediacaaran fauna were negatively affected by the increases in UV-B radiation, and that organisms with the ability to burrow vertically through matgrounds were protected from UV-B radiation. The vertical burrowing behavior resulted in the so-called agronomic revolution (substrate revolution), and was one of the major adaptations that took place ahead of the Cambrian radiation.
region for the invasion in equatorial Laurentia (Bighorn Dolomite in the Bighorn Mountains, WY), and the recipient region on the Cincinnati Arch. Of 94 genera combined between the two areas, only 37 are shared, reflecting the environmental differences between a warm-water carbonate platform in equatorial Laurentia and the mixed carbonate-siliciclastic ramp on the distal edge of the Taconic foreland basin. Of the 37 genera shared between regions, ten are identified as invaders, taxa not known to occur previously within the type Cincinnatian Series. The other 27 genera represent mostly different species of genera shared between regions. Prior to the invasion, equatorial Laurentia and the Cincinnati region did not exchange taxa for at least 9 million years, which sets a minimum time on the divergence of species of shared genera. We compared niche parameters (preferred environment, occupancy, median abundance, rank abundance) for shared genera between tropical Laurentia and the Cincinnati region. We found that for three of four niche parameters, invader taxa had high Spearman rank correlations (>0.5) suggesting a high level of niche conservatism for invaders. In contrast, non-invading shared taxa had low correlations of niche parameters (<0.3), suggesting niche evolution. Previous work (Holland and Zaffros, 2011) finds no evidence for niche evolution in the Cincinnati region over the 8 million-year interval prior to and including the Richmonidian Invasion. This finding suggests that most niche evolution between shared non-invader genera occurred in a pulse at the origin of the Cincinnati Province, marked by a shift from warm-water carbonates to cool-water carbonates in the eastern United States that coincided with the onset of the Taconic orogeny.

Session 37-2: Tuesday, 8:15 AM
Presenter: Aldo F. Rincon

THE EARLY MIOCENE PROTOCERATIDS (MAMMALIA, ARTIODACTYLA) FROM THE PANAMA CANAL BASIN

Rincon, Aldo F., Department of Geological Sciences, University of Florida, 241 Williamson Hall, Gainesville, FL 32611; Bloch, Jonathan I., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; MacFadden, Bruce J., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

New paleontological collecting efforts along the Panama Canal offer an opportunity to investigate the diversification processes that affected terrestrial vertebrates after colonizing tropical volcanic terrains exhumed during the early Neogene in southern Central America. Although Cenozoic protoceratid artiodactyls are known from throughout North America, the Miocene protoceratine Paratoceras is restricted to the subtropics of the Gulf Coast to southern Mexico, and the tropics of Panama. Recently discovered protoceratines from the late Arikareean (20.93 +/- 0.17 Ma) Lirio Norte Local Fauna (L.F.) in the Panama Canal basin include partial dentitions that are similar to the Arikareean Paratoceras tedfordi from Mexico. This relationship confirms a rapid colonization of recently emerged early Miocene volcanic terrains (upper Las Cascadas Formation). Partial protoceratine lower dentitions restricted to the lowermost stratigraphic levels of the Hemingfordian Centenario Fauna (upper Culebra Formation) are referred to a new species of Paratoceras based on its relatively small size, shallower mandible, and narrower cheek teeth. Fossil protoceratines from the uppermost stratigraphic levels of the Hemingfordian Centenario Fauna (upper Cucaracha Formation) include a partial male skull and several dentitions that, together with specimens previously referred to P. wardi (only known from the Barstovian of Texas), are now referred to a new species of Paratoceras based on a relatively reduced and wider lower p4, wider molars, longer nasals, and more gracile male cranial ornamentation. Results from a phylogenetic analysis of 11 protoceratine species using 15 craniodental characters supports Paratoceras as a monophyletic clade. This clade originated in subtropical areas of Central America, and is closely related to the late Oligocene–early Miocene Protoceras. Paratoceras inhabited tropical forested areas of Panama from the late Arikareean through the early Hemingfordian, reaching more temperate areas of the Gulf Coast during the middle–late Miocene (Barstovian and Clarendonian NALMAS).

Session 37-3: Tuesday, 8:30 AM
Presenter: Andrew Zaffros

THE PERSISTENCE OF ECOLOGICAL GRADIENTS: WHAT DO WE REALLY KNOW?
Zaffros, Andrew A., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Brett, Carlton E., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221; Miller, Arnold L., University of Cincinnati, Department of Geology, 7148 Edwards One, Cincinnati, OH 45221

It is now common practice in stratigraphic paleobiology to reconstruct onshore–offshore gradients via multivariate ordination, and assess the persistence of these gradients among successive depositional sequences. Three questions naturally arise about the effectiveness of these analyses. First, given that ordinations are dependent on: 1) the stratigraphic completeness of the sampled section, 2) the ensemble of present taxa, and 3) the potentially changing habitat preferences of each taxon, is it possible to attribute changes in gradient structure to just one of these factors? Second, although a simple null model might be to predict no change between two successive gradients, this is an unreasonable standard given that no two ordinations will be identical due to inevitable differences in sampling between intervals. Therefore, is there a ‘fair’ method for assessing the similarity of ecological gradients? Third, depositional sequences develop with an internal temporal hierarchy, wherein higher-order sequences are nested within lower-order sequences. Does the temporal scale of the sequence affect the degree of gradient persistence? To address these questions, we use a combination of computer simulation and empirical data from the Middle Devonian Hamilton Group of New York and the type-Cincinnatian (Late Ordovician) Series of Ohio. Specifically, we apply a variety of resampling procedures (a standard bootstrap and a jackknife variant) to our data to produce a range of potential ordination scores for each taxon. These scores represent the range of gradients that could possibly be reconstructed within the same sampling universe. In other words, they are an estimate of sampling error. Using
these error estimates, we test whether 1) any taxon’s score is statistically different from the ‘norm’ during a particular interval, and 2) whether a taxon’s scores from any two intervals are statistically different from each other. Our empirical results demonstrate that although successive gradients are commonly correlated, many taxa exhibit ordination scores that are statistically significant deviations from the norm. The frequency and magnitude of deviations, however, do not necessarily scale with the strength of the correlation or the temporal length of compared intervals; instances of either gradient persistence or restructuring can be observed at the bed, member, or formation levels. The scale-independent nature of gradient (in)stability emphasizes the potential uniqueness of each interval, where epibole or invasion taxa, in particular, may substantially alter the milieu of an environmental gradient.

Session 37-4: Tuesday, 8:45 AM
Presenter: Amy Singer

THE INVERTEBRATE PALEOECOLOGY OF THE BEAR GULCH LIMESTONE

Singer, Amy E., CHCB 302 University of Montana, 32 Campus Drive, Missoula, MT 59812; Stanley, George D., CHCB 302 University of Montana, 32 Campus Drive, Missoula, MT 59812

The Late Mississippian Bear Gulch Limestone (BGL) is well exposed in central Montana, and stands as one of the outstanding marine konservat lagerstätten in the United States. The BGL is best known for soft-tissue preservation of fish, but there are abundant and diverse invertebrates remaining to be studied. Recent landowner relationships have reactivated collecting in the area for the University of Montana Paleontological Center. Over the past two field seasons (2012 and 2013), new excavations and systematic collecting techniques have revealed an even more abundant invertebrate fauna than previously recorded. The BGL is a plattenkalk, a finely laminated micritic limestone, which may record tidal, seasonal, or climatic signals. To discern which signal is controlling deposition of this plattenkalk, high-resolution composite sections are being measured at the mm-scale. Additionally, samples are being collected for physiochemical and microfacies analysis. This information will be integrated with paleoecological and stratigraphic information gained from systematic excavations of benthic invertebrate macrofossils to clarify the model of basin-wide processes, which remain controversial. Current stratigraphic models place the BGL within or very close to the Serpukhovian stage, a time of great global climatic fluctuation. The BGL likely preserves a unique snapshot into this critical time in Earth’s history, which may further our understating of the Serpukhovian Biodiversity Crisis (SBC). Changes to the biotic composition and forms common to other Mississippian faunas that are missing in BGL, may shed light on a biosphere in transition due to an unstable climate. Alternation of flinz and flaune bedsets may reflect these climatic shifts, and an integrative approach that includes detailed paleoecology, geochemistry, and sedimentology can elucidate these changes and their effects on the biosphere, which will place the BGL within a regional setting and global context.

Session 37-6: Tuesday, 9:15 AM
Presenter: Kathryn M. Smith

TEMPORAL AND PALEOENVIRONMENTAL DISTRIBUTION OF BASILOSAURUS (MAMMALIA: CETACEA) IN THE SOUTHEASTERN UNITED STATES: NEW EVIDENCE FROM THE EOCENE OF SOUTHWEST GEORGIA

Smith, Kathryn M., Department of Geology and Geography, Georgia Southern University, P.O. Box 8149, Statesboro, GA 30460; Hastings, Alexander K., Zentralsammlungen Naturwissenschaftlicher Sammlungen, Geisseltal Museum, Martin Luther Universität Halle-Wittenberg, Halle, Germany; Bebej, Ryan M., Biology Department, Calvin College, 1726 Knollcrest Circle SE, Grand Rapids, MI 49546; Uhen, Mark
Basilosaurus is a fully aquatic archaeocete characterized by elongated posterior thoracic, lumbar, and anterior caudal vertebrae. The genus was present in North America by the late Eocene, with most occurrences within the Gulf Coastal Plain. In Georgia, there are only three confirmed reports of Basilosaurus, two of which are of isolated elements. Here we report a fourth Basilosaurus from Georgia, found on the banks of the Flint River in Albany. This specimen appears to be the most complete Basilosaurus known from Georgia, and upon initial discovery, consisted of a series of seven elongate vertebrae (five complete and two partial) and some probable rib fragments. Since the discovery, three vertebrae have been stolen, but excavation is ongoing, and there is potential for recovery of additional material beyond what has been identified. The specimen is encased in the Ocala Limestone, a fine-grained, white to cream-colored limestone that formed during the late Eocene (Priabonian: 37.2–33.9 Ma) in the shallow open waters of the continental shelf. The goal of this study is to investigate the facies, temporal, and geographic distribution of Basilosaurus in North America in order to identify paleoenvironmental and geographic limitations to its distribution. To address this goal, Basilosaurus occurrences and depositional environment for each site were plotted on a paleogeographic reconstruction of Eocene North America for four time intervals (middle to late Priabonian, early Priabonian, Bartonian/Priabonian boundary, and Bartonian). Occurrences of Basilosaurus are rare near the Bartonian/Priabonian boundary, which coincides with a sea-level lowstand. Following this lowstand, the Jackson Sea transgressed, and Basilosaurus dispersed from Florida to as far north as South Carolina and as far west as Louisiana. The North American Basilosaurus population reached its peak during the height of the Jackson transgression, just prior to the Eocene/Oligocene boundary, with specimens found as far north as Arkansas and Tennessee, and in abundance in Mississippi and Alabama. There are no apparent associations between geography and paleoenvironment, or time and paleoenvironment, as Basilosaurus fossils are typically found in nearshore, shallow-marine environments regardless of age or location. There is, however, some association between geography and age, as specimens track the movement of the shoreline through time. Basilosaurus fossils also indicate the presence of an embayment leading to Arkansas and Tennessee, a feature that is absent in many paleogeographic reconstructions. The presence of an embayment leading to Arkansas and Tennessee, a feature that is absent in many paleogeographic reconstructions of the Eocene. Continuation of this study will ultimately provide a better understanding of the habitat preference and timing of dispersal of Basilosaurus, with implications for the evolution of archaeocetes in southeastern North America.
In marine settings, quantitative bathymetric models can be developed using various water-depth proxies, including epibenthic distribution, sedimentological features, and the distribution of benthic taxa in time and space. Here, the late Quaternary bathymetric history of the Po Plain (Italy) has been reconstructed using mollusk samples from a network of 16 cores. Multiple analytical approaches have been applied in a comparative fashion. A direct ordination approach was used to estimate sample bathymetry using weighted averaging of genera with known preferred depth. Weighted averaging carries an advantage of analytical simplicity and produces direct ordination models expressed in environmentally meaningful units. Indirect ordination methods, based on depth estimates developed using posteriori-calibrated ordination strategies (Correspondence and Detrended Correspondence Analysis calibrated against present-day bathymetric data), yielded results consistent with weighted averaging. Comparable results were obtained using Correspondence Analysis, Non-Metric Multidimensional Scaling, and Principal Coordinate Analysis. Regardless of the choice of analytical methods, mollusk assemblages yielded bathymetric proxies congruent with independent sequence-stratigraphic interpretations derived previously for both the late Pleistocene and Holocene transgressive-regressive cycles. The mollusk-derived proxies quantify spatial bathymetric gradients across the basin, and local trends in absolute water depth in response to relative changes in sea level. However, for cores located in the most proximal part of the basin, mollusk-based ordinations failed to provide viable estimates due to inclusion of mixed marine and non-marine mollusk faunas and scarcity of fossiliferous horizons necessary for adequate quantitative sampling. These models can be used to constrain the timing and position of transgressive-regressive cycles, track faunal distributions through time and space, and create 4D paleobathymetric reconstructions of the coastal Po plain throughout the late Quaternary. The multiple analytical approaches cross-evaluated in this study consistently suggest that high-resolution quantitative bathymetric estimates can be derived for mollusk samples independent of stratigraphy for fully marine settings. When applied simultaneously to both samples and taxa, these approaches provide a viable strategy for quantifying stratigraphic and palaeontological patterns and enhancing interpretations of basin-scale depositional systems.

Session 37-9: Tuesday, 10:30 AM
Presenter: Austin J.W. Hendy

**STRATIGRAPHIC PALEOBIOLOGY THROUGH TIME AND ACROSS SPACE: CASE STUDIES AND CHALLENGES**

Hendy, Austin J.W., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

The analysis of paleobiological data within a sedimentary context has deep roots within the discipline of paleoecology. The increased utility of stratigraphic paleobiology in recent years reflects an expanded quantitative toolkit, and the recognition that paleobiological analyses can inform sequence stratigraphy. Presented are a number of case studies where quantitative approaches to stratigraphic paleobiology are applied to strata of varying geologic age, spatial scale, and data quality. Among the examples reviewed are: sequence-stratigraphic analysis of the Oligocene Te Kuiti Group, New Zealand; analysis of middle Miocene biofacies of the Otunui Group, New Zealand; analysis of high-frequency sedimentary sequences in the Miocene–Pliocene Matemateonga Formation of New Zealand; spatial analysis of tectonic deformation and sedimentation through the Plio–Pleistocene in the East Coast Basin, New Zealand; and assessment of changing paleoenvironments in the late Miocene Gatun Formation, Panama. These case studies illustrate the utility and challenges with employing such techniques in deeper time beyond the Quaternary. While paleoenvironmental assessment using multivariate analyses can be carried out regardless of age, the inability to employ transfer ecology as a means to quantitatively assess paleobathymetry makes interpretation less precise. Quantitative paleoenvironmental data may also be utilized in a spatial sense, particularly in conjunction with GIS spatial interpolative techniques. Doing so can reveal patterns of tectonic deformation or sediment flux across a sedimentary basin, and during basin evolution. Lastly, a wide range of data types may be adopted by existing quantitative approaches to stratigraphic paleobiology, each with advantages and disadvantages. Well-known examples of stratigraphic paleobiology have employed bulk or census data from both outcrop and subsurface (core) material. Core-derived data has an advantage in that it offers potentially more complete stratigraphic coverage and higher temporal resolution than that often available in outcrop, although with reduced sample size. However, relative abundance, and even presence-absence data may also be used in these analyses, offering increased data accessibility. Quantitative analysis of paleobiological data have tremendous potential in both stratigraphic and spatial dimensions to reveal information about the factors that have shaped the rock and fossil records. In turn, the stratigraphic framework provided by sedimentary sequence architecture provides a convenient means to explore past and future biotic changes.

Session 37-10: Tuesday, 10:45 AM
Presenter: Daniele Scarponi

**STRATIGRAPHIC PALEOECOLOGY OF THE VALLE DI MANCHE SECTION (CROTONE BASIN, ITALY): A CANDIDATE GSSP OF THE MIDDLE PLEISTOCENE**

Scarponi, Daniele, Dipartimento di Scienze Biologiche Geologiche e Ambientali, University of Bologna, via Selmi 3, I-40126, Bologna, Italy; Huntley, John W., Department of Geological Sciences, University of Missouri, 101 Geology Building, Columbia, MO 65211; Capraro, Luca, Dipartimento di Geoscienze, University of Padova, Via G. Gradenigo 6, I-35131, Padova, Italy

The Pleistocene fossiliferous cyclothemnic succession of Valle di Manche, a candidate Middle Pleistocene stratotype section, was used to assess the informative strength of multivariate paleoecological macrobenthic patterns in resolving depositional settings from a sequence-stratigraphic perspective. The application of two-way cluster and detrended correspondence analysis (DCA) to a composite fossil dataset (mollusks and serpulids) allowed for the
construction of a high-resolution representation of stratigraphic variations in macrofaunal content from Pleistocene shelfal depositional settings, which helps elucidate the main paleoenvironmental variables that account for such variations. Specifically, two-way cluster analysis allowed for the characterization along section of five primary biofacies related to paleoenvironments and their stratigraphic development. DCA faunal curves constructed on the basis of stratigraphic changes in DCA axis 1 (DC1) sample scores provided a series of deepening-shallowing upward trends developed at different time-scales. Furthermore, the DCA scores, calibrated using bathymetric distribution of extant species recovered in Val di Manche, refined quantitative estimates of paleobathymetry in these shelfal settings. Finally, the integration of multivariate outputs along with previously defined stratigraphic and isotopic data represented a powerful synergy able to provide an improved understanding (prompt identification and bathymetric characterization) of key surfaces and stratal stacking patterns for sequence-stratigraphic interpretations. In this respect, depth-related faunal curves derived from DC1 stratigraphic changes track the oxygen isotope curves, suggesting a strong climate-controlled development of recognized sequences. Furthermore, depth-related faunal curves could be employed—if framed in a highly refined chronostratigraphic framework—as a tool of correlation at basin or regional scales. The results are consistent overall with previous independently derived sequence-stratigraphic interpretations and in some cases, suggest the interpretation of previously unresolved deposits.

Session 37-11: Tuesday, 11:00 AM
Presenter: John Warren Huntley

STRATIGRAPHIC PALEOBIOLOGY OF TREMATODE PARASITES AND BIVALVE HOSTS
Huntley, John W., Department of Geological Sciences, University of Missouri, 101 Geology Building, Columbia, MO 65211; Scarpioni, Daniele, Dipartimento di Scienze della Terra e Geologico-Ambientali, Università di Bologna, via Zamboni 67, 40126, Bologna, Italy

Digenean trematode parasites have complex life cycles during which they infest invertebrates as intermediate hosts. The growth of oval-shaped pits with raised rims within the pallial line of bivalves is induced when they serve as second intermediate host. The trematode life cycle is completed when the second intermediate host is consumed by a vertebrate predator, and the trematode sexually matures within the predator’s digestive tract. These pits are preserved in fossil bivalves, and there is a growing interest in the fossil record of parasitism amongst paleoecologists. Our previous work with 11,785 fossil and modern mollusks from the Po Plain and northern Adriatic Sea has shown that trematodes are not only taxonomically selective of their hosts, but temporal trends in their prevalence seem to be controlled by glacio-eustatic processes. Trematodes are significantly more common in preferred taxa from the lower shoreface/inner shelf water depths preserved in transgressive system tracts (TST) than in highstand systems tracts (HST). We hypothesized that this discrepancy could be controlled by differences in lower-shoreface/inner-shelf environmental conditions between TST and HST settings. In particular, free-living trematodes between intermediate life stages are particularly vulnerable to decreases in salinity. A survey of 17,299 modern mollusks from both TST-like and HST-like conditions among eleven northern Adriatic shoreface locations supported this hypothesis. Trematode prevalence was higher, and a greater diversity of host taxa were infested in the TST-like barrier-island/lagoon/estuary complexes north of the Po River delta than in the HST-like delta and strand plains to the south. Trematode prevalence increased again >130 km south of the delta. There was no significant difference in trematode prevalence values between fossil and modern samples. We further explore the spatial and environmental variation of trematode prevalence in a survey of 7,633 modern mollusks from six shoreline and two estuarine bulk samples from the Netherlands North Sea and IJsselmeer coasts. Indeed, mean summed trematode prevalence values by location are nearly seven times higher in the strongly TST-like Dutch North Sea samples (0.491) than in the Adriatic Sea (0.077). Molluscan bulk samples from the two basins also strongly diverge in predation intensity and prey effectiveness (both much higher in the North Sea) and in diversity (much lower in the North Sea). Though there is much work remaining before we can clearly interpret the disparities in biotic interactions and diversity between the North Sea and Adriatic Sea samples, these results strongly reiterate the need to interpret biotic trends in the contexts of their sequence-stratigraphic architecture as well as spatial and environmental variation. Such dissections of temporal trends are especially important in section-, basin-, and regional-scale studies.

Session 37-12: Tuesday, 11:15 AM
Presenter: Paulo Souto

DISCOVERY OF VERTEBRATE COPROLITES FROM THE CRATO MEMBER, ARARIPE BASIN IN THE NORTHEAST OF BRAZIL.
Souto, Paulo R.F., Ciencias Naturais, Universidade Federal do Estado do Rio de Janeiro, Av. Pasteur, 458, sl 405, Rio de Janeiro, 22290, RJ, Brazil

The Santana Formation of the Araripe Basin is a thick sequence of limestones and shales outcropping on the Araripe plateau northeast of Brazil, and is thought to have been deposited in a large, virtually landlocked lagoon. Sediments deposited in the lower Cretaceous Santana Formation are organized into three stratigraphic members: Crato (lower), Ipubi (middle) and Romualdo (upper). The coprolites were first discovered at the end of the last century in the Romualdo Member preserved inside carbonate concretions, and after that, in the Ipubi Member associated with laminar shales. Now for the first time, coprolites have been discovered in the Crato Member. This unit has sedimentation processes associated with lacustrine environment during Aptian age, and contains a rich and well-known fossil fauna represented by insects (more that twenty orders), frogs, lizards, crocodilians, and pterosaurs. The two coprolites were collected in sandstone layers from a quarry near Nova Olinda County, in Ceara State. The specimens are complete, and three-dimensionally preserved in the associated sedimentary matrix. The coprolites studied reveals autochthonous condition, and show different morphology. The morphotype registered by institutional code LIBA 068 is
longer than wide with symmetric ends, with 3.6 cm long and maximum thickness 45 cm, yellowish color, and is densely packed with only one transverse groove in the middle. It is possibly associated with a medium fish size. The second coprolite is LIBA 069, and has a dark brown color with an asymmetrical form like a racquet shape, with the distal ending in an ovoid mass changing to the proximal end into a long cylinder shape. The distal end is 3.76 cm thick, and proximal end 1.8 cm thick. Probably that producer excreted this material close to the sediment-water interface, and it resembles to liquefied excrement produced by modern frogs and turtles. Still in progress, the chemical analysis of these structures and thin-section analysis can provide a correlation of paleoenvironmental indicators and biologic affinity. This study confirms coprolites have been found in all three members of the Santana Formation, in autochthonous positions, and expands the stratigraphic distribution in time. This research received financial support of FAPERJ program.

Session 37-13: Tuesday, 11:30 AM
Presenter: Thomas R. Holtz Jr.

LARAMIDIA: ENGINE OF DINOSAUR DIVERSITY OR PERFECT STORM FOR COLLECTING? (OR BOTH?)

Holtz Jr., Thomas R., Department of Geology, University of Maryland, College Park, MD 20742

The latest Cretaceous (Campanian and Maasstrichtian) of western North America has produced the highest species diversity of non-avian dinosaur taxa in the Mesozoic record. This diversity is startling in comparison to the paleogeographic context: during this interval of oceanic highstand, western North America was isolated from the rest of the continent by the Western Interior Seaway, resulting in the island continent of Laramidia. It has been proposed that the remarkable diversity of Laramidian dinosaurs is a byproduct of their unique biogeographic setting: a small area subject to repeated eustatic sea-level changes driving episodes of isolation, divergence, and migration. Alternatively, Laramidia represents a confluence of nearly all factors necessary for the generation and recovery of terrestrial fossil material: a nearby active orogenic belt, yielding a thick alluvial wedge marked with numerous datable volcanic ash beds; a relatively short distance for sediment accumulation; subsequent uplift and exposure of these deposits; and a modern arid setting with relatively easy access to fossil localities. Thus, the question arises if the high level of Laramidian dinosaur diversity represents an artifact of superior recovery or instead of an intrinsically higher number of local species than other regions during the Late Cretaceous. The Laramidian dinosaur record is reexamined in light of recent high-resolution biostratigraphies and alternative models of synonymy of taxa. These reductions in numbers of taxa present at any given time-slice result in community species levels less outstanding compared to other dinosaurian faunas than lumping all the biozones of a formation together as a single unit. Nevertheless, they remain as among the highest observed diversity in the Mesozoic. Various statistical degradation methods were used to subsample Laramidian assemblages to model how these faunas would appear if collection histories were more similar to those of other dinosaur-bearing units. Following this, the dinosaur faunas of Laramidia do not show particularly high levels of diversity compared to other well-known assemblages. As a result, the hypothesis that other dinosaursian communities (if they were capable of being sampled at the high resolution of the Campanian and Maasstrichtian of western North America) actually possessed species diversities comparable to those of Laramidia cannot be rejected at this time.

Session 37-14: Tuesday, 11:45 AM
Presenter: Rebecca Koll

SPATIAL AND TEMPORAL DISTRIBUTION PATTERNS OF EARLY AND MIDDLE PERMIAN GIGANTOPTERID SEED PLANTS IN WESTERN PANGEA

Koll, Rebecca A., Department of Botany and Florida Museum of Natural History, University of Florida, Gainesville, FL 32611; DiMichele, William A., Department of Paleobiology, Smithsonian Institution National Museum of Natural History, NHB MRC 121 P.O. Box 37012, Washington, DC 20013

Gigantopterids are an enigmatic group of seed plants, most likely belonging to the Peltaspermales, a derived group of ‘seed ferns.’ They have been taxonomically differentiated largely on distinctive patterns of leaf venation and gross architecture. The biogeographic and paleoenvironmental significance of this group, however, remains poorly understood. Numerous studies have examined the taxonomy and morphology of individual genera or groups of related species or genera (Mamay 1960, 1967, 1986, 1988, 1989; Mamay et al., 1986, 1988; Taylor and Taylor, 1993; Li et al., 1994; Glasspool et al., 1994; Booi et al., 2009; DiMichele et al., 2011). However, existing studies tend to focus on taxonomic descriptions or analysis of a singular, specialized character rather than large-scale systematics or stratigraphic patterns of the entire clade. The present study focuses on development of a comprehensive, multidisciplinary approach capable of circumscribing genera based on a suite of morphologic characteristics and patterns of variation, which then can be evaluated within the context of spatio-temporal distribution. This study reports the results of a preliminary investigation into the spatial and temporal distribution of North American gigantopterids. The early and middle Permian paleobotanical specimens on which this study is based are housed in the US National Museum of Natural History. They were collected between 1909 and 2013 by paleobotanists of the U.S. Geological Survey and Smithsonian Institution from strata of the Witchita, Bowie, Clear Fork, and Pease River Groups of north-central Texas. The fossil leaf compressions and impressions occur in a range of lithologies from claystone to siltstone and sandstone; some deposits show evidence of pedogenic overprinting. Sedimentologic and pedogenic conditions at the sites suggest correlation of gigantopterid distributional patterns with environmental conditions and depositional settings, which provide a refined understanding of climatic factors associated with the fossil assemblages. Initial analysis indicate that variations in venation and leaf shape will reveal greater diversity in the North American gigantopterids than is presently understood, requiring reassessment of their relationships. Whereas foliar characters alone may prove
insufficient to determine phylogenetic relationships among the genera, they do provide a clearer understanding of the progression of venation patterns through time. Linkage of the various morphologies to environmental conditions may help determine if vein architecture is conservative or if it includes significant eco-phyenoptypic variation. A further objective is to assess the nature and degree of morphological convergence among groups separable on suites of otherwise conservative characteristics. Environmentally, the gigantopterids show a general trend of more complex venation and simpler leaf architecture in evermore seasonally dry or environmentally stressful habitats.

Session No. 38: Digitization in vertebrate paleobiology

Chair: Aaron R. Wood and P. David Polly

Tuesday Morning 8:00 AM to 12:15 PM

Session 38-1: Tuesday, 8:00 AM
Presenter: Martin Rücklin

VISION IMPOSSIBLE? TOMOGRAPHIC TECHNIQUES IN PALEOBIOLOGY

Rücklin, Martin, Department of Geology, Naturalis Biodiversity Center, Postbus 9517, 2300 RA Leiden, The Netherlands

Tomographic methods have been used in comparative morphological research on fossils for more than 100 years. Traditional physical techniques, such as serial grinding or sectioning, result in tomographic data sets of photos and drawings. Morphology of structures hidden in rocks, internal skeletal anatomy, and histology are reconstructed as physical wax models or digital computer models. The advantage of the method is that the highest possible resolution can be obtained in polished sections. The invasive character of the method, destruction of the fossil, loss of any repeatability of the experiment, and reconstruction inaccuracies caused by having only one sectioning plane are all limitations, and are probably the reason why the method is not widely used. These limitations are overcome by X-ray based tomographic methods, which are non-invasive, meaning that fossils are not destroyed during the data acquisition and therefore experiments are repeatable. MicroCT is a method using axial CT to visualize small-scale items in detailed tomograms with a voxel size of less than 5 µm. Synchrotron Radiation X-ray Tomographic Microscopy (SRXTM) is an axial method using a synchrotron as high-brilliance and coherent X-ray source, resulting in tomograms with a voxel size of submicron scale. 3D visualization programs and powerful computing enable visualization of the data in three dimensions, and it is even possible to produce oblique planes in any orientation. The segmentation of micron-sized structures and sclerochronology allow the reconstruction of morphology and development in detail. The most reliable procedure for doing this involves digital reconstruction methods based on microCT and SRXTM data. This reliability and repeatability of experiments are the main reasons for the widespread application of digital tomographic methods and the renaissance of comparative morphology. Data sets and models can be used to test hypotheses from scientific disciplines such as histology and functional morphology to evolutionary and developmental biology.

Session 38-2: Tuesday, 8:15 AM
Presenter: Corey Toler-Franklin

PRACTICAL OPTICAL IMAGING TECHNIQUES FOR ANALYZING NATURAL HISTORY COLLECTIONS

Toler-Franklin, Corey, Department of Earth and Planetary Sciences, University of California, Davis, One Shields Avenue, Davis, CA 95616

The introduction of new low-cost optical imaging techniques allows researchers to study artifacts and biological specimens as they never have before. These methods produce high-resolution digital-media formats with interactive re-lighting capabilities. Methods range from simple approaches that inspect surfaces under a raking light to complex hyperspectral imaging systems that expose objects to radiation at wavelengths outside the visible spectrum. Of particular interest are new data-capture methods that use multi-illumination digital photography to compute and visualize 3D details more accurately than traditional photographs or low-cost 3D scans. In this session, I will show how aspects of these technologies can be combined to create practical protocols for archiving and analyzing natural history collections. I will focus on recent digitization methods developed in computer science that accurately capture the shape and physical appearance of objects using new imaging formats that store a combination of color, 3D surface orientation, and multi-spectral data. I will then show how the computed high-resolution information can be used to generate interactive visualizations that reveal subtle surface details as well as subsurface material composition. Finally, I will show specific examples of how this work is currently being used to document specimens from rare collections at the American Museum of Natural History (AMNH), Vertebrate Paleontology and Mammalogy departments, and Duke University Lemur Center, Fossil Primates Division. The results of this work will expand the range of digital media formats traditionally stored in collection databases beyond simple 2D photographs and text (and in some cases 3D scans), and provide new provide new insights into the study of biological specimens. When combined with existing archives, these new datasets will enable more comprehensive analysis for study by researchers and the general public alike.

Session 38-3: Tuesday, 8:30 AM
Presenter: Mark Sutton

SPIERS—a FREE PACKAGE FOR TOMOGRAPHIC COLLECTIONS
**RECONSTRUCTION**

**Sutton, Mark D.,** Department of Earth Science and Engineering, Imperial College, London, SW7 2AZ, UK

SPIERS (Serial Palaeontological Image Editing and Rendering System) is a free software suite that enables paleontologists to reconstruct and view 3D models from any kind of tomographic dataset (e.g., CT, serial-grinding). The SPIERS suite consists of three applications: SPIERSalign (used to register or align datasets, and perform initial region-of-interest cropping); SPIERSedit (the core application, used to perform virtual specimen preparation), and SPIERSview (a lightweight, interactive 3D viewer). SPIERS is available for Windows and OSX systems. It is written and maintained by paleontologists, is specifically designed for palaeontological datasets, and is provided with detailed and carefully written manuals. Its design philosophy assumes that users will prioritize the investment of time to extract maximal information over the production of 'quick-and-dirty' visualizations, although it does not prevent users from producing the latter. SPIERSalign uses a manual registration approach for maximal precision, although it includes semi-automated tools as well. SPIERSedit is a slice-by-slice editor intended to facilitate careful preparation of noisy data, but includes many tools to shortcut this process. Models are reconstructed using a paradigm which separates source and working datasets, and provides parallel labeling systems based on material type (segmenting) and area labeling (masking). SPIERSview, the interactive 3D model inspection tool, is designed to be simple to use and to minimize hardware requirements; it is well-suited to the study of virtual specimens of over 10 million triangles on computers of modest power, and scales to handle far larger specimens on workstation-class machines. It includes stereo-rendering and limited post-processing capabilities (e.g., model smoothing, mesh simplification). SPIERSview also acts as a free viewer for VAXML, a proposed open and general-purpose virtual-paleontology file-format intended to facilitate the dissemination of virtual specimens.

---

**Generation of three-dimensional (3D) surface models of baleen whale skulls (Cetacea: Mysticeti) for morphometric analyses: possibilities and limits of photogrammetry**

**Fahlke, Julia M.,** Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstr. 43, 10115 Berlin, Germany

All modern whales originated from Eocene archaeocetes. High-frequency hearing in toothed whales (Odontoceti) is well understood today. However, the development and physiology of low-frequency hearing in baleen whales (Mysticeti) remains enigmatic. Cranial asymmetry is known in odontocetes and archaeocetes, but not in mysticetes. This study aims to resolve whether mysticetes have (secondarily) symmetrical skulls, and, if so, whether cranial symmetry correlates with the development of low-frequency hearing. For this purpose, mysticete cranial shape is analyzed, applying geometric morphometrics to 3D surface models generated with the help of photogrammetry. Results will subsequently be compared to those of studies of mysticete periotic anatomy that are simultaneously conducted at the Museum für Naturkunde Berlin. Photogrammetry was originally used for mapping purposes and in architecture, and has recently become a popular digitization method in many fields of science due to ever-increasing computing capacities. In order to create 3D models with the help of photogrammetry, overlapping photographs of mysticete skulls were taken from all possible angles using a Canon EOS 650D digital camera. Only well-preserved and undeformed skulls were used. Because of large object size, special attention to focusing was required in some cases. Depth of field was problematic in head-on photographs. Lighting needed to be consistent over the entire skull, which proved to be difficult when working in daylight (rapid photo acquisition required), or in museums that use spotlights. Alignment of photographs with back light tended to fail more often than when skulls were evenly lit. Photo alignment and surface generation were done in Agisoft PhotoScan Professional. Accuracy settings were chosen individually, depending on skull size and desired detail, but always reflecting camera resolution. When alignment was problematic, model creation was split into chunks, or partial surfaces were created and aligned during post-processing. Post-processing was also required in order to clean and decimate all resulting meshes, and was mainly done in GOM Inspect. Surfaces were not smoothed so that morphological features were retained as accurately as possible. In a preliminary study, 18 landmarks were placed on the surfaces of 13 selected archaeocete and fossil and modern mysticete skulls using Landmark editor. Landmark coordinates were then imported into Morphof for morphometric analyses. First results suggest that archaeocetes and mysticetes, as well as families within these groups, can only be resolved when looking at the symmetrical (not the asymmetrical) component of cranial shape difference. Whether this finding indicates a similar degree of asymmetry in all included families and how much asymmetry there actually is, is currently being tested under the inclusion of a larger sample and an improved set of landmarks.

---

**Mobile scanning of large and rare specimens**

**Graf, John F.,** Roy M. Huffington Department of Earth Sciences, Southern Methodist University, 3225 Daniel Ave., Dallas, TX 75275; **Poleyn, Michael J.,** R Roy M. Huffington Department of Earth Sciences, Southern Methodist University, 3225 Daniel Ave., Dallas, TX 75275; **Jacobs, Louis L.,** Roy M. Huffington Department of Earth Sciences, Southern Methodist University, 3225 Daniel Ave., Dallas, TX 75275

Ongoing research under the auspices of Projecto PaleoAngola includes the description of fossil cetaceans recovered from Angola to determine their systematic placement within the family Mysticeti. For this research, comparative observations of several large-sized, rare specimens, including *Caperea marginata* (USNM 550146), have been made. We determined that having a 3D surface...
scan of USNM 550146 would facilitate efficient comparison of morphology and 3D morphometric analysis. After comparing all available technologies, it was determined that the VIALUX OEM 3D scanner best suited our needs for the project. This is a low-powered, structured light scanner that has available software integration for custom software. The unit can run on a 12-volt power source, making it highly mobile. We present here our methods for 3D surface scans. Multiple scan families were generated by repositioning the VIALUX scanner relative to a target plate that the unit was calibrated to. On-site merging of the scan families was done using Meshlab, a freely available, open-source software. Scanning was completed within two days. Final assembly of the meshes was completed at the laboratory at SMU using Rapidform. This methodology resulted in high-resolution, archival 3D surface scans of USNM 550146, available at the National Museum of Natural History at the Smithsonian Institute. The methods discussed here make it possible for quick mobile scanning of large and rare specimens. Scans produced from these methods will make it possible to study large and delicate specimens outside of the institutions that they are held in.

Session 38-6: Tuesday, 9:15 AM
Presenter: Theodorou Georgios

A STUDY CASE FOR A 3D SKELETAL RECONSTRUCTION OF ELEPHAS TILIENSIS BASED ON CT AND LASER SCANS; MORPHOLOGY, POPULATION DATA, AND TAPHONOMY.

Theodorou, Georgios E., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Mitsopoulos, Vasiliki, National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Isidorou, Stelios K., National Technical University of Athens, School of Mechanical Engineering, Mechanical Design and Control Systems Section, Zografou Campus, Po 15784, Athens, Greece; Vasilopoulos, Theodoros K., National Technical University of Athens, School of Mechanical Engineering, Mechanical Design and Control Systems Section, Zografou Campus, PO 15780, Athens, Greece; Roussiaakis, Socratis J., National Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Zografou Campus, PO 15784, Athens, Greece; Theodorou, Evangelos G., National Technical University of Athens, School of Mechanical Engineering, Mechanical Design and Control Systems Section, Zografou Campus, PO 15780, Athens, Greece; Wilson, Gregory P., Department of Biology, University of Washington, Box 351800, Seattle, WA 98195

The fossil record of mammals is predominated by isolated teeth and dentulous jaw fragments. Although these elements represent only a fraction of mammalian skeletal parts, they provide substantial insight into taxonomy, body size, and feeding ecology of extinct forms. The link between mammalian tooth shape and diet, in particular, has long been known, but has been challenging to extract from the fossil record. Paleobiologists have applied various methods to this problem, from qualitative characterization of gross tooth shape analogized with modern forms to more quantitative approaches using two-dimensional (2D) linear measurements, geometric morphometrics, functional metrics, such as wear facet area and shearing crest lengths, analysis of tooth enamel microwear, and many others. These approaches have advanced our understanding of mammalian paleoeology, however, they have critical limitations. In
some cases, the tooth-shape proxy either coarsely or poorly predicts diet; in other cases, the proxy captures only part of the tooth shape or function; and more often, the proxy is a reliable predictor of diet but it only applies to a narrow morphological or phylogenetic subset of mammals. In recent years, three-dimensional (3D) laser scanning and microCT scanning technologies have become increasingly accessible to paleobiologists and led to major advances in our understanding of fossil forms. Mammalian paleoecologists have taken advantage of these technologies by adapting 2D approaches and developing novel approaches for the analysis of 3D data to quantify tooth shape and infer diet in extinct taxa. In one such approach, my colleagues and I have employed Geographic Information Systems (GIS) analyses to quantify the number of discrete surfaces on cheek-tooth rows by differences in orientation. This measure of ‘dental complexity,’ called Orientation Patch Count (OPC), does not require cusp and facet homologies and thereby enables comparisons of morphologically and phylogenetically divergent taxa. Moreover, we have found a robust correlation between OPC and feeding ecology in several modern placental groups. In turn, we have applied this approach to extinct clades and faunas of early mammals to track temporal patterns of dental complexity and reconstruct diets. For example, we have shown that in multituberculate mammals, the range of dental complexities unexpectedly increased 20 million years before the extinction of non-avian dinosaurs, possibly caused by a shift toward herbivory and in response to the ecological rise of flowering plants. We have also shown that in mammalian faunas across the Cretaceous–Paleogene boundary, extinction selectivity operated against herbivores and in favor of faunivores, consistent with results from other approaches. Thus, application of GIS to fossil teeth holds exciting promise for mammalian paleoecology, but additional work must be done to standardize this approach and test its applicability across other mammalian clades.

Session 38-8: Tuesday, 9:45 AM
Presenter: Stephanie M. Smith

MAMMALIAN DENTAL ECOMORPHOLOGY AND DISPARITY ACROSS THE CRETACEOUS-PALEOGENE BOUNDARY: A COMPARISON OF 3D METRICS

Smith, Stephanie M., Department of Biology, University of Washington, Box 351800, Seattle, WA 98195; Wilson, Gregory P., Department of Biology, University of Washington, Box 351800, Seattle, WA 98195

Dental morphology offers insight into the dietary ecology of extinct mammals. Diet inferences from fossil mammal teeth can be especially useful in elucidating ecological responses to environmental perturbations, such as those causing mass-extinction events. Various measures of dental morphology have been used in the prediction and analysis of feeding ecology in fossil mammals, including two-dimensional (2D) estimates of total shearing-crest length (TSCL) and blade sharpness, as well as three-dimensional (3D) estimates of dental complexity such as orientation patch count (OPC). The merit of previously used 2D metrics has not been fully evaluated in a 3D context. Here, we used high-resolution 3D scans of mammalian cheek teeth across the Cretaceous–Paleogene boundary to test for congruence in patterns of dental ecomorphology and disparity as indicated by a 3D metric (OPC) and a historically 2D metric (TSCL) that we measured in three dimensions. To calculate TSCL, we summed linear measurements of the six principal shearing crests of the lower second molar of eutherians (15 species) and the lower third molar of metatherians (10 species). We compared TSCL with the corresponding OPC values taken from the same lower molar row. Our results indicate that TSCL is negatively correlated with OPC, which positively correlates with herbivory in extant mammals. We also separately considered trigonid crests and talonid crests to further refine our understanding of the relationship of these metrics to OPC. We find that the K–Pg extinction resulted in a significant reduction in the range of TSCL among local survivors, reflecting a loss of diversity in mammalian feeding ecologies. However, an immediate influx of archaic ungulate immigrants following the extinction recovered pre-K–Pg dental disparity and significantly decreased mean TSCL, suggesting a shift toward increased herbivory. These patterns are consistent with previous results from OPC, geometric morphometrics, and dental microwear that reveal K–Pg ecological selectivity, and stress the importance of immigrants in the initial phase of post-K–Pg recovery.

Session 38-9: Tuesday, 10:30 AM
Presenter: Jussi T. Eronen

MAMMAL PROXY METHODS FOR ESTIMATING PRECIPITATION

Eronen, Jussi T., Department of Geosciences and Geography, University of Helsinki, P.O. Box 64, 00014 University of Helsinki, Finland; Fortelius, Mikael, Department of Geosciences and Geography, University of Helsinki, P.O. Box 64, 00014 University of Helsinki, Finland; Puolamäki, Kai, Finnish Institute of Occupational Health, Topeliuksenkatu 41 a A, FI-00150 Helsinki, Finland

Mammals have been used to describe and reconstruct environments in paleontology since the beginning of the discipline. Apart from few studies in recent years, the mammalian fossil record has not been used much to quantify environments using measurable variables. Here we present two novel applications developed by us to quantify the changes in habitats and environments during the Cenozoic (65–2 Ma). The first approach uses the molar crown height of the herbivorous mammals to estimate the precipitation by a regression tree algorithm. The regression trees provide a reasonably accurate estimate of precipitation values for today’s world. The R2 value for the mean annual precipitation is 0.658. The second approach uses both molar crown height and tooth crown morphology to estimate environmental conditions. We show that these two functional traits of herbivore molars can be used to extract reasonable estimates of both rainfall and temperature, i.e., the main climatic determinants of terrestrial net primary production (NPP). Together, molar height and the number of longitudinal lophs explain 73% of the global variation in terrestrial NPP today and resolve the main terrestrial biomes in bivariate space. We demonstrate the performance of our proxy methods by estimating the present-day conditions, and discuss the possible caveats and pitfalls. We also apply our method to fossil material, and compare the output to previous
The rise and decline of the Neogene ungulate fauna of North America has been attributed to environmental changes associated with the Mid-Miocene Climatic Optimum and late Neogene cooling and aridity trends, respectively. On a continental scale, taxonomic diversity patterns are similar among fossil ungulate clades: diversity increases in the early Miocene, peaks in the mid- to late Miocene and declines during the latest Miocene–early Pliocene. Regional patterns differ, however. Horse species richness in the Gulf Coast remained high during the Hemphillian (late Miocene–early Pliocene) North American Land Mammal Age (NALMA) relative to the Great Plains, suggesting persistence of humid and wooded habitats absent in the continental interior. Postcranial ecomorphology should reflect such regional changes in habitat structure with the expectation of greater dissimilarity in morphospace occupation during the Hemphillian. Here, I quantify size and three-dimensional (3D) shape among fossil horse astragali from Florida and Nebraska to track morphospace occupation during the Miocene–Pliocene. 3D digital models of astragali (N=215) from the Hemingfordian (early Miocene), Clarendonian (late Miocene), and Hemphillian NALMAs were generated using a surface laser scanner. 3D semi-landmarks were selected, aligned, and superimposed using an automated subsampling algorithm. A principal components analysis (PCA) was used to find statistically significant PCs of astragalar shape, resulting in a morphospace defined by a size axis and 2 axes of shape. MANOVA results show that, whereas there are no significant regional differences in morphospace occupation during the Hemingfordian and Hemphillian, Clarendonian horse astragali do differ between the regions, counter to expectations. Visualization of PCA results indicates functional differences in astragalar shape related to running gait, such that Florida Clarendonian horses exhibit more characters associated with a gallop gait (e.g., symmetrical trochlea and reduced lateral ligament attachment sites) than their Great Plains contemporaries. Gallop gaits are more often used by modern taxa with open-habitat preferences, suggesting that open habitats were more abundant along the Gulf Coast during the Miocene than previously thought. Overall, these ecomorphological results indicate that greater horse species richness during the Gulf Coast Hemphillian is better explained by greater diversity in dietary resources, a hypothesis supported by regional stable isotope studies of horse dentitions.

**TRANSFORMING MORPHOLOGY WITH MATHEMATICS: CAN MORPHOMETRIC METHODS MODEL EVOLUTION OF COMPLEX MORPHOLOGIES?**

**Polly, P. David,** Department of Geological Sciences, Indiana University, Bloomington, IN 47405

Scanning technology has made it possible to obtain digital representations of complex phenotypes, even entire skeletons. Geometric morphometrics and similar techniques are being extended to deal with these morphologies. They provide tools for direct quantitative analysis of morphologies that could previously only be studied with grossly simplified variables. With these tools, the evolution and development of complex phenotypes can easily be simulated in the same morphospaces that are used for empirical morphometric studies. It is possible to apply standard evolutionary genetic equations for processes such as selection and drift to simulate the evolution of morphology under these conditions, to infer past modes of evolution from phenotypes, or to reconstruct ancestral phenotypes. However, these exciting possibilities raise new concerns: is the order of phenotypes in morphometric space the same as the ordering in developmental or evolutionary transformations? How can the gain and loss of structures be represented in morphometric space? Does real morphology change in the same way that mathematics arranges shapes in morphometric spaces? These questions define the frontiers of quantitative evolution. Here I illustrate issues related to these questions and present possible solutions. ‘Homology-free’ morphometrics has the potential to represent the gain and loss of features in a mathematically tractable way. Phenotypic landscapes, which are mathematical expressions of the non-linear interactions between genotypes, developmental processes, and phenotypes, have the potential of building biological processes into otherwise purely mathematical morphometric spaces. Such developments may be necessary to produce the next generation of tools for studying adaptive landscapes and morphological evolution.

**GETTING BACK TO BASICS: A VIRTUAL DISSECTION OF THE CRANIUM OF MICROSYOPS ANNECTENS (MAMMALIA, EUARCHONTA) USING MICROCT**

**Silcox, Mary T.,** Department of Anthropology, University of Toronto Scarborough, 1265 Military Trail, Toronto, ON, M1C 1A4, Canada; **Bloch, Jonathan L.,** Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

The use of 3D imaging techniques opens up new possibilities for answering questions in paleobiology. Specifically, internal mapping of anatomical features previously only observed on the exterior of crania provides new data to test the homology of structures, including foramina and grooves thought to relate to soft-tissue anatomy by analogy to extant taxa. New interpretations can have a profound effect on anatomical interpretations and emergent hypotheses of the phylogenetic position of fossil species. This study details a virtual dissection of a ~48 million year old cranium of...
Microsops annectens (UW 12362). This is the best-preserved skull known for the Microsyopidae, extinct mammals from the late Paleocene-middle Eocene of North America and the late Paleocene of Europe. The relationships of the Microsyopidae are in debate. There is general consensus that the family is related to Euhesperoidea, the supraordinal grouping that includes Primates, Dermoptera (flying lemurs), and Scandentia (treeswifts). However, opinions differ as to their exact ordinal attribution, with similarities in the teeth suggesting a relationship to Primates, while the cranium has been interpreted as sharing traits with both Primates and Dermoptera. Analysis of new high-resolution microCT data allows for evaluation of numerous details of anatomy relevant to this question. First, tracing the pathway for the facial nerve demonstrates that this structure exited the ear through a stylomastoid foramen primitivum, which contrasts with the situation in Euprimates (and Scandentia), in which this nerve is contained in a bony tube. Second, the microCT data allow the assessment of the position of the lacrimal foramen. Previous workers have suggested that this opening was extraorbital in microsyopids, as in euprimates. However, microCT data demonstrate that the supposed extraorbital lacrimal foramen is a blind pit, and that the lacrimal foramen corresponds to an opening previously identified as the ventral member of a paired infraorbital foramen, in the orbit. As such, microsyopids differ from euprimates in having an infraorbital lacrimal foramen. Third, tracing the boundaries of the bones making up the roof of the middle ear demonstrates that the caudolateral portion of the cranium, suggesting that the form and rostral processes of the petrosal are unexpanded, contrasting in this way from euprimates (and scandentians). On the other hand, one of the traits that microsyopids share with dermopterans is a large, rugose mastoid process. The microCT data reveal that this feature differs between the two groups in its internal structure. Unlike in dermopterans, expansion of the mastoid is not related to inflation of the caudal portion of the cranium, suggesting that the form of the mastoid may represent a convergent similarity. In sum, the microCT data highlight the primitive, and in some cases autapomorphic, nature of the microsyopid cranium, demonstrating that there is no easy answer to the problem of the family’s relationships.

Session 38-13: Tuesday, 11:30 AM
Presenter: Arianna R. Harrington

RECONSTRUCTING THE VIRTUAL ENDOCASTS OF TWO EOCENE PRIMATES FROM HIGH-RESOLUTION X-RAY COMPUTED TOMOGRAPHY DATA

Harrington, Arianna R., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; Silcox, Mary T., Department of Anthropology, University of Toronto Scarborough, 1265 Military Trail, Toronto, ON, M1C 1A4, Canada; Bloch, Jonathan L., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

A large brain-to-body size is often cited as a key characteristic of the order Primates. While numerous natural and latex endocasts of fossil euprimate taxa have previously been described and analyzed, the use of high-resolution x-ray computed tomography (CT) has furthered non-destructive research on the endocasts of specimens with relatively intact crania unsuitable for latex casting. In this study, the high-resolution x-ray CT scans of the crania of two closely related North American notharctine adapiform euprimates from the middle Eocene (Notharctus tenebrosus, AMNH 127167; and Smilodectes gracilis, UM 32773) were processed to yield their virtual endocasts. The endocranial space of each crania was segmented in the image processing program ImageJ (Rashband, 1997–2013), and the resulting slices were stacked in the three-dimensional visualization program Avizo (Visualization Sciences Group, 2007–2013) to generate a high-resolution endocast surface that may be easily manipulated and studied in closer detail. The virtual endocast of AMNH 127167 suggests brain morphology similar to those of known adapiform euprimates, with small frontal lobes compared to extant euprimates and non-overlap of the cerebrum on the olfactory bulbs or cerebellum. AMNH 127167 is also similar to other adapiforms in differing from stem primates in the more globular shape of the temporal and occipital lobes and the more ventral position of the rhinal fissure (separating the neocortex from the paleocortex) relative to stem primates. These contrasts suggest an expansion of the visual centers of the brain had occurred in adapiforms. Preliminarily, the virtual endocast of UM 32773 appears to be fairly similar in general morphology to AMNH 127167, although the former preserves a clear fissura prima that the latter does not. The virtual nature of these endocasts also facilitates the extraction of precise empirical data such as total endocranial volume and olfactory bulb volume. The endocranial volumes were used to calculate each species’ encephalization quotient (EQ), a measure of the brain size to body size of a specimen relative to a typical mammal of its size. The EQ of AMNH 127167 is within the range of other adapiform euprimates, with small frontal and temporal lobes compared to extant euprimates and non-overlap of the cerebrum on the olfactory bulbs or cerebellum. AMNH 127167 suggests that N. tenebrosus had a relatively smaller olfactory bulb than stem primates. These results suggest that early euprimates were beginning to rely less on olfaction and more on vision. As such, these endocasts help to document a fundamental shift in the early evolution of the Order as primates became more visually oriented animals.

Session 38-14: Tuesday, 11:45 AM
Presenter: Ornella Bertrand

ISCHYROMYS TYPUS: FIRST VIRTUAL ENDOCAST OF A FOSSIL RODENT

Bertrand, Ornella C., Anthropology Department, University of Toronto, 19 Russell Street, Toronto, ON M5S 2S2, Canada; Silcox, Mary T., Department of Anthropology, University of Toronto Scarborough, 1265 Military Trail, Toronto, ON, M1C 1A4, Canada

Rodents are one of the most diverse groups of living mammals, and are commonly used as model organisms in experimental work. However, the diversity of external brain morphology present in the order is not well characterized. With the help of digitization technology, this study is one of the first attempts to understand brain evolution in rodents.
Ischyromyidae is one of the oldest rodent families (late Paleocene to late Oligocene), either at the base of Rodentia, or to the ancestor to some modern families such as Sciuridae and Aplodontidae. The genus *Ischyromys* is one of the better represented rodents of the North American Oligocene, known from postcranial and cranial material. Using the high resolution X-ray computed tomography scanner from the Shared Materials Instrumentation Facility (SMIF) at Duke University, the skull of *Ischyromys* was scanned with a source-object distance of 229.08 mm and energy settings of 155 kV and 0.186 mA. A total of 1204 slices were reconstructed using 2300 views with an interslice spacing and interpixel distance of 0.039 mm, stored as 16-bit tiffs, resulting in a 2.31 GB dataset. Segmentation of the dataset and interpixel distance of 0.039 mm, stored as 16-bit tiffs, resulting in a 2.31 GB dataset. Segmentation of the dataset was completed in ImageJ, and a virtual endocast reconstructed in Avizo 7.0. This constitutes the first virtual endocast described for a fossil rodent, and provides the first reconstructed as *Avizo* 7.0. This constitutes the first virtual endocast described for a fossil rodent, and provides the first quantitative data known for any fossil rodent endocast. Total volume of the *Ischyromys typus* virtual endocast is 5.6 cm³. Body mass was estimated at 1330g by generating regression equations for two cranial measurements (skull length and length of the palate without incisor) from a large sample of living rodents (N=192). The encephalization quotient (EQ) was estimated at 0.38 with Jerison’s equation and 0.55 with Eisenberg’s equation. The olfactory bulb volume is 1.8 cm³, which corresponds to 3.12% of the total volume of the brain. Those values were compared with data from extinct members of the closely related rodent suborder Sciuromorpha, which exhibit a large range of ecological habits from terrestrial to arboreal. *Ischyromys typus* has been reconstructed as terrestrial, and had an EQ similar to living terrestrial sciuromorphs, but lower than arboreal and gliding members of the group, suggesting a correlation between high EQ and arboreal habits in rodents. Two natural endocasts assigned to *I. typus* were compared with the virtual specimen. The virtual endocast has a longer circular fissure compared to the natural ones. The cerebrum does not cover the cerebellum in any of the endocasts, so that the confluence of sinuses covers the colliculi in all fossil endocasts. This condition is seen in *Aplodontia* (extant terrestrial sciuromorphs), but contrasts with the condition in the arboreal rodents *Sciurus* and *Glaucomys*, in which the cerebrum covers the rostral colliculi. This result suggests an expansion of the cerebrum may be correlated with arboreality in rodents.

Session 38-15: Tuesday, 12:00 Noon
Presenter: Stephanie Baumgart

**AIR VERSUS BONE IN THE WING SKELETON OF A PTEROSAUR**

**Baumgart, Stephanie L.,** Organismal Biology and Anatomy, The University of Chicago, 1027 E 57th St., Chicago, IL 60637

Pterosaur fossils are often crushed during preservation, yielding little information about three-dimensional or internal structure. Although internal air-filled pneumatic spaces have been described in pterosaur vertebrae, little is known about such spaces within the wing skeleton. The wing skeleton is composed of exceptionally thin-walled long bones that resemble avian bones with well-developed pneumatic spaces. A partial forelimb of an ornithocheirid pterosaur was discovered in Early Cretaceous rocks in Niger, and preserves much of a wing in articulation, including the minor digits of the manus. Computed tomographic (CT) scans were used to visualize in three dimensions the interior of these bones, and reconstruct pneumatic spaces and potential cross-joint interconnections. The long bones and the bones of the minor digits are hollow, and may have been connected in series by pneumatic diverticulae. Using standard mass estimates for bone, the mass of the middle and distal portions of the wing skeleton of the Niger pterosaur is estimated and compared to the equivalent portion of the wing skeleton of a vulture. Birds developed a more limited pneumatic air-sac system in the wing skeleton, often involving only the humerus. As vultures spend considerable time soaring and gliding, their flight style is similar to that of a large pterosaur. This comparison will shed light on the corresponding skeletal mass devoted to the wing skeleton between pterosaurs and birds, and may help to explain how pterosaurs were able to achieve extraordinary body size as powered fliers.
isotopic ratios derived from micro-sampling of shell increments validate the observational data. The isotopic data also confirm a similar pattern in archaeological hard-clam assemblages collected from adjacent coastal shell midden sites spanning the last 1,700 years. With these data in hand, it was possible to evaluate the ontogenetic age structure and survivorship patterns for both the modern and archaeological hard-clam populations as well as the season of harvest for the archaeological shells. The data indicate all of the zooarchaeological shells were harvested during the winter and spring seasons. Harvesting pressure was most intense between 1690 B.P. and 560 B.P., when hard clams were consumed at a high rate. The mean ontogenetic age class composition declined from 7.8 years to 3.2 years over this interval. After 560 B.P., harvesting pressure relaxed and the survivorship of the hard clam assemblages rebounded, with the mean ontogenetic age rising to 7.9 years. This pattern of intense Pre-Hispanic exploitation of hard clams appears to have occurred more than once and in many locations throughout the Southeast, indicating baseline population structures have shifted dramatically throughout the past two millennia. Carbon isotope data also reveal anthropogenic influences reflected in modern shells. Where there is evidence for dense human populations, sedentism, or in places where hard clams represent a major target taxon in subsistence behavior, annual shell increments reveal depressed mean ontogenetic age classes and altered survivorship patterns. This study illustrates the potential role annual shell increments may play in elucidating population dynamics in fossil mollusks from ancient paleoecologic contexts.

Session 39-2: Tuesday, 8:30 AM

Presenter: Simon Schneider

BIOTIC CONTROL OF (LOW) BIODIVERSITY IN RUDIST BIVALVE REEFS—AN EXAMPLE FROM THE TITHONIAN OF AUSTRIA

Schneider, Simon, CASP, University of Cambridge, West Building, 181A Huntingdon Road, Cambridge, CB3 0DH UK; Harzhauser, Mathias, Naturhistorisches Museum Wien, Burgring 71010 Vienna, Austria; Kroh, Andreas, Naturhistorisches Museum Wien, Burgring 71010 Vienna, Austria; Lukeneder, Alexander, Naturhistorisches Museum Wien, Burgring 71010 Vienna, Austria

It is generally regarded that rudist bivalve reefs harbor a comparably low biodiversity of associated biota. However, while rudist associations themselves have been intensely studied, the interaction of these bivalves with other organisms has been less frequently addressed. Rigorous assessment of biodiversity in rudist reefs is generally lacking. Extending from an example from the Tithonian (Late Jurassic) Ernstbrunn Limestone from the Alpine-Carpathian transition area in Austria the present study tries to assess the low biodiversity in rudist reefs, and investigate into its causes. Vertical sections of a large block of reefal Ernstbrunn Limestone have been polished and scanned for rudist (Heterodiceras, Epidiceras) and non-rudist fossils, employing investigation under UV light. Additionally, (semi-)quantitative collections of reworked Tithonian fossils from karst fissures are evaluated. The observed low biodiversity in the epideridic rudist reefs contrasts with a generally high biodiversity in the lagoonal facies of the Ernstbrunn Limestone. The study of in-situ reefs and thin section analysis show that, apart from congeners, epideridic rudist shells are neither overgrown nor significantly encrusted by other organisms during life. The case study is supplemented by a review of the literature on associations of rudists and some of their potential forerunners. Since environmental factors can usually be ruled out, the impression is gained that, as a kind of an ecologic autapomorphy, rudists actively diminished biodiversity in their immediate surrounding. Because bivalves hardly have mechanical abilities of self cleaning and defense, it is proposed that rudists were capable of producing effective biochemical deterrents.

Session 39-3: Tuesday, 8:45 AM

Presenter: Adiël A. Klompmaker

ARE RIBS ON BIVALVES EFFECTIVE AGAINST GASTROPOD DRILLING PREDATION?

Kломpmaker, Adiël A., Florida Museum of Natural History, University of Florida, 1659 Museum Road, PO Box 117800, Gainesville, FL 32611; Kelley, Patricia H., Department of Geography and Geology, University of North Carolina Wilmington, Wilmington, NC, 28403

Ornamentation on bivalve shells has been suggested to be important in maintaining a stable life position in the sediment, for burrowing purposes, and as a protection against predators. One type of common ornamentation is concentric ribs. To test the effectiveness of such ribs against drilling predation, we examined drill-hole size, position, and completeness for four Cenozoic bivalve species that differ in coarseness of ribs (Astarte radiata, A. goldfussi, Lirophora glyptocyma, and L. latilirata, ordered by increasing rib strength). Shell length and thickness, rib thickness, and position of complete and incomplete drill holes with respect to ribs were recorded, and drilling frequencies (DF) were determined for the two species of Astarte, both from the same locality and stratigraphic age. Interspecific comparisons were conducted at a standardized shell length (5.1–10.0 mm). The drilling frequency for shells of A. radiata within this size range is 0.343, whereas DF is significantly lower for stronger ribbed shells of A. goldfussi (0.271). Results indicate that the percentage of drill holes located between the ribs increases with increasing rib strength, whereas the percentage of drill holes on top of ribs decreases. These results suggest that natural selection favors gastropods that select drill-hole sites between the ribs, thus saving time and energy, as rib strength increases. Because of this greater stereotypy as rib strength increases, the percentage of drill holes that are incomplete is generally lower in strongly ribbed species. The proportion of drill holes that are located on top of ribs is greater for incomplete than complete holes, implying that ribs can be effective against predators, but only when selected as the drilling location. The outer drill-hole diameter is smaller for incomplete drill holes, suggesting that younger individuals produced these holes. This study shows that ribs are most effective against drilling predation for bivalves with moderately sized ribs, between which gastropods have difficulty siting drill holes. Gastropods are more likely to select a drill-hole site between ribs for species with coarser ribs.
 Session 39-4: Tuesday, 9:00 AM
Presenter: Robyn Dahl

**BELLEROPHONTID GASTROPODS OF THE MIDDLE ORDOVICIAN KANOSH SHALE**

Dahl, Robyn M., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521; Droser, Mary L., Department of Earth Sciences, University of California-Riverside, 900 University Ave, Riverside, CA 92521

A well-studied fossil assemblage is preserved in the Middle Ordovician Kanosh Shale of the Basin and Range Province in the Western United States. While this assemblage is dominated by and most well known for its brachiopod- and ostracod-dominated shellbeds, the Kanosh Shale also contains a diversity of gastropod taxa, including a horizon of well-preserved bellerophontid gastropods. This horizon occurs as 15 cm-thick wackestone within a black-shale dominated member of the Kanosh. This interval is interpreted to represent deposition in deep, low oxygen conditions, and gastropods are the only macrofauna present, suggesting adaptation to this environment. While bellerophontid gastropods are not uncommon in Ordovician assemblages, this deposit provides a unique taphonomic window into the clade’s poorly understood paleoecology.

Session 39-5: Tuesday, 9:15 AM
Presenter: Cristina Robins

**AN OVERVIEW OF FOSSIL SQUAT LOBSTERS (DECAPODA: ANOMURA: GALATHEOIDEA)**

Robins, Cristina M., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

Numerous studies focusing on the phylogeny of anomuran clades have cast a spotlight on the large gaps in their fossil record. Within the Anomura, galatheoids, commonly called squat lobsters, have a cosmopolitan geographic distribution, with around 900 extant species described. Their fossil record, which extends to the Middle Jurassic, has fewer than 150 species described. Approximately half of the known fossil species are from two formations in the Late Jurassic (Tithonian): the Ernstbrunn Limestones of Austria and the Stranberk Limestones of Poland and the Czech Republic. All four families within Galatheoidea have their first representatives in the Mesozoic, and they coexisted in coralgal reef environments within the shallow-water Tethyan seas. Today, modern galatheoids are separated by depth gradients within the oceans. Typically, munidopsids inhabit abyssal plains and hydrothermal vents, munidids occupy outer slope areas, galatheids live in reefal environments, and porcellanids populate both reefs and rocky intertidal areas. Mapping the change in diversity across time, as well as the changing environmental preference, paints an intriguing picture.

Session 39-6: Tuesday, 9:30 AM
Presenter: Alexander Nützel

**PALEOBIODIVERSITY OF THE CASSIAN**

Session 39-7: Tuesday, 9:45 AM
Presenter: George D. Stanley Jr.

**CORAL AND REEF EVOLUTION DURING BIOTIC REORGANIZATIONS OF THE LATE TRIASSIC**

Stanley Jr., George D., University of Montana Paleontology Center, 32 Campus Drive, Missoula, MT 59812; Roniewicz, Ewa, Institute of Paleobiology, Polish Academy of Sciences, Institute of Paleobiology, ul. Twarda 51/55, PL-00-818, Warsaw, Poland

Scleractinia appeared during the Middle Triassic, 7–8 million years after the end of the Permian, and were components of reefs of that time. They were not significant as reef builders until the Late Triassic, a time which coincided with dramatic increases in reef diversity. Exact timing of a world-wide, late Carnian–early Norian reorganization or diversification event among reef-building corals and sponges has remained poorly
known. Higher-resolution conodont dating in the Alps helped pinpoint it more accurately as an intra-Norian event, mostly likely Laciain to Alumunian 1. Coral diversity of that time reached 50 genera, with representatives in the Hexanthiniaria, Volzetoidea, and Coryphellidae. Paleogeographic isolation and paleoecologic setting may account for some differentiation between Tethys and eastern Panthalassa. The biotic turnover leading up to this Norian event has been interpreted as a mass extinction, and occurred not only among corals but in other reef groups as well. In the late Norian to Rhaetian interval, corals exceeded sponges as reef builders, but were marked by a drop in diversity, domination by Reimaniphylliidae, Pamiroseriidae, and Stylophyllidae, and extinction or severe reduction of corals of the previous group. Biotic and physio-chemical events at or near the end of the Triassic removed most of that diversity, leading to a reef ecosystem collapse and global reduction of carbonate sediments. Only a handful of Triassic corals survived into the Early Jurassic, and these were of low diversity and inhabited mostly non-reef settings. Taxonomic study is incomplete, but among 25 Late Triassic coral families, only seven survived into the Jurassic and these contained only one or two genera. Unlike corals of the Triassic, solitary or simple growth form predominated during the earliest Jurassic. The evolution of photosymbiosis between corals and algal hosts and the severance of this ecologic relationship was proposed to explain coral diversity, evolution of reef building, collapse and rebuilding, but issues may be more complicated than previously thought, and questions still need to be resolved to test this hypothesis.

Session 39-8: Tuesday, 10:30 AM
Presenter: Lee E. Monnens

A PRELIMINARY REPORT ON A DINOSAUR TRACK SITE AT THE GREENBELT NASA GODDARD SPACE FLIGHT CENTER, ELK NECK BEDS (INFORMAL), BASAL UPPER CRETACEOUS (LOWER CENOMANIAN), ATLANTIC COASTAL PLAIN OF MARYLAND

Monnens, Lee E., Parsons Corporation, 1776 Lincoln Street, Denver, CO 80203

A basal Late Cretaceous dinosaur track site was discovered in part of the informally named Elk Neck beds exposed on the campus of the NASA Goddard Space Flight Center, Greenbelt, Maryland. The tracks are preserved in an ironstone layer that grades downward into unconsolidated cross-beded fine grained sand sediments. At least four different kinds of tracks are preserved during this unique window of time when animals were traversing the area in an east-west direction.

Session 39-9: Tuesday, 10:45 AM
Presenter: Dhurjati Prasad Sengupta

DIVERSITY AND EXTINCTION OF THE TRIASSIC TEMNOSPONDYLs OF INDIA

Sengupta, Dhurjati Pr., Geological Studies Unit, Indian Statistical Institute, 203 Barrackpore Trunk Road, Kolkata, 700108, India

India is rather rich in fossil remains of several families of Triassic temnospondyl amphibians. India has records of brachyopids, lydekkerinids, rhytidosteids, metoposaurids, mastodonsaurids, lapillopsids, trematosaurids, and chigutisaurids. Reports of possible benthosuchids, rhinesuchids, and tupilakosaurus remains are also there. Recently a new plagiosaurus has been described from Indian Early Triassic sediments. Notable absentees are the almasaurids, luzecephalids, thoosuchids, and various triangular skull bearing morphs such as Laidleria, Deltasaurus, Mahavisaurus, and Pelostega. Both the families that are present or absent in India had global distributions. During the Triassic, India’s position was at the circum-Tethyan region, almost equidistant from the centers of Laurasia and Gondwana. This may help in explaining the presence of several Pangean families in India. The absence of other Pangean families is enigmatic. There are possibilities of recovering fossils of those families from India in future. On the other hand, the Early Triassic temnospondyls of India were most diversified, with at least five different families and few are yet to be identified. The Middle Triassic had four different genera of mastodonsaurids. The Late Triassic had two families, and one is replaced by the other at the Carnian–Norian Boundary. The Carnian land vertebrate fauna, of the Late Triassic Maleri Formation (Pranhita, Godavari River basin, India), was very cosmopolitan and had xanacanthid, ptychoceratodontid, and ceratodontid fishes, temnospondyl amphibians like the metoposaurids and among the amniotes rhynchosaurids, prolacertids, phytosaurids, aetosaurids, unidentified saurischians, therapsids, and cynodontids in the lower part. This is overlain by the early Norian fauna of upper Maleri, where the metoposaurids were replaced by chigutisaurids, phytosaurids are represented by advanced taxa, and rhynchosaurids, prolacertids and cynodontids became extinct. The saurischians were also replaced by a different taxon. Hence the Carnian–Norian boundary in India witnessed a major extinction event. The chigutisaurids that replaced the metoposaurids at the boundary became extinct by the early Norian. Overall, the temnospondyl fauna of India failed to reach the Rhaetian. The Hettangian fauna is a new fauna, where none of the phytosaur, rhynchosaur, aetosaur, and temnospondyls were present, and it indicates the beginning of the Jurassic in India.

Session 39-10: Tuesday, 11:00 AM
Presenter: F. J. Rich

MASTODON, HEMLOCK AND FRESHWATER WETLANDS—NEW EVIDENCE OF TERRESTRIAL ENVIRONMENTS ALONG THE COASTAL ZONE OF THE SOUTHEASTERN US

Rich, Fredrick J., Department of Geology and Geography, Georgia Southern University, P.O. Box 8149, Statesboro, GA 30460; Smith, Kathryn M., Department of Geology and Geography, Georgia Southern University, P.O. Box 8149, Statesboro, GA 30460

A new American mastodon site was discovered in a dried creek bed in North Charleston, SC, an area that was within the proposed late Pleistocene thermal enclave of southeastern North America. The site produced a tusk, both mandibles, three molars, a humerus, four vertebrae, and several ribs.
from a single individual. The mastodon is male, based on femur size and tusk circumference, and died between 43 and 47 years of age, based on molar wear and stage of molar eruption. Sediment surrounding the fossil was brownish-gray silt-to-granule sized, indicative of a fluvial/overbank depositional environment. Palynological analysis revealed palynomorphs of probable northern, southeastern coastal plain, and freshwater origins (e.g., *Pinus resinosa*, *Tillandsia usneoides*, and *Myriophyllum* sp., respectively). Pollen from what are believed to be similarly aged strata have been reported from Reid’s and Bell’s bluffs, on the Georgia–Florida state line, and from the Central Depression on St. Catherines Island, GA. Northern taxa include *Tsuga* (hemlock) from the Florida locales, and *Tilia* (basswood) and *Juglans* (walnut/butternut) from the island. *Polygonum* (jointweed), *Nuphar* (yellow waterlily), and abundant grasses and composites indicative of freshwater marshes have also been recovered from strata of the Central Depression. The three sites had to have been inland locales during the late Pleistocene. What is less understood is the degree of patchiness of these two habitats, and if there were any large areas of either closed or open habitats. While some of the vertebrate localities found subsequently have a similar makeup, others are quite different. The Rainbow River (RR) locality in Marion County and the Millenium Park (MP) Site in Pinellas County are two newly collected, rich vertebrate faunas, both with > 3,000 identifiable specimens. At RR, large browsing mammals outnumber grazers by a ratio of 9.3, the largest known value among 18 studied faunas in Florida. RR also produced large numbers of freshwater fish, aquatic salamanders, turtles, and snakes, water birds, and the aquatic rodent *Neofiber aleni*. The RR landscape is interpreted as a large body or bodies of permanent water with surrounding wetlands and closed forest. In contrast, at MP, large grazing mammals outnumber browsers by a ratio of 7.6; it has relatively fewer browsers than any other known Rancholabrean fauna in Florida. Other components of the MP fauna likewise differ from those found at RR or even sites such as Melbourne: freshwater taxa are rare, and those that are present are mostly small-bodied; terrestrial turtles and tortoises (*Terrapene, Hesperotestudo*, and *Gopherus*) are very common; and the small mammal fauna is dominated by the cotton rat *Sigmodon hirsutus*, which today is most numerous in grasslands and other open habitats. The MP landscape is interpreted as a dry prairie with ephemeral ponds. Although RR and MP represent the extreme cases, there are others like them, with forested habitats mostly in northern Florida, and prairie more widespread in southwestern Florida.

Session 39-12: Tuesday, 11:30 AM

Presenter: Paul E. Morse

CHANGES IN BODY SIZE AND DENTAL DEVELOPMENT IN MAMMALS DURING THE PALEOCENE-EOCENE THERMAL MAXIMUM OF THE BIGHORN BASIN, WY

Morse, Paul E., Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; *Wood, Aaron R.*, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611; *Bloch, Jonathan I.*, Florida Museum of Natural History, University of Florida, 1659 Museum Road, P.O. Box 117800, Gainesville, FL 32611

The Paleocene–Eocene Thermal Maximum (PETM) was a brief period of significant global climate change that occurred ~56 Ma, with a rapid increase in temperature of ~5-10°C, followed by a return to pre-PETM temperatures. One major biotic effect of the PETM was dwarfing in mammal lineages that then increased in size after the PETM. Our study utilized fossils from a well-constrained stratigraphic sequence that allows for evaluation of morphological trends over the course of the PETM. We
asked: 1) how tightly correlated are body-size shifts in mammal lineages, and 2) do we see differences in tooth development patterns in lineages as they shift from smaller to larger body size? We first measured linear dimensions of M1 in specimens of two ecomorphologically similar genera that experienced dwarfing in the PETM and body size increase thereafter: the phenacodontid *Ectocion* (n=65), and the equid *Sifrhippus* (n=49). The smallest specimens in both lineages occur at the same stratigraphic level, and are closely followed by larger specimens. A moving window log-rate-interval analysis found a significant decrease in size in both lineages during the PETM, a significant increase in size in *Ectocion* after the PETM, and constrained the termination of the decrease in size in both lineages to a 50 kyr interval. These findings suggest that body-size change in these lineages is tightly correlated. To test our second question, we compared relative sizes of molars in dentaries between small-sized species from the PETM, *E. parvus* (n=25) and *S. sandrae* (n=12), and large-sized species that followed the PETM, *E. osbornianus* (n=103) and *S. grangeri* (n=84). Bootstrap analyses and ANCOVA of log-corrected molar areas found significant differences in relative tooth sizes. *S. grangeri* showed a higher ratio of M2/M1 area and M3/M2 area, but no change in slope from *S. sandrae*. Under an inhibitory cascade model of tooth development, this is consistent with decreased anterior molar inhibition leading to expanded posterior tooth size in *S. grangeri*. *E. osbornianus* showed no change in the ratio or slope of M2/M1 from *E. parvus*. Yet, the M3/M2 ratio was increased and had a significantly different slope, indicating that development in the M3 was altered without a concurrent effect on the anterior molars and suggesting different dental developmental integration in *Ectocion*. Data from modern taxa suggest that feeding ecology may be an important control on the activator/inhibitor ratio during dental development. We infer that climate-induced changes in feeding ecology invoked different evolutionary pathways of tooth development in these taxa. Geometric morphometric analyses of occlusal morphology are underway to detect potential functional shape changes associated with the altered developmental processes.
* = presenter

Abbott, Richard, Session 3-4, p. 18
Abderamane, Moussa, Session 27-13, p. 135
Adrain, Tiffany S., Session 21, Poster 35*, p. 94; Session 25-5*, p. 104
Al-Qattan, Nasser M., Session 20, Poster 33*, p. 92
Aldridge, Anthony E., Session 10-7, p. 45
Alford, Aaron A., Session 25-11, p. 125; Session 25-16*, p. 127
Allen, Sarah E., Session 3-1*, p. 17; Session 3-2, p. 17
Allmon, Warren D., Session 4-8*, p. 24
Amaral, Cesar R.L., Session 7, Poster 4, p. 32
Amatangelo, Kathryn L., Session 12-7, p. 53
Amorosi, Alessandro, Session 37-7*, p. 166; Session 37-8, p. 166
Anderson, Brendon M., Session 4-8, p. 24
Anderson, Evan P., Session 29-10*, p. 142
Anderson, Laurie C., Session 5-4, p. 27
Andre, Thomas, Session 25-9, p. 106
Andres, Brian, Session 6, Poster 1, p. 31
Angielczyk, Kenneth D., Session 26-12, p. 130
Antoine, Pierre-Olivier, Session 10-4, p. 43
Archibald, Bruce, Session 25-12, p. 125
Arenzo, Monica, Session 10-5, p. 44
Arison, Richard B., Session 5-8, p. 28; Session 13-10*, p. 61
Astrop, Timothy I., Session 28-7*, p. 118
Atkinson, Benjamin K., Session 13-3*, p. 58
Aubry, Marie-Pierre, Session 28-9, p. 119
Auffenberg, Kurt, Session 18, Poster 30*, p. 92
Baczynski, Allie A., Session 26-15, p. 131
Badgley, Catherine, Session 9, Poster 26, p. 41; Session 27-1*, p. 112
Bailey, Jake V., Session 29-2, p. 120
Balk, Meghan A., Session 12-3, p. 52; Session 17-6*, p. 90
Bantel, Thomas E., Session 29-15, p. 144; Session 34, Poster 68, p. 154
Bapst, David W., Session 11-6*, p. 48
Barber, Bruce, Session 2-7, p. 15
Barboni, Doris, Session 27-13, p. 135
Barclay, Kristina M., Session 11-8*, p. 49
Barclay, Richard S., Session 26-15, p. 131
Barreda, Davide, Session 14-8, p. 66
Barrett, James H., Session 9, Poster 23, p. 40
Barron-Oritz, Christian, Session 27-18, p. 137
Barry, John C., Session 9, Poster 26, p. 41; Session 27-1, p. 112
Barry, Savanna, Session 24, Poster 50, p. 101
Bartley, Julie K., Session 29-8*, p. 123
Bass, Davide, Session 1-9, p. 12
Batchelor, Cameron J., Session 26-2, p. 108; Session 35, Poster 71, p. 155
Bates, Steven M., Session 11-16, p. 75
Beerling, David J., Session 27-15, p. 136
Behrensmeyer, Anna K., Session 1-2, p. 8; Session 1-3, p. 9; Session 1-5, p. 10; Session 9, Poster 26, p. 41; Session 12-7, p. 53; Session 27-1, p. 112; Session 29-1*, p. 120
Belanger, Christina L., Session 26-7*, p. 110
Benayahu, Yehuda, Session 29-9, p. 123
Bender, Heather L., Session 2-9*, p. 16
Bengston, Stefan, Session 11-11*, p. 50
Benjamini, Chaim, Session 13-16, p. 80
Berggren, William A., Session 7, Poster 7, p. 33
Bertrand, Ornella C., Session 38-14*, p. 175
Betzn er, Tristan, Session 5-5*, p. 27
Bhattacharya, Dipen, Session 15-4, p. 69
Bjonerud, Marcia G., Session 35, Poster 73, p. 156
Blake, Daniel D., Session 5-8, p. 28
Blake, Ruth E., Session 29-6, p. 122
Blok, Jonathan I., Session 7, Poster 5, p. 32; Session 7, Poster 9, p. 34; Session 26-17, p. 132; Session 37-2, p. 164; Session 38-12, p. 174; Session 38-13, p. 175; Session 39-12, p. 180
Blos, Jessica, Session 12-7, p. 53
Blondel, Cécile, Session 27-13, p. 135
Blume, Thomas, Session 25-5, p. 104
Bobe, Rene, Session 1-5, p. 10
Bohaty, Stephen M., Session 28-17, p. 141
Bonanni, S. I., Session 13-18, p. 81
Bonde, Niels, Session 3-7*, p. 19; Session 7, Poster 4, p. 32
Bord, David, Session 28-9*, p. 119
Bosch, Stephanie, Session 8, Poster 15, p. 36
Bosellini, Francesca R., Session 4-1, p. 22
Bottjer, David J., Session 23, Poster 49, p. 101; Session 26-9*, p. 111
Bourque, Jason R., Session 39-11, p. 180
Bown, Gabriel J., Session 26-15, p. 131
Bown, Paul R., Session 28-18, p. 141
Boyer, Diana J., Session 26-3, p. 109
Brandt, Danita S., Session 15-10*, p. 72; Session 15-11*, p. 72
Brasier, Martin D., Session 36-3, p. 159; Session 36-11, p. 162
Brett, Carlton E., Session 29-15, p. 144; Session 31, Poster 58, p. 149; Session 37-3, p. 164
Briggs, Derek E.G., Session 11-13, p. 73; Session 29-6, p. 122; Session 31, Poster 55, p. 148
Brightly, William H., Session 8, Poster 10*, p. 34
Brito, Paulo M., Session 7, Poster 4, p. 32
Broce, Jesse, Session 29-13*, p. 143
Brock, Glenn A., Session 2-10, p. 16
Brooks, Gregg R., Session 2-7, p. 15
Brown, Amanda R., Session 2-4, p. 14
Brown, Garett M., Session 32, Poster 60*, p. 150
Brown, Russell D., Session 34, Poster 70, p. 155
Brunet, Michel, Session 27-13, p. 135
Bryan, Jon, Session 4-7*, p. 24
Bucher, Hugo, Session 13-22, p. 83
Buckler, Carolyn S., Session 25-17, p. 127
Budd, Ann F., Session 4-1*, p. 22; Session 26-8, p. 111
Bulimski, Katherine V., Session 15-8*, p. 71; Session 32, Poster 61*, p. 151
Burke, Janet E., Session 9, Poster 26*, p. 41
NAPC AUTHOR INDEX

Sibert, Elizabeth C., Session 28-11, p. 138; Session 28-12*, p. 139
Sidor, Christian A., Session 26-12*, p. 130
Sievers, Friedrich, Session 11-9*, p. 49
Silcox, Mary T., Session 38-12*, p. 174; Session 38-13, p. 175; Session 38-14, p. 175
Silveira, Emily L., Session 2-4, p. 14
Simmons, Nancy B., Session 14-13, p. 85
Simons, Erika H., Session 8, Poster 16*, p. 37
Simson, Carl, Session 12-4*, p. 52
Sims, Hallie J., Session 21, Poster 35, p. 94
Singer, Amy E., Session 37-4*, p. 165
Slapcinsky, John, Session 18, Poster 30, p. 92
Slattery, Joshua S., Session 6, Poster 1, p. 31; Session 8, Poster 17*, p. 38; Session 32, Poster 60, p. 150
Smith, Dena M., Session 13-7*, p. 59; Session 25-10*, p. 107; Session 29-10, p. 142
Smith, Felisa A., Session 12-9*, p. 54
Smith, Jansen A., Session 13-23*, p. 83
Smith, Kathryn E., Session 13-10, p. 61; Session 37-6*, p. 165; Session 39-10, p. 179
Smith, Kimberly J., Session 27-5, p. 114
Smith, Nathan D., Session 4-1, p. 22
Smith, Roger M.H., Session 26-12, p. 130
Smith, Selena Y., Session 27-5, p. 114; Session 27-6*, p. 114; Session 27-7-7, p. 115; Session 27-8, p. 115
Smith, Stephanie M., Session 38-8*, p. 173
Smrecak, Trisha A., Session 15-11, p. 72; Session 25-17, p. 127
Snyder, Daniel, Session 33, Poster 66*, p. 153
Solon, Christine M., Session 11-2*, p. 46
Solounias, Nikos, Session 27-18, p. 137
Soto, Luis P., Session 24, Poster 51*, p. 102
Souto, Paulo R.E., Session 37-12*, p. 168
Srivastava, Ashwini, Session 16-6*, p. 88; Session 23, Poster 48*, p. 100
Stanley Jr., George D., Session 37-4*, p. 165; Session 39-7*, p. 178
Starmer, John, Session 18, Poster 29*, p. 91
Steadman, David W., Session 12-14, p. 77; Session 39-11, p. 180
Stemann, Thomas A., Session 4-5*, p. 23
STEPPE Executive Director, Session 26-1*, p. 108
Stenberg, Michael E., Session 25-12*, p. 125
Still, Christopher, Session 27-15, p. 136
Stilson, Kelsey T., Session 29-18*, p. 145
Storrs, Glenn W., Session 25-2*, p. 103
Strömberg, Caroline A.E., Session 27-5, p. 114; Session 27-6, p. 114; Session 27-7, p. 115; Session 27-8, p. 115; Session 26-16*, p. 132; Session 27-15, p. 136; Session 28-13, p. 139
Stull, Gregory W., Session 3-2*, p. 17
Sumrall, Colin D., Session 7, Poster 6, p. 33
Sun, Chengkai, Session 16-4, p. 87
Surge, Donna, Session 9, Poster 22, p. 39; Session 9, Poster 23*, p. 40
Suttner, Thomas J., Session 26-2, p. 108; Session 35, Poster 71, p. 155
Sutton, Mark D., Session 38-3*, p. 171
Swart, Peter, Session 10-5*, p. 44
Swift, Sandra L., Session 16-4, p. 87
Syme, Caitlin E., Session 29-3*, p. 121
Syverson, V. J., Session 8, Poster 18*, p. 38
Tabor, Neil J., Session 26-12, p. 130
Tacker, Christopher, Session 30, Poster 52, p. 147
Tang, Qing, Session 29-14, p. 143
Tao, Kai, Session 4-6, p. 23; Session 5-3, p. 26
Tarhan, Lidya G., Session 36-7*, p. 160; Session 36-10, p. 162
Taylor, Lyla L., Session 27-15, p. 136
Tejada-Lara, Julia V., Session 10-4*, p. 43
Terry, Rebecca C., Session 13-8*, p. 60
Thatje, Sven, Session 13-10, p. 61
Theodorou, Evangelos G., Session 8, Poster 19, p. 38; Session 38-6, p. 172
Theodorou, Georgios E., Session 8, Poster 19*, p. 38; Session 38-6*, p. 172;
Thomas, Daniel B., Session 29-17, p. 145
Thomka, James R., Session 29-15*, p. 144
Thompson, Jeffrey R., Session 23, Poster 49*, p. 101
Ting, Su-yin D., Session 7, Poster 2, p. 31
Todd, Jonathan A., Session 12-17*, p. 78; Session 26-8, p. 111
Toler-Franklin, Corey, Session 38-2*, p. 170
Toljagic, Olja, Session 22, Poster 46*, p. 100
Tomasovych, Adam, Session 1-8*, p. 11
Toomey, Heidi M., Session 2-2*, p. 13
Toth, Aniko B., Session 1-2*, p. 8; Session 1-3, p. 9
Toth, Nicholas P., Session 8, Poster 13, p. 35
Townsend, Beth, Session 7, Poster 8, p. 34
Trusler, Peter, Session 14-2, p. 63
Twitchett, Richard J., Session 12-15, p. 77; Session 26-5, p. 109
Tyler, Carrie L., Session 1-6*, p. 10
Uemura, Kazuhiko, Session 14-12, p. 85
Uhen, Mark D., Session 37-6, p. 165
Valenciano, Javier, Session 20, Poster 34, p. 93
Vasilopoulos, Theodoros K., Session 8, Poster 19, p. 38; Session 38-6, p. 172
Velez-Juarbe, Jorge, Session 3-8*, p. 20
Vickers-Rich, Patricia, Session 14-2, p. 63
Viotti, Laura A., Session 29-2*, p. 120
Vignaud, Patrick, Session 27-13, p. 135
Villarosa Garcia, Marites, Session 26-7, p. 110
 Villasenor, Amelia, Session 1-3, p. 9
Virgos, Emilio, Session 20, Poster 34, p. 93
Visaggi, Christy C., Session 13-15, p. 79; Session 21, Poster 42*, p. 98
Vitek, Natasha S., Session 21, Poster 43, p. 98
Vos, Stephanie C., Session 13-10, p. 61
Wade, Bridget S., Session 2-11, p. 17; Session 26-6, p. 110
Wall, Alexander F., Session 15-5, p. 70; Session 25-17, p. 127
Wallace, Steven C., Session 13-2, p. 57; Session 16-3, p. 87
Waller, Lyla L., Session 27-15, p. 136
Wallace, Lyla L., Session 27-15, p. 136
Wallace, Lindsay J., Session 13-7, p. 59
Walker, Sally E., Session 31, Poster 54, p. 148
Wall, Alexander F., Session 15-5, p. 70; Session 25-17, p. 127
Wang, Yuan, Session 16-4, p. 87
Wang, Wei, Session 11-15, p. 74
Wang, Yuan, Session 16-4, p. 87
Wang, Zixiao, Session 21, Poster 43*, p. 98
Ward, Carol V., Session 17-1*, p. 88
Waters, Johnny A., Session 26-2*, p. 108; Session 35, Poster 71, p. 155
Watts, Jesse C., Session 2-4, p. 14
Weaver, Patricia G., Session 30, Poster 52*, p. 147
NAPC AUTHOR INDEX

Webb, Amelinda E., Session 13-20*, p. 82
Weeks, Steven C., Session 28-7, p. 118
Wei, Guangbiao, Session 16-4, p. 87
Werdelin, Lars, Session 27-19*, p. 137
Werner, John E., Session 15-2*, p. 68
Wesoloski, Catherine, Session 8, p. 14
Wesselingh, Frank P., Session 13-24, p. 84
Westgate, James, Session 7, Poster 8*, p. 34
Wheaton, Cathryn, Session 2-7, p. 15
White, Elizabeh, Session 21, Poster 37, p. 95
Whitenack, Michael, Session 21, Poster 37, p. 95
Whitten, Mark, Session 3-4, p. 18
Whorley, Theresa L., Session 6, Poster 1, p. 31
Wilby, Philip R., Session 36-8, p. 161
Wildermuth, Sarah, Session 21, Poster 36, p. 95
Wilf, Peter, Session 14-5, p. 64; Session 14-6, p. 65; Session 14-8*, p. 66
Wilson, Gregory P., Session 15-9, p. 71; Session 26-13*, p. 130; Session 28-14, p. 140; Session 38-7*, p. 172; Session 38-8, p. 173
Wilson, Jeffrey A., Session 26-13, p. 130
Wilson, Mark A., Session 8, Poster 15, p. 36
Wilson, Paul A., Session 28-17, p. 141
Wing, Scott L., Session 26-14, p. 131; Session 26-15*, p. 131
Wittmer, Jacalyn M., Session 37-8*, p. 166
Wolfe, Ben A., Session 21, Poster 36, p. 95
Wood, Aaron R., Session 3-8, p. 20; Session 38-10*v174; Session 39-12, p. 180
Woodruff, Emily D., Session 7, Poster 9*, p. 34
Wu, Mengyin, Session 11-4, p. 47
Xiao, Shuhai, Session 11-4, p. 47; Session 11-13, p. 73; Session 11-15*, p. 74; Session 29-12, p. 142; Session 29-13, p. 143; Session 29-14, p. 143
Yabe, Atsushi, Session 14-12, p. 85
Yacobucci, Margaret M., Session 15-1*, p. 68
Yanes, Yurena, Session 5-9*, p. 29; Session 10-9*, p. 46; Session 20, Poster 32, p. 92; Session 20, Poster 33, p. 92
Yao, Jinxian, Session 29-14, p. 143
Yasuhara, Moriaki, Session 2-6, p. 15; Session 2-8, p. 16; Session 28-15*, p. 140
Yates, Kimberley, Session 2-7, p. 15
Young, Allison L., Session 29-15, p. 144
Young, Graham A., Session 11-5, p. 48
Yuan, Xunlai, Session 11-15, p. 74; Session 29-14, p. 143
Zachos, Louis G., Session 8, Poster 20*, p. 39
Zaffos, Andrew A., Session 37-3*, p. 164
Zamaloa, Maria C., Session 14-1, p. 62
Zhao, Yuanlong, Session 11-4, p. 47
Zheng, Longting, Session 16-4, p. 87
Zhou, Chuanning, Session 11-15, p. 74
Zinga, Anna, Session 11-18, p. 76

189