

Crossroads Geology Conference 2017

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CROSSROADS GEOLOGY CONFERENCE 2017

Welcome

We would like to extend a special thank you to all of those participating in the 17th Annual Crossroads Geology Conference at Indiana University. This conference is a rich tradition for the Department of Earth and Atmospheric Sciences and we anticipate that **this year's presentations** will uphold previous standards of excellence. Additionally, we are excited to present our keynote speaker, Dr. Darren Ficklin from the Indiana University Department of Geography. Finally, we want to thank our sponsors, judges, the Department of Earth and Atmospheric Sciences at Indiana University, and all of those who have volunteered their time for the preparation and execution of Crossroads 2017.

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**DEPARTMENT OF EARTH
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INDIANA UNIVERSITY
College of Arts and Sciences

DAILY SCHEDULE

FRIDAY MARCH 31		
8:00 AM	breakfast (GY 220)	
9:00 AM	poster session 1	oral session 1 (GY 220)
10:00 AM		break
11:00 AM	lunch (GY 221 & 220)	
12:00 PM	poster session 2	break
1:00 PM		
2:00 PM	keynote talk (GY 124)	
3:00 PM	poster session 3	break
4:00 PM		oral session 2 (GY 220)
5:00 PM	judges meeting (GY 220) (5:15- 5:45)	break
6:00 PM		
7:00 PM	Networking Social at Crazy Horse	
8:00 PM	(214 W. Kirkwood Ave. Bloomington, IN 47404)	

NOTE: All poster presentations will be held in the Geology Building Lobby

SATURDAY APRIL 1	
8:00 AM	breakfast (S201)
8:30 AM	
9:00 AM	awards ceremony (S201)
9:30 AM	career panel discussion (GY 214)
10:00 AM	
10:30 AM	campus geology tour- meet in GY Lobby (led by Dr. Brian Keith)
11:00 AM	
11:30 AM	
12:00 PM	lunch (S201)
12:30 PM	

PRESENTATIONS SCHEDULE

POSTER SESSIONS					
SESSION 1 (9:00-11:00 AM)		SESSION 2 (12:00-2:00 PM)		SESSION 3 (3:00-5:00 PM)	
Xiaomeng Cao	Sedimentology	Grace Carlson	Geophysics	Mohammad Alrowaie	Geochemistry
Scott David	Geomorphology	Dante Curcio	Geophysics	John Kearney	Sedimentology
Graham Johnston	Geomorphology	Adam Esker	Geophysics	Jennifer Laughlin	Geochemistry
Bei Liu	Sedimentology	Garrett Goff	Petrology	John Luchok	Paleontology
Brigid Lynch	Geomorphology	Shay Xuechange Liu	Atmospheric	Sydney Olund	Geochemistry
Andrew Reese	Paleontology	M. Anna Nowicki Jessee	Geophysics	Daniel Rhoda	Paleontology
Cameron Stewart	Sedimentology	Matthew Shirley	Geophysics	Andrea Shilling	Organic Geochem
Don Tripp	Geomorphology	Mitchell Spangler	Geophysics	Xiao Tan	Paleontology
Andrea White	Sedimentology				

ORAL SESSIONS		
SESSION 1 (9:00-10:00 AM) GY 220		
time	presenter	topic
9:00	Ross Caton	Geophysics
9:15	Devon Colcord	Organic Geochem
9:30	Jennifer Lingeman	Mineralogy
9:45	Britt Rossman	Sedimentology
SESSION 2 (4:00-5:00 PM) GY 220		
4:00	Rebecca L. Caldwell	Sedimentology
4:15	Bei Liu	Sedimentology
4:30	Jeff Valenza	Geomorphology

KEYNOTE SPEAKER

Dr. Darren Ficklin
Indiana University, Department of Geography

The Past, Present, and Future of Western United States Hydroclimate

One of the most urgent challenges facing the world today is ensuring an adequate supply and quality of water for human and ecosystem needs in the face of climate variability and change. Recent increases in air temperature are resulting in increases in evaporation/evapotranspiration and changes in precipitation, leading to an overall intensification of the hydrologic cycle. This intensification is projected to continue into the 21st century at potentially faster rates. Using observed climate data and projected climate data from General Circulation Models (GCMs), this talk examines how these changes in the hydrologic cycle will affect water resources and their quality throughout the western United States. These changes will not only impact agricultural and urban communities that depend on these resources, but also aquatic species that are adapted to particular hydrologic regimes and stream temperatures. This work indicates that changes in air temperatures and precipitation will lead to changes in streamflow magnitude and timing (shifting streamflow peaks earlier into the year by 1-2 months), as well extreme events such as flooding and droughts. The streamflow changes coupled with air temperature increases will also result in stream temperature changes by 1-5 °C, subsequently affecting habitat ranges for aquatic species such as trout and salmon that are both culturally and economically significant. These results indicate a very different hydroclimatic future for the western United States, thus requiring an adaptation of water resource and aquatic species management.

Geochemical Evidence of a Large Shift in Redox Conditions and Long Term-Deep Burial Oxidation by Radiolysis Associated with Elevated Organic-Matter Content and Gamma- Ray Intensity in the Paleozoic New Albany Shale, USA

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The New Albany Shale (NAS) was deposited in a marine setting in the cratonic Illinois Basin during the Devonian to Mississippian. The NAS is a source of hydrocarbons and contains high organic carbon (C_{org}) and pyrite. Data are presented here from sequentially extracted fractions of sulfur for the Ellsworth, Clegg Creek, and Camp Run members of the NAS. Sulfur geochemistry of whole-rock samples, metal concentrations, and visual microscopy of organic particles (macerals) were used (i) to understand the depositional environment of the NAS, (ii) to investigate linkages between shale intervals with high gamma ray and shifts in sulfur isotopic compositions ($\delta^{34}S$), and (iii) to explore using proportions of metals as indicators of depositional environments.

Members of the NAS are characterized by depletion of ^{34}S in pyrite and reflect sulfide production by bacterial sulfate reduction in open-system conditions. The Camp Run Member and lower portion of the Clegg Creek Member are characterized by similar $\delta^{34}S$ of pyrite. Isotopic data gradually change from the middle portion of the Clegg Creek Member into the Ellsworth Member and indicate increasing variability of depositional conditions. Extreme depletion in ^{34}S for sulfides in some samples reflect alternating oxic/suboxic or anoxic conditions with shifts in benthic redox conditions and associated opportunities for microbial disproportionation of intermediate sulfur species in accumulating fine-grained sediment. Systematic variation in $\delta^{34}S$ for large grains of pyrite was discovered during repeated chrome-reduction extraction, suggesting overgrowths of pyrite under changing microbial ecologies during diagenesis. C_{org} , acid-insoluble sulfur, degree of pyritization, maceral compositions, and metal-ratio paleoredox indices suggest that the Camp Run Member and lower portion of the Clegg Creek Member were deposited under poorly oxygenated and moderately reducing conditions in sediment compared to the upper portion of the Clegg Creek Member and the Ellsworth Member.

The presence of extractable sulfate in Camp Run and Clegg Creek members results from gradual oxidation of sulfides in the subsurface over hundred millions of years. The overlying Ellsworth Member is dominated by sulfate, likely originated from seawater and was trapped in carbonate-associated sulfate. Correlation between $\delta^{34}S$, gamma ray intensity, and uranium concentration are consistent with abiotic oxidation of pyrite by radiolysis in the Clegg Creek Member.

Morphodynamic stratigraphy of river-dominated deltaic bars

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The ability to predict the stratigraphic architecture of deltaic deposits, which form significant hydrocarbon reservoirs, depends on understanding how deltaic morphodynamics influence stratigraphy. However, the connection between delta stratigraphy and morphology remains incomplete. Here, we seek to define the coupled morphodynamics and stratigraphy for two different modern deltaic bars. We focus on bars because they are the fundamental building blocks of deltaic morphology and stratigraphy. Results are presented from a comparative study of bars with different growth processes and morphologies found on the braided Goose River delta, Canada, and the elongate Beanblossom Creek delta, USA. Geomorphically, these bars cause bifurcations on the delta topset and form at the river mouth or within distributary channels. From serial aerial imagery we know that the Goose River delta is sculpted by highly mobile bars morphologically similar to bars found in braided river channels, whereas the Beanblossom Creek delta is created by channels that elongate via levee growth and bifurcate around stable river mouth bars that are morphologically similar to those deposited within expanding turbulent jets. To characterize the internal stratigraphy of each bar, ground-penetrating radar was collected and tied to sediment cores. The Goose River delta bar stratigraphy is dominated by concave-up bounding surfaces, a homogenous distribution of stratal bodies with similar geometries, and a homogenous spatial grain-size distribution of medium sand. The Beanblossom Creek delta bar stratigraphy, on the other hand, is dominated by flat to slightly dipping bounding surfaces, a heterogeneous distribution of stratal bodies with a range of geometries, and a heterogeneous spatial grain-size distribution of mostly mud and fine sand with some medium sand. Our results indicate that different growth processes and morphologies result in different stratigraphies, and that these sedimentary models for different deltaic bar types may be used to enhance predictions of the stratigraphic architecture of deltaic deposits that formed under a variety of environmental conditions.

Reservoir characteristics and well-logging evaluation of the Lower Cambrian shales in southeast Chongqing, China

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To accurately identify the reservoir characteristics and main controlling factors of the Cambrian Niutitang black shale in the southeast Chongqing, a series of systematic measurements were conducted on core samples from Well Yuke-1 and Well Youke-1. The measurements include clay mineral analysis, XRD analysis, petrophysical properties, specific surface area, pore diameter and TOC of rocks, and as well as R_o and maceral compositions. The Niutitang shale reservoir contains detrital minerals and clay minerals averagely of 51.34% and 32.74%, respectively. The average effective porosity and permeability are 1.2% and 8.0×10^{-3} mD, respectively, typically of ultralow porosity and permeability. Mesopores are dominant, accounting for approximately 73% of the total pore volume. The average BET specific surface area is $7.75 \text{ m}^2/\text{g}$ and the average pore diameter is 5.3 nm. The average TOC is 2.29% and the average R_o is 3.12%, indicating that the reservoir is in over-maturity stage. Statistical analyses of the measurements show that the micropore volume is positively correlated with TOC but negatively correlated with the total content of clay minerals; the mesopore volume is positively correlated with TOC, the total content of clay minerals and the content of carbonate minerals; the macropore volume is positively correlated with TOC and the content of carbonate minerals, weakly positively correlated with the content of detrital minerals but negatively correlated with the total content of clay minerals. The porosity and TOC of the Niutitang shale are computed using the conventional well-logging method for the Yuke-1 and Youke-1 wells, and the porosities are quite consistent with the core analysis results. However, in the shallow reservoir that contains no oil and gas, the TOC exhibits no correlation with the core analysis results.

State of Stress in the Midcontinental United States

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Understanding the stress regime in the Midcontinental United States has been a focus of research for many years due to its anomalously high rates of seismicity. In the Midcontinental region also lays the Illinois Basin, a Paleozoic sedimentary basin filled with layers of sandstones, limestones, and shales. Select units in the Illinois Basin have recently been considered as potential reservoirs for supercritical CO₂. Fluid injection has been known to cause seismicity through fracture initiation and fault reactivation, and although most often seen in wastewater injection associated with oil and natural gas production, CO₂ sequestration also comes with substantial risk of inducing seismicity. This risk is particularly high for faults optimally oriented to the existing direction of maximum compressive stress. In order to help mitigate this risk, we have conducted an assessment of the present state of stress in the Illinois Basin and surrounding region. Using a damped least-squares inversion of focal mechanism solutions and maximum horizontal stress orientations (S_H orientations) from borehole breakout, core fracture, overcoring, hydraulic fracture, and strain gauge measurements we compute maximum horizontal stress orientations through estimation of a reduced deviatoric stress tensor across a grid covering the study area and produce a map of dominant faulting styles. We find the stress field across the Midcontinent to be homogeneous favoring strike-slip faulting with maximum horizontal stress dominantly oriented between N60E and N80E. We do find, however, there exists significant local rotations in the stress field both in the New Madrid Seismic Zone, where this rotation has been previously reported, and outside of it with rotations as large as N70W. Additionally, we expand on other standard inversion methods, adding a mechanism for choosing the fault plane, not differentiated from the auxiliary plane in the focal mechanism solutions. Because the inversion used relies on the Wallace-Bott hypothesis that faults slip in the direction of maximum resolved shear stress, the choice of the fault plane and associated slip vector is extremely important in the estimation of the stress tensor. We show that reducing the uncertainty in the choice of the slip vector creates a stress map with a better fit to the data.

Solar normal modes in seismic data: Time series analysis of the Homestake 3D array

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In 1998 it was shown that the free oscillations, i.e. “normal modes” of the Earth are in a constant state of excitement. These modes are standing waves which have known frequencies from both observations of large earthquakes and from standard global Earth models. Their constant excitation is often called the Earth’s “hum,” and the source of the excitation is of interest to long period seismology and the study of seismic noise sources. Proposed mechanisms include 1) atmospheric turbulence, 2) ocean wave interference over continental shelves, and 3) solar coupling to the solid Earth, likely through electromagnetic fields. After roughly 2005, with the publication of several papers by Rhie & Romanowicz, ocean waves have been considered the dominant source, at least at periods of several minutes or less. However, in 2007 Thomson et al. published the first evidence that solar normal modes may produce signals at long periods in seismometers, and Thomson & Vernon followed this up in 2015 with a more extensive study. They suggest that below 5 mHz, solar signals dominate the hum (in the absence of large earthquakes), and above this cutoff, ocean signals dominate the hum. In this study, we independently search for solar modes in seismic data from the Homestake Mine 3D array, which has 15 underground stations isolated from noise sources such as weather and traffic. Note that this data is not yet publicly available. By using this array, we attempt to improve upon the methods of Thomson & Vernon by stacking data in the time domain to reduce noise, or by jackknifing spectra in the frequency domain to reduce bias. By jackknifing, we can also obtain an estimate of the variance of the final spectrum. Using an array of seismometers also lowers the degrees of freedom of the final spectral estimate, which enables us to more confidently identify harmonic lines. We identify several candidates for solar modes in our data, and present evidence for the possible presence of a family of solar modes called g-modes. We estimate that the spectral feature associated with this is significant at a level of approximately 40σ . Although the task remains of eliminating other possible sources, this may represent the first step in confidently observing g-modes for the first time.

Climate's role on hominin evolution: A biomarker perspective

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Over the past century, extensive studies in East Africa have yielded an unprecedented wealth of information that has shaped our understanding of hominin evolution, including evidence for the critical role played by climatic and environmental variability. Testing such hypotheses benefits from access to more complete and detailed stratigraphic records of the timing and nature of changes in climate and the environment experienced by hominins. Olduvai Gorge, a location in northern Tanzania rich in hominin fossil discoveries, exposes a sedimentary sequence of ~2.0 Ma, which includes multiple lacustrine intervals. In 2014, the Olduvai Gorge Coring Project (OGCP) recovered a sequence of sediment cores that provide a record of the paleolacustrine systems in this area and are ideally suited for high-resolution analyses of organic geochemical proxies, providing an opportunity to build on previously published data from Olduvai that employed outcrop samples.

The section between 76.6 to 86.9 m depth, which spans a time interval of ~20-30 kyr, was sampled every 16 cm for organic geochemical analyses. The isotopic composition of organic carbon ($\delta^{13}\text{C}_{\text{TOC}}$) from this section varies between values representative of more forested (~-27‰) and open grassland (~-15‰) ecosystems over ~21 kyr, consistent with the Milankovitch precession cycle previously observed in lower resolution studies of outcrop samples. Additional proxies, including the relative abundance of hop-17(21)-ene and the $\delta\text{D}_{\text{nC}_{31}}$, also record this same variation between a relatively wet, forested to a relatively dry, grassland environment.

These proxies also provide evidence for sub-Milankovitch changes superimposed on the precession cycle, suggesting that environments inhabited by hominins varied even more than previously documented. With the resolution provided by the OGCP cores, the temporal resolution is sufficient to directly evaluate how climate and environmental variability experienced by hominins at Olduvai compares to the various hypotheses of climate's role on hominin evolution during a critical time in their evolutionary history.

Exploring the lower crustal structure from OIINK array seismic and gravity data in the Illinois Basin

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The Illinois Basin is perplexing to geoscientists in that recent studies have shown the Mohorovičić discontinuity (Moho) to be imaged at great depths (>60 km in some locations). While the average continental crust is roughly 35-40 km thick, the crust in the Illinois Basin is significantly thicker. A crustal thickness of 60 km would be expected in a mountainous region due to isostatic equilibrium, but certainly not in a low-relief zone such as the Illinois Basin. This anomalously thick crust in combination with the minimal topography requires abnormally dense lower crust or unusually light upper mantle. To address this problem, we will be looking at gravity data to determine lower crustal rock densities. We have been using Common Conversion Point (CCP) stacking generated from seismic data to image the Moho and possible lower crustal conversions that may mark the top anomalously dense lower crust. An additional goal of our study is to understand how tectonics have shaped the structure of the Illinois Basin. Xiaotao Yang, a recent PhD graduate of Indiana University, has hypothesized why regions of the Illinois Basin, mainly the Sparta Shelf, are so thick. These models will be tested by combined interpretation of gravity data and lower crustal conversion horizons produced by interpretation of converted wave imaging results from the OIINK (Ozarks, Illinois, Indiana, Kentucky) experiment.

The mechanics and rate of headcut growth on floodplains: Implications for the formation of channel networks

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Floodplain channel networks have important implications for sediment transport dynamics on floodplains, floodwave conveyance, and mechanics of the main river channel. Floodplain channels form independently of the main channel and can span multiple meander wavelengths. A potential mechanism for floodplain channel formation is the development of headcuts nucleating off topographic lows in the floodplain. In this study, we test this mechanism using Delft3D, a physics based morphodynamic model, by simulating flow over an oxbow lake on a generic floodplain. We build a generic floodplain using initial and boundary conditions consistent with floodplain hydrodynamics on the West Fork of the White River, Indiana, USA. Our experiments show that oxbows can serve as a nucleation site for the development of headcuts. The headcuts form from a water level gradient developing at the interface of the upstream edge of the oxbow and the floodplain. The lower water level in the oxbow drives flow acceleration over the lip of the oxbow initiating erosion. The water profile remains unchanged as the headcut migrates further up-valley. Headcuts branch into multiple channels forming a channel network. Additionally, we investigate how oxbow morphology, substrate composition, and flood discharge influence the rate of headcut migration on floodplains and the resulting channel network morphology. We find that increasing discharge and initial oxbow depth creates faster headcut migration rates, deeper floodplain channels, and a higher channel density in the network. The initial substrate appears have no influence on the ability to develop headcuts, however migrations rates slightly decrease with increasing non-cohesive sediment. The resulting channels are deeper and narrower for cohesive dominated substrates, where non-cohesive produces wider shallower channels. Results suggest that headcut migration rates, and channel network morphology and density scale with a characteristic flood discharge.

Mapping the depth of the Moho of the continental US from USArray seismic data

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Mapping the depth of the Moho can help us better understand tectonic processes, including the fate of the Farallon slab. Using the USArray passive seismic data, we mapped the depth of Moho in the continental United States from common conversion point (CCP) stacks generated from the USArray data. Using Petrel, the Moho and the possible multiple was manually picked from the processed seismic data. Depth ranges from 25-40 km in the western US and east coasts of the U.S. while deeper Moho depths of 50-60 km were found along the Rockies and Appalachian mountain ranges. A depth map of the Moho can help us determine if multiples exists and if they obscure the east dipping horizons of the western U.S. The Moho map will also be useful as a static reference with defining any feature in the deep earth.

Petrologic implications of the Palisade Crest Intrusive Suite

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The Sierra Nevada batholith forms the intrusive part of a Mesozoic magmatic arc. The Jurassic Tinemaha Granodiorite and granodiorite of McMurry Meadows comprise the Palisade Crest Intrusive Suite in the eastern part of the batholith. These plutons share similar geochemical compositions and record magma reservoir evolution during a time of voluminous ignimbrite eruptions in the overlying volcanic arc. This project serves to link the Palisade Crest Intrusive Suite to the tuff of Sardine Canyon. Comparing whole rock and zircon geochemistry in these rocks helps to better understand the link between intrusive and extrusive arc magmas and the provenance of detrital zircons in nearby fore-arc and retroarc basins. TAS and Harker plots classify the plutons as well as suggest a fractional crystallization process as the magma reservoir formed. Whole rock silica ranges from 57 to 72% and SiO₂ vs. K₂O trend positively with moderately high correlation coefficients; however SiO₂ vs. MgO, CaO, TiO₂, and Al₂O₃ trend negatively with high correlation coefficients. REE plots show that the plutons are light rare earth enriched and are depleted in Eu, with the negative Eu anomaly mostly 0.6 to 0.8. The overlying tuff of Sardine Canyon, erupted during assembly of the Woods Lake mass of Tinemaha Granodiorite, has 68 – 72% SiO₂, and similar REE patterns with negative Eu anomalies (~0.64). Whole rock Nd isotope ratios are identical. Zircons in samples of the tuff and granodiorite have overlapping ranges of Hf (9000-13000 ppm), high Th/U (0.5-1.2) and similar ranges in U/Yb. These observations support the hypothesis that the tuff was erupted from the underlying magma chamber while zircon was crystallizing (T ~750°C) but before any significant crystallization of sphene.

Can we predict the impact of seismically induced landslides?

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Among the most prominent causes of earthquake-related fatalities are seismically induced landslides. As populations grow, there is increasing pressure to inhabit landslide-prone areas, leading to growth in landslide vulnerability. In this study, we present a new approach to assess the potential impact of seismically induced landslides on affected populations. The analysis makes use of a comprehensive database of 138 historical earthquakes, including 60 events with known landslide fatality counts. Using this database we develop a model that estimates the relationship between exposure of population to expected landslide occurrence and recorded fatalities from landslides. We calculate predicted landslide probabilities in individual pixels surrounding each earthquake using a global statistical landslide model (Jessee et al. 2016), then identify predicted population exposure by overlaying the predicted probability grid with a global population database. The expected population exposure to landslides is calculated by summing over all affected pixels for each event to determine a predicted ‘landslide impact factor’. We compare these values to the number of actual fatalities for each training event, and use these comparisons to calibrate a scale of relative impact; in principle, this scale can then be used to project the potential impact of future earthquakes. We observe a significant positive correlation between predicted and observed fatalities, but with high variability in fatality rates for similar exposure levels, suggesting that other factors (building type, landslide density, population growth curves) may improve this estimate. These estimates of landslide impacts, in collaboration with use of scenario earthquakes, can be used by vulnerable communities to improve land-use planning, structural design, and emergency response in landslide-prone areas. Ultimately, our goal is to integrate these estimates into the USGS Prompt Assessment of Global Earthquakes for Response (PAGER) system for rapid earthquake impact assessment.

Hydrodynamic and sedimentological controls governing fluvial levee geomorphology

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Fluvial levees are familiar features commonly found on the margins of river channels, yet we know little about what controls their height and shape. Due to their shape and sedimentary structure, ancient fluvial levee formations often generate stratigraphic traps for hydrocarbons and are commonly targeted as a natural resource. Despite the familiarity and importance of levees, there is a surprising lack of basic geomorphic data on fluvial levees. Because of this I want to understand: 1) what is the range of cross-sectional shapes for levees? and 2) what geomorphic and hydrodynamic variables control cross-sectional shape? I will address these questions by extracting levee shape from LiDAR data and by collecting hydrodynamic and sedimentological data from reaches of the Tippecanoe River, the White River, Big Raccoon Creek, and the Muscatatuck River, Indiana, USA. Using this dataset, I will conduct a multivariable regression analysis that will uncover the correlations between the independent variables: channel geometry, suspended sediment concentration, sediment grain size, flow conditions, channel slope, floodplain slope, flooding depth, flooding frequency and the dependent variables: levee height and levee shape. The results of this study will aid in developing models for the controls on levee shape and height along rivers and will help predict the lateral extent of ancient levee deposits in the subsurface in order to more efficiently exploit these stratigraphic units for groundwater and hydrocarbon resources.

Using conglomerates and paleosols to make paleoenvironmental reconstructions in the Side Gorge of Olduvai Gorge, Tanzania

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Hominin fossils and stone artifacts can be found in a range of ancient environments in East Africa, but many hominin sites are found in and around ancient lake basins for reasons varying from taphonomy to hominin resource utilization. These lake deposits are extensively studied to extract imperative fine-scale climate data, allowing for interpretations to be made about the role of a changing climate on the evolution of early humans. Such is the case for Olduvai Gorge, Tanzania, arguably one of the most important archaeological sites that exposes nearly continuous deposits from the past ~2 million years. The oldest deposits are termed Bed I and Bed II and consist primarily of lacustrine facies, while the overlying deposits, termed Bed III and Bed IV, consist primarily of soil and fluvial facies. Much of the geologic research of the past several decades has focused on the older lacustrine deposits, and the younger deposits of Bed III and Bed IV have been comparatively understudied. In order to make detailed paleoenvironmental reconstructions of Bed III and Bed IV, stratigraphic sections need to be measured and correlated. Here I present previously unmeasured stratigraphic sections from the Side Gorge using field data collected in the summer of 2016. Thick paleosols in these sections indicate extended periods of time of little to no deposition that allowed for soil formation, and intermittent conglomerates indicate relatively shorter periods of time of rapid deposition by high-energy streams and floods. These conglomerates are further characterized quantitatively using paleocurrent directions measured in the field and stream energy using clast composition and size. These methods allow for detailed paleoenvironmental reconstructions to be made in exposed deposits that lack the ideal fine-scale resolution of lacustrine deposits.

Regional trace element geochemistry of zircons in the Jurassic volcanic arc of the southwest U.S.

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The geochemistry of zircon provides an important link between magmatic arcs and deposition of sediments in adjacent basins, because zircon can survive erosion and sediment transportation. We are examining longitudinal variations in arc zircon geochemistry in order to better understand the link between intrusive and extrusive magmas and the provenance of detrital zircons in fore-arc and backarc basins. The Jurassic arc of the southwest U.S. formed as a northwestern marine arc and a southeastern continental margin arc across the edge of the North American craton. Zircons from volcanic rock sections of both the marine and continental segments of the arc will help to describe longitudinal differences in arc magma chemistry and characterize the Jurassic volcanic arc upper crust that is now largely eroded and deposited in adjacent basins. A comparison of Jurassic volcanic sections from the Ritter Range and Oak Creek pendants in the eastern Sierra Nevada, the Sidewinder (Fohey-Breting et al., 2010) and Holcomb Creek sections in the Mojave Desert, and the Dome Rock sequence in the Colorado River region (Tosdal and Wooden, 2015) shows that populations of zircons from all three regions have a range of Hf contents (7,000-14,000 ppm), and REE quantities are similar, being HREE-enriched. Middle Jurassic zircons have similar amounts of REE at all sites, but Late Jurassic zircons from the Mojave Desert sites have lower Ce/Gd. Zircons in most samples are high U/Yb, except again those from Late Jurassic within the Mojave Desert that are lower. High Th/U is a characteristic of zircons from all sites - Th/U ranges from 0.5 to 1.5, with Mojave Desert samples having the highest Th/U (up to ~3). These data suggest that high Ce, high Th/U zircons are a distinguishing characteristic of the Middle Jurassic volcanic arc along strike from the central Sierra Nevada to the Colorado River region.

A biomineral investigation in human kidney stones

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The formation of a kidney stone is a biogeological process. Several mammalian species are known to produce such stones including: ferrets, dogs, cats and humans. The minerals that are formed in kidney stones vary in chemical composition but are closely similar to those found in rocks of the Earth. The medical study of urolithiasis (kidney stone disease) is challenged by a limited understanding of the time spans required for nucleation, precipitation, and growth of minerals to form such stones. The objective of this investigation is to characterize the variety of minerals present in one such kidney stone, as well as to compare the processes by which a stone forms in the human body with the geologic processes at play during their formation on Earth. Empirical evidence was obtained by micro CT as well as Infra-red Spectrometry (IR) in order to describe the relationships of a variety of biominerals in kidney stone specimens obtained by surgical removal. Analysis of these kidney stones will hopefully prove useful in providing clues regarding the environmental conditions that enable the precipitation of a variety of biominerals in animals.

Authigenic Minerals Formation and Detrital Particles Accumulation Associated with Tasmanites Cysts, and Thermal Degradation of Alginite in the New Albany Shale, Illinois Basin

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Alginite derived from Tasmanites algae is an important contributor to the organic matter in the New Albany Shale (NAS) of the Illinois Basin. Tasmanites cysts play a significant role in the formation of authigenic minerals in the NAS, providing a comparatively large and partially walled off pore space with potential for hosting diagenetic microenvironments that facilitate mineral precipitation. Detailed study of the diagenesis of the NAS from two cores drilled in Daviess County, Indiana and Webster County, Kentucky was conducted by optical microscope (transmitted and reflected light) and a field emission scanning electron microscope with an attached energy dispersive spectrometer. Authigenic minerals precipitated in these cysts include quartz, pyrite, marcasite, and calcite. Quartz is the most common cement and can occur as microcrystalline quartz (chert), cryptocrystalline quartz (chalcedony) and monocrystalline quartz. The quartz enclosed in Tasmanites cysts can be distinguished from detrital quartz grains on the basis of embayments, as well as on the basis of SEM-CL characteristics. Differential compaction around quartz-filled Tasmanites cysts grains indicate that they were formed before the onset of compaction. Tasmanites cysts can also be filled with detrital particles (quartz, K-feldspar, clay and mica) and recycled dolomite when reworked during lowstand intervals, and these detrital infills are readily distinguishable from chemically precipitated infills. Algal cysts filled with detrital minerals are always associated with quartz silt lamina and conodont fragments. Sandy and silty lags (1-2 cm thick) largely composed of authigenic quartz and pyrite (0.02-0.3 mm in size) could be formed by intermittent reworking and erosion of underlying muddy sediments by intermittent storms. Intervals that show abundant silica infill of Tasmanites cysts also contain abundant finely dispersed matrix quartz that together with cyst fills provides a compaction retarding 3D network of silica “bridges” that on one hand enhance brittleness of shale and the possibilities for reservoir stimulation, and on the other hand help to preserve diagenetic porosity (intraparticle porosity in clay and organic matter and interparticle porosity) and favorable reservoir characteristics. Alginite derived from Tasmanites cysts started transformation to pre-oil bitumen at the maturity of $R_o \sim 0.8\%$. Alginite is dark under reflected light and oil immersion and shows weak orange fluorescence under fluorescent light. It shows rough surface and flow characteristics, and could develop secondary organic porosity during the thermal degradation process.

SEM petrography of organic matter in the New Albany Shale and its implication for porosity development with thermal maturity

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Organic matter (OM) type is very important in controlling the development of organic matter-hosted porosity besides thermal maturity. Three New Albany Shale samples with different thermal maturities ranging from $R_o \sim 0.55\%$ to 1.42% were analyzed using microscope with reflected light and a field emission scanning electron microscope (SEM). Organic porosity was examined in specific organic macerals at different thermal maturities. Vitrinite and inertinite derived from terrestrial woody materials are particulate OM in black shale and do not develop secondary porosity with thermal maturation. Amorphous organic matter (AOM) disappeared at the maturity of $R_o \sim 0.8\%$ because it finished thermal transformation. Alginite derived from Tasmanites cyst matures later than AOM and could not be identified at the maturity of $R_o \sim 1.42\%$. Solid bitumen (SB) could be observed at the maturity of $R_o \sim 0.55\%$ and occurs as interparticle filling (quartz, dolomite and K-feldspar) and cavity filling (cellular pores in inertinite). Cellular pores ($0.2\text{--}10\text{ }\mu\text{m}$) in inertinite were observed throughout the whole maturity range and are always filled with SB, authigenic quartz and pyrite. Alginite began to develop porosity when it was in the process of transformation to pre-oil bitumen. SB-hosted porosity ($20\text{--}1000\text{ nm}$) is the main organic porosity type and it is more common in gas window than in oil window. Secondary nanoporosity formed by the expulsion of liquid and gaseous hydrocarbons in the interconnected solid bitumen network plays a significant role in hydrocarbon storage and migration.

Using legacy satellite data to detect climate variability and cloudiness

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Large scale circulation change has been affecting cloud behavior. The climate variability and trends in cloudiness, however, are not recognized until last few decades when satellite data started playing a role. To characterize the climate variability and how it is associated with global cloudiness, we carefully combine imagery and cloud type data from the Advanced Very High Resolution Radiometer (AVHRR) with spectrally resolved data from the High Resolution Infrared Radiation Sounder (HIRS) on-board NOAA polar-orbiting weather satellites, which have been in orbit since 1978. The objective of presented work is to examine the effects of climate variability on longitudinal cloud and radiance statistics over the southern ocean and tropics. In particular, we examine how the southern barotropic and baroclinic annular modes and southern oscillation indices affect cloud properties using the HIRS 11.1- and 12.5 μm bands. The variance and higher order statistics provide a unique way for us to better understand the atmospheric variability and both natural variability and observational uncertainty.

Paleoecology of “Butter” shale communities from the Waynesville Formation (Upper Ordovician) in the Cincinnati Arch

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This study is centered upon the “butter shales” of the Ordovician-aged (~445 ma) Kope Formation in eastern Indiana and the older Ordovician-aged (~450 ma) Waynesville Formation in southwestern Ohio. “Butter shale” is a type of shale that is not as lithified as normal, brittle shale; rather it has the consistency of clay. The reason as to why “butter shales” lithified this way is still up to debate, but there is evidence that suggests active, storm currents that caused high flocculation of clays before deposition contributing to the unique texture in these shales. “Butter shales”, however, do contain fossils that help with relative age dating, specifically biostratigraphy. The problem arises in that the “butter shales” of the Waynesville Formation have many well-preserved fossils, albeit small, whereas the Kope Formation lacks a diverse assemblage of fossils even though their overall community of fauna found within the siltstones and carbonates are similar to the butter shale fauna in the Waynesville.

To solve the disparate fossil assemblage problem between the butter shales of different ages, samples (“butter shales” and accompanying carbonates) will be collected at a butter shale Kope outcrop, and compared to the already collected samples from the Waynesville Formation from previous studies. After collection, fossil content and diversity within samples will be compared across butter shales, as well as with using clay mineralogy and chemistry analytical techniques to determine whether or not these two “butter shale” samples from each formation endured the same type of depositional event, fauna, and clay formation. With this data, we can help solidify the idea that “butter shales” were a result of a unique depositional deposit in a marine environment with abundant amounts of suspended sediment as a result of storm generated currents that swept organisms living on the sea floor and buried them rapidly.

Modeling landscape evolution and climate: How erosion and precipitation are linked in active orogens

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The tectonic history and the climate driven erosional processes acting in a region are the primary controls on the evolution of a landscape. Quantifying these controls is essential to our understanding of uplift and erosion histories in mountain ranges. Our understanding of how landscapes respond to tectonic forcings is generally well constrained but the influence of climate on landscape evolution remains unclear. This uncertainty is especially apparent when comparing field experiments; some studies have demonstrated a positive feedback between climate and erosion, while others have not. To complement the field experiments and gain important quantitative insight into what climatic properties influence landscape evolution, we implement a numerical modeling approach. We investigate climate-landscape interactions by coupling a high-resolution climate model, Weather Research and Forecasting Model (WRF), and a landscape evolution model, Landlab. The Andes act as the climatic setting for this study, due to the variation in climate along the length of the orogen, and serve as a natural laboratory to test controls on erosion. Discharge is quantified across the landscape with the WRF Hydro model. Discharge and topography are passed between the models, allowing for a feedback relationship to form between topography and precipitation. We will present our preliminary model runs that result from an asynchronous model coupling approach. These results will allow us to run further experiments to test feedbacks between topography and climate by monitoring topographic metrics and erosion histories. This work provides a necessary next step in landscape evolution modeling by using an actively evolving climate to model real precipitation dynamics. This next step allows for modeling more accurate representations of precipitation through the development of an orogen. This will result in an improved understanding of the co-evolution of climate and topography in these settings.

Iron and nutrients in coastal Antarctic streams

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The Southern Ocean (SO) has been an area of much biogeochemical interest due to the role of Fe limitation for primary production. Primary production is associated with increased carbon sequestration, making it important to characterize and quantify the fluxes of Fe and other nutrients to the ocean. Water samples were collected in the McMurdo Dry Valleys, Antarctica (MDV) from four subaerial streams flowing into the Ross Sea. They were analyzed for macronutrients (N, P, Si) and Fe to determine the potential impact of terrestrial water input on the biogeochemistry of coastal oceanic waters. Our stream data yield an average filterable composition of $N_3P_1Si_{100}Fe_{0.8}$, which is substantially different from the planktonic composition as demonstrated by empirical measurements, and suggests that these streams are a potential source of Fe and P, relative to N and Si, to coastal phytoplankton communities.

The behavior and potential colloidal/nanoparticulate speciation of the Fe in these streams was investigated through analysis of three physiochemical forms of Fe - environmentally active Fe (acid-soluble/no filtration), filterable Fe (filtered through 0.4 μm), and dissolved Fe (filtered through 0.2 μm). It has been suggested that the dissolved fraction is mainly nanoparticulate and represents a more bioavailable form of Fe, as compared with colloids and large particles. Overall, the combined average annual flux from two MDV streams is approximately 240 moles fFe yr^{-1} , which is consistent with previously predicted values. The dissolved fraction of Fe (<0.2 μm) was between 18% and 27% percent of the fFe, meaning the fFe pool is mostly colloidal. While the Fe flux from these streams is several orders of magnitude less than aeolian and iceberg sources, terrestrial streams are expected to become a more significant source of Fe to the Ross Sea. As the Antarctic climate warms, ice-free regions similar to the MDV should increase in extent and glacier melt. This study questions how, and in what quantities, Fe is solubilized and transported from the landscape into the SO to better inform predictions of Fe fluxes following continued warming.

Evaluating measurement error using fossil Brachiopods and their 3D models

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Three-dimensional (3D) scanning of fossils provides the opportunity to quantitatively analyze shape and to experimentally assess properties such as hydrodynamic performance, structural strength, or resistance to puncture using techniques such as finite element analysis or computational fluid dynamics. However, inferences derived from 3D models of fossils depend heavily on the fidelity of the scanned object to the original. Here we present the results of an investigation of accuracy and reproducibility of digital fossil objects based on a series of scans from the IU Paleontology Collection. In this study, we created 3D models of fossil brachiopods of various morphologies and performed tests for measurement error across technologies (calipers and 3D scanners) and individual measurers.

We scanned 65 brachiopods from the Ordovician (Saluda, Whitewater, Waynesville formations), Silurian (Waldron Shale), Devonian (Ludlowville Formation), Mississippian (Glen Dean Limestone), and Pennsylvanian (Cherryvale Formation). We used the NextEngine® Ultra HD 3D Laser Scanner and the CreaForm® Go!Scan 20 optical scanners to create 3D models. The ScanStudio and VXEelements software packages were used to create and manipulate the 3D object models. The length, width, and depth of each fossil brachiopod was measured twice with digital calipers and the same dimensions were measured twice on the corresponding 3D digital objects using VXEelements. Each object was measured independently by two of us (AR and KC). We partitioned the variance in the measurements into between-objects, between-measurer, and between-scanner components and calculated percent measurement error for each type. We then compared the measurements obtained from the real and digital objects and assessed which methods produced the greatest error.

Overall, the measurements from the 3D scans were consistent within the bounds of measurement error with those taken on the actual fossils. Height measurements had greater error (caliper=1.11%) than length or width measurements (length caliper=0.59%, width caliper=<0.0%). Also the measurements taken by a single researcher from 3D objects and fossils were consistent with each other, as were the measurements taken by different researchers on the same object. To reach these conclusions, we considered measurement error less <5% of the total variation to be small.

Phylogenetic supertree of fossil North American carnivores

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Phylogeny is the study of evolutionary relationships – the genealogy or family tree of life. The phylogeny of living organisms is usually studied with molecular sequences, but the phylogeny of extinct organisms is based on analysis of characteristics that preserve in the fossil record. Because this is difficult, specialized work, most studies only include a few closely related species. In order to address broader problems involving many different groups, phylogenetic trees from many different studies must be combined.

One approach to combining phylogenetic trees is the “supertree” method. Supertrees are constructed by combining the topologies of many smaller, overlapping phylogenetic trees (source trees) instead of directly using the character data used to derive those trees. Overlapping source trees allows us to compare evolutionary relationships over a broader taxonomic range, and therefore to test hypotheses on a much larger scale.

There are many different methods used to create supertrees, including the MinCutSupertree, Bayesian, Reduced Consensus, and Average Consensus methods. The most commonly used, however, is matrix representation using parsimony (MRP) which uses matrices to represent topologies of source trees. The source tree matrices can be combined into a larger matrix that expresses the topology of a tree incorporating species from all source trees. MRP allows us to combine otherwise incompatible sets of source trees.

Using the MRP method in Mesquite, we constructed a supertree of extinct and extant North American species in the Order Carnivora. We used five partial trees of the family Procyonidae, three complete phylogenies of the family Canidae, and two recent phylogenies of the family Felidae. Phylogenies of two subfamilies of canids, Borophaginae and Hesperocyoninae were included, as well as phylogenies of the genera *Ferinestrix*, *Martes*, *Gulo*, *Pekania*, and the infraorder Arctoidea. Phylogenies of the families Procyonidae, Canidae, Amphicyonidae, Hyaenidae, Miacoidea, Nimravidae, and Ursidae from an encyclopedia of North American carnivores were also used. Separate studies provide multiple interpretations of phylogenetic relationships, which allow us to create a more objective tree. Phylogenies as recent as 2014 were included.

Sedimentological Characterization of the Tununk Shale: Petrographic and Chemical Interpretation of Depositional Systems for Cretaceous Mudstone Parasequences

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Three detailed sedimentologic sections were measured in the field to document mm- to cm-scale variations in sedimentary facies characteristics in three parasequences within the Mid-Late Cretaceous Tununk Member of the Mancos Shale Formation. Lithofacies were defined for all units based primarily on sedimentary structures, degree of cementation, and bioturbation index (BI). Different lithofacies show both subtle and drastic variations – usually in energy – in the depositional conditions shown through the measured intervals.

Gamma logs of outcrops were also taken to approximate changes in the clay content within the rocks. In the lab, pXRF was used on slabbed samples in order to 1) track chemical changes throughout measured intervals and to 2) help differentiate lithofacies. Chemical proxies can be particularly helpful in differentiating more homogeneous sections, though subtle variations (+/- ~5%) in any one elemental concentration may not be reflective of distinct changes in depositional conditions.

Petrographic observations, under both light microscope and SEM, are used to characterize petrographic fabrics, and are used in the final phase of identifying lithofacies in mudstones. It is often found that the observed microfabrics are in turn responsible for many macro-features, including decimeter to meter-scale outcrop weathering patterns. Petrographic observations also help to identify principle grains in both composition and size range.

Typical size range is medium-coarse silt, despite previous interpretations as dominantly claystone or clayshale. Coarser grains in the lower sections are dominantly calcareous foraminiferal tests, while in upper sections the coarse fraction is more commonly volcanogenic rock fragments. Volcanic fragments constitute most of the coarse detrital input in all measured sections with finer material being dominated by clays. The lower section shows mostly and argillaceous clasts derived from weathering of intermediate-felsic volcanics, while the upper sections contain weathered clay-rich fragments adjacent to less-altered igneous volcanic rock fragments. The occurrence of both well- and poorly-preserved volcanics in the same section is indicative of mixing from multiple sources, *in-situ* reworking of material by frequent bottom currents on a storm-dominated shelf, and/or other processes of recycling.

Environmental changes associated with the shallowing of Lake Olduvai (ca. 1.8 Myr) as recorded by sedimentary biomarkers

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The Olduvai Gorge Coring Project (OGCP) recovered a sequence of sediment cores providing a long-term record of lacustrine systems within the Olduvai region extending through most of the Pleistocene. These sediments provide a unique opportunity to examine organic geochemical proxies as measures of environmental changes and climatic characteristics of this region during a critical interval of hominin evolution. Here we examine biomarker distributions and occurrences to evaluate the nature and timing of significant changes in the lacustrine environment. Development of an understanding of temporal variations in Lake Olduvai will document how environments were changing and help assess whether they might prompt adaptations of hominin dependent on resources connected to the lake. This report focuses on analyses of the sedimentary transition from dark anoxic claystone containing pyrite to light-colored sandy claystone.

This stratigraphic interval (ca. 1.80 to 1.85 Myr) records the progressive shallowing of Lake Olduvai associated with volcanoclastic input and increasing aridity. Preliminary analyses of the sedimentary biomarker compositions for this interval (66.3 – 71.7 m) show that they reflect this change in depositional setting. The anoxic claystones preserve a suite of alkenones derived from phytoplankton, with a distribution (C₃₇, C₃₉ alken-2-ones; C₃₈, C₄₀ alken-3-ones) typical of saline lacustrine settings except that alkadienones are dominant and alkatetrenones are absent; they also contain series of microbial C₂₇-C₃₂ hopanes and their 2-methylhopane homologues. In the sandy claystones the biomarkers are dominated by *n*-alkanes maximizing at C₃₁ or C₃₃ and exhibit high CPI (carbon preference index) values for C₂₅-C₃₅ (6.1-8.7) typical of inputs from leaf waxes. Further evidence for contributions from terrestrial organic matter is provided by the prevalence of dehydroabietic acid, and abundant series of both *n*-alkan-2-ones and *n*-alkan-3-ones likely derived from soils. Thus, biomarker distributions document two distinct organic geochemical facies corresponding to a shift in inferred sources of organic matter from aquatic to terrestrial. This shift in dominant organic matter source occurs in conjunction with a change in lithofacies and depositional setting associated with the shallowing of Lake Olduvai over ~50 kyr.

Local Earthquakes in the Illinois, Missouri, Indiana, and Kentucky Region from a Dense Seismic Array in the U.S. Midcontinent

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Local earthquakes found within relatively stable continental regions are predominantly small events that are less well studied than earthquakes associated with tectonic plate boundaries. Our project uses data collected in the second and third phases of the Ozark-Illinois-Indiana-Kentucky Seismic Experiment (OIINK project) to locate local earthquakes, which ultimately will help in the assessment of earthquake hazards in the region. The third phase of OIINK project was a dense array of seismometers operating throughout Kentucky and southern Indiana with 70 high-sensitivity broadband digital seismometers deployed along a grid with approximately ~25 km spacing. We use an automated detector program in conjunction with an associator program to find potential events within the body of the data. However, visual discrimination of events must still be employed as mine blasts have similar seismic signatures to real events. We utilized a pilot set of 10 days of data to refine parameters for the detector and associator. With these refined parameters, we analyzed the period of full-array coverage to look for candidate local events. The strongest candidates for local events that they were further scrutinized and located with manually refined arrivals and a more complex velocity model. Only the strongest candidates for true local earthquakes were kept along with events that corresponded to known earthquakes in catalogs published by the USGS and CERI. We finally performed a magnitude analysis on the local and the array-proximal regional earthquakes. We found a total of 82 earthquakes from January 2013 through March 2015. These earthquakes are located within or near New Madrid, the St. Genevieve, the Wabash Valley, and the Rough Creek seismic zones at depths ranging from 5km to 25km.

Teleseismic P-wave amplitude variations in the Illinois Basins

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We measured relative amplitudes of teleseismic P-waves recorded by the Ozark, Illinois, Indiana, Kentucky (OIINK) experiment. The OIINK experiment deployed 140 broadband seismic stations in three phases. We examined data from the two main operational phases of the experiment that operated from summer 2012 to spring 2015 where the array had 70 operational instruments operating simultaneously. We also used data from 90 regional broadband instruments that were a mix of permanent stations and temporary USArray stations. We processed all events with a magnitude of 5.5 or greater using a program called dbxcor. Dbxcor cross-correlates P-wave signals to determine an accurate arrival time for every seismic station and the amplitudes of each station relative to the array average (array beam). We applied short-period and long-period filters depending on event signal clarity and type to eliminate extra noise. We compute relative amplitudes for each event by removing the average amplitude in dB from each measurement. We visualized the amplitude variations by fitting a surface to the relative amplitudes and displaying a map of the variations with a color bar scaled by amplitude in dB. Preliminary results indicate lower amplitudes in southern Missouri and southern Kentucky. Higher amplitudes are observed in southern Illinois, southwestern Kentucky, and southeastern Missouri. Most events originated between the 300 and 360-degree azimuthal range from sources in the western Pacific. These events tended to show lower amplitudes in all of Kentucky more than events originating elsewhere. Cumulative average amplitudes from different source azimuths are being calculated that will be visualized by the same approach but will allow appraisal of repeatability of the results.

Stratigraphic and petrographic analysis of the Late Devonian-Early Mississippian Lower and Upper Bakken Shale Members, for the development of a sequence stratigraphic framework

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A definitive sequence stratigraphic framework has not been established for the lower and upper Bakken shale members of the Bakken Formation, North Dakota, despite its extreme economic importance as the top unconventional source for oil production in the United States. The lower and upper shales are black carbonaceous mudstones. Historically, sequence boundaries have been difficult to identify in fine-grained sedimentary rocks and this study provides new perspectives with regard to the sedimentary features that characterize these surfaces in the Bakken shales. The Bakken Formation is primarily located in the subsurface of the intracratonic Williston Basin and is distributed throughout North Dakota, South Dakota, Montana, and Saskatchewan. Three primary members make up the Bakken Formation, the lower Bakken member, the coarser grained middle Bakken member, and the upper Bakken member. Separate facies within the lower and upper shale members are not commonly described, but through sedimentologic analysis of the Bakken Formation from drill cores, subtle and distinct facies transitions are observed. Facies shifts are significant since they represent a change in depositional and diagenetic processes. Abrupt facies changes occur at erosional surfaces and flooding surfaces, the key surfaces that bound sequences and parasequences. Silt, pyrite, and conodont lag deposits are helpful indicators of significant surfaces. Recording changes in rock properties, such as hardness, was found to be a useful proxy for detecting subtle shifts in facies. Rock hardness changes in cyclical fashion and reflects changes in the amount early diagenetic siliceous cement. Application of above criteria helped to identify sequences and parasequences in lower and upper Bakken shale members. Further development of this concept will aid in the development of a regional sequence stratigraphic framework and a better understanding of the depositional and diagenetic boundary conditions that resulted in the accumulation of the fine-grained strata of the Bakken Formation.

New material of Ginkgoales from the Middle Jurassic of Daohugou, Inner Mongolia, and its implication on paleo-CO₂ reconstruction

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Recent research on the vertebrate, invertebrate, plants and palynoflora fossils from the Middle Jurassic Daohugou region of northern China indicates that there has been a terrestrial ecosystem with high biodiversity level. As a significant part of this system, the fossil plants have been reported with fewer taxa than insects and animals. Only several species of Bryophyte, Cycads Conifers, Bennettitaleans and possibly angiosperm have been reported. More new taxa are gradually found to supplement.

Our fieldwork on Jurassic outcrops from Daohugou, Inner Mongolia has discovered numerous well-preserved Ginkgoales leaves with cuticle. Those leaves are very common in the Daohugou flora, and the leaves with similar characters were described by Zhou (2007) as associated Ginkgoites leaves of *Yimaia capituliformis* and were mentioned by Wang (2012) as a mimicry plant with hangingfly. However, the epidermal anatomy and the detailed taxonomic information has never been reported before. In present research, the epidermal anatomy of those leaves is provided for the first time. Three taxa are described based on the leaf morphology and epidermal anatomy, and the stomatal parameters are analyzed for the reconstruction of paleo-atmospheric CO₂ concentrations.

The stomatal ratio (SR) data collected from nine specimens of the new material yielded a semi-quantitative pCO₂ estimate of 780–1150 ppmv. Combined with the results from the early Middle Jurassic Ginkgoales material (Wu, 2013), it seems to show an increase trend of atmospheric CO₂ concentration between the Aalenian-Bajocian and Bathonia-Callonian, which is agree with the trend revealed by Berner (2006) in GEOCARBSULF model.

Characterization of extensional tectonics in North Boulder Basin, Montana, through detailed analysis of longitudinal stream profiles

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Research was conducted in North Boulder basin of southwestern Montana in order to characterize spatial differences in extensional tectonics (base level drop) through detailed analysis of longitudinal stream profiles by the combined use of Shuttle Radar Topography Mission (SRTM) images in the form of 10-meter resolution DEMs, watershed algorithms contained within ARC GIS, Post Processing Kinematic (PPK) surveys, and ³⁶Cl age dating techniques. The goal of this study was to be able to quantify the spatial distribution of differential base level changes over time using normalized steepness indices, and total river incision taken from relict profile reconstructions based off the Stream-Power Limited Detachment model.

The area of focus involved the southern ~92 km² area of the North Boulder basin which contains nine tributaries that flow westward over a north-south striking normal fault scarp into the North Boulder River. A range of different lithologies can be seen along each of these streams ranging from homogenous limestone that dominate the Mississippian Mission Canyon formation to heterogeneous reaches that contain formations that range in age from the pre-Cambrian to the Tertiary consisting of sandstones, carbonates, siltstones, and shales. The earthquakes at Hegben Lake in 1959 (M 7.1) and Borah Peak in 1983 (M 7.3) as well as numerous magnitude 2 through 4 earthquakes are indicative that extension within the region is ongoing.

Each of the nine tributaries were surveyed and the following data was collected: 1) sub-meter X, Y, and Z coordinates at specified intervals, 2) locations and heights of knickpoints along each of the stream segments, and 3) streambed sediment and bedrock composition. The X, Y, and Z coordinates taken from the surveys were incorporated with SRTM data and uploaded into ARC GIS so that steepness and concavity indices could be extracted. Relict profiles were reconstructed using the same survey coordinates so that total incision for each of the streams could be measured. Limestone samples were collected from the prominent north-south striking normal fault scarp where it displays the greatest topographic expression on the surface and tested for exposure age using ³⁶Cl isotopes. These dates were to provide a time reference frame in which the stream profiles could be interpreted.

Both of the results from the steepness indices and total river incision showed very similar patterns, quantifiably describing the magnitude of base level change rates along the north-south striking normal fault. Despite complications brought on by variable lithologies, values from both incision and steepness indices are consistent with the topographical expression of the normal fault concluding that the Stream-Power Limited Detachment model can be useful in heterogeneous lithology for a preliminary analysis of river response to extensional tectonics.

Understanding fluvial avulsions: Mapping, modeling, and section measurement

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Channel avulsions are a hallmark of aggrading fluvial systems (Stouthamer and Berendsen, 2000), and cause dramatic and often sudden changes to river channels and floodplains (Smith et al., 1989). Avulsion models have been proposed, tested, and compared in the lab (Bryant et al., 1995), numerical models (Hajek and Wolinsky, 2011; Jerolmack and Paola, 2007), modern (Smith et al., 1989; Chatanantavet et al., 2012) and ancient (Jones and Hajek, 2007; Kraus and Wells, 1999) fluvial systems. In virtually all models, avulsion events are attributed to at least one of two variables: superelevation of the primary channel and floodplain dynamics and substrate composition (Slingerland and Smith, 1998; Tornqvist and Bridge, 2002; Aslan et al., 2005; Hajek and Edmonds, 2014). Both variables are the result of finer-scale physical processes including river hydrodynamics (sediment load, capacity, competence, and discharge), regional controls (tectonics, precipitation rates and cycles, etc), and the resulting sediments deposited by interactions of these processes in local channels and floodplains.

The primary purpose of this research is to identify the key variables controlling the avulsion process in fluvial systems and to develop a numerical model that can accurately predict the geomorphology and stratigraphy of an avulsive system. This will be accomplished by 1) gathering observations of modern and recent fluvial avulsions (including using remotely sensed data and taking measurements, to fill gaps in avulsions that are poorly documented), using this body of observations to identify important variables, and 2) developing a numerical model that accurately depicts the interactions of physical parameters in the avulsion process (as understood using the avulsion data synthesis of objective 1). Conclusions made from the first two objectives will be used to attain a third objective: testing and refining the numerical model using real world systems. These will include a modern and ancient avulsive fluvial system, with the latter being used to correlate changes in physical parameters and signals preserved in the stratigraphic record.

Sedimentology and Facies Analysis of the Jurassic Summerville Formation, Utah – A Potential Analog for Martian Mudstones

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Subtle features in mudstones can reveal a great deal about the sedimentological history of those sediments. Mudstones on Earth commonly have some degree of bioturbation that has destroyed portions of the primary sedimentary structures and influenced the chemistry of that system. These added complications makes using terrestrial mudstones as Mars analogs a more complicated process. The Jurassic Summerville Formation of the Colorado Plateau was deposited in a hypersaline, marginal marine environment that was likely only capable of supporting life in the form of microbes, algae and organisms of similar hardiness. The Summerville consists of a succession of thinly bedded, reddish-brown mudstones and siltstones that are in places interbedded with very fine to fine grained green-tan, often glauconitic, sandstones and evaporite beds. The abundance of calcium sulfate, lack of macro organisms, and the presence of sedimentary features that have already been observed in Mars rover investigations, make the Summerville a valuable Earth analog for the study of Martian mudstones. Two detailed stratigraphic columns from Summerville outcrops approximately 6 km apart were measured and described at centimeter to decimeter scale near Hanksville, Utah. One complete section measured 46 meters thick, while the other only exposed the uppermost 20 meters. Both sections were sampled approximately every 2 meters, with representative samples collected of all facies types. These samples were slabbed and polished to reveal subtle features and are also being analyzed by thin section and SEM petrography. The Summerville contains several evaporite related facies and textures that have been observed in mudstones on Mars. These evaporitic facies include beds of nodular calcium sulfate and crystalline calcium sulfate. Other evaporitic features include large, isolated calcium sulfate nodules, calcium sulfate filled syneresis cracks, and satin spar veins. These evaporitic facies and structures, although seemingly laterally continuous at the outcrop scale, are laterally discontinuous over larger distances (km's). The syneresis crack bearing facies are particularly variable between the two field sites. The South Hanksville field site has few horizons with syneresis cracks, whereas the West Hanksville site has much more frequent syneresis cracks throughout the section. The chemically harsh but low-energy physical environment of the Summerville may be comparable to Martian environments, even though there are fundamental differences to Earth in terms of physical boundary conditions. Summerville evaporites, particularly calcium sulfate filled syneresis and desiccation cracks, have potential to help us better understand Martian sedimentary processes. Though rare in the sedimentary rock record, syneresis cracks, subaqueous mudcracks formed due to a salinity induced collapse in clay structure, are well-preserved in the Summerville. Because comparable cracks have been observed in Martian mudstones and are abundant in the Summerville, the Summerville is an ideal laboratory to study the sedimentary context of syneresis and associated features and applying derived insights to Mars. Because syneresis depends on water chemistry, studying these features on Earth has the potential to find thresholds of water salinity that might be applicable to Mars.



