



CROSSROADS 2019

CROSSROADS CONFERENCE 2019

Welcome

We would like to extend a special thank you to all of those participating in the 18th annual Crossroads 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. We are excited to present our keynote speaker, Dr. Rebecca Caldwell from Chevron. Additionally, we are excited to incorporate our second annual career fair and we want to thank all the individuals and companies that are participating. Finally, we want to thank our sponsors, judges, career panelists, 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 2019.

-The Crossroads Committee and members of the
Rho chapter of Sigma Gamma Epsilon

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Crossroads Judges

Larry Whitmer	<i>Wabash Energy</i>
Quinn Lewis.....	<i>IU Dept. of Earth and Atmospheric Sciences</i>
Ashley Landis	<i>Arcadis</i>
Jeffrey Woods	<i>United States Geological Survey</i>
Rebecca Caldwell	<i>Chevron</i>
Joel Degenstein... ..	<i>EP Energy (retired)</i>
Tom Skirvin... ..	<i>Skirvin Geoscience Consulting</i>
Stan Carpenter... ..	<i>Colonial Pipeline Company</i>
Jennifer Anné.....	<i>Children's Museum of Indianapolis</i>
Carrie Burke.....	<i>ConocoPhillips</i>
Claudia Johnson.....	<i>IU Dept. of Earth and Atmospheric Sciences</i>

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**DEPARTMENT OF EARTH
AND ATMOSPHERIC SCIENCES**

INDIANA UNIVERSITY
College of Arts and Sciences

DAILY SCHEDULE

FRIDAY MARCH 23		
7:30 AM	Breakfast (GY 522)	
8:30 AM	Poster session 1	Oral session 1 (GY 522)
9:30 AM		
10:30 AM	Career Fair (GY 522)	
11:30 PM	Lunch (GY 522)	
12:30 PM	Poster session 2	Oral session 2 (GY 522)
1:30 PM		
2:30 PM	Keynote talk with Rebecca Caldwell (GY 522)	
3:30 PM	Poster session 3	Break
4:30 PM		
5:30 PM	Judges meeting (GY 507) (5:30-6:00)	Break
6:30 PM- 9:00 PM	Networking Social at Crazy Horse (214 W. Kirkwood Ave. Bloomington, IN 47404)	

SATURDAY MARCH 24	
8:00 AM	Breakfast (GY 522)
8:30 AM	
9:00 AM	Awards ceremony (GY 522)
9:30 AM	Career panel discussion (GY 522)
10:00 AM	
10:30 AM	
11:00 AM	PaleoCollections Tour
11:30 AM	
12:00 PM	
12:30 PM	Lunch (GY 522)

Oral Presentations in GY 522

Session 1 Presenters	Presentation Time
Silvia Ascari	8:45 AM
John Kearney	9:00 AM
Matthew Wanker	9:15 AM
Ben Liu	9:30 AM
Nate Mitchell	9:45 AM
Kathryn Mudica	10:00 AM
Danielle Peltier	10:15 AM

Session 2 Presenters	Presentation Time
Sarah Burgess	12:30 PM
Patrick Griffin (1)	12:45 PM
Patrick Griffin (2)	1:00 PM
Marissa Schorr	1:15 PM
Samuel Smith	1:30 PM
Joshua Smith	1:45 PM
Fotios Fouskas	2:00 PM
Colleen Rosales	2:15 PM

Poster session 1 (8:30-10:30 am)	Poster session 2 (12:30-2:30 pm)	Poster session 3 (3:30-5:30 pm)
Kathryn Evans	Jacob Dorsett	Anne Kort
Kendall Gibson	Evelyn Becerra	Arianna Lagunas
Riuguang Pan	Thomas Brimm	Brigid Lynch
Elizabeth Sherrill	Emilee Darling	Ricardo Ely
Ian Armstrong	Allie Wyman	Emily Thorpe
	Jeff Larimer	Alex Zimmerman

Poster Session 1

TEACHING GEOLOGY IN THE FIELD: FIELD PEDAGOGY AND THE IMPERATIVE KNOWLEDGE OF LEARNING ON-SITE

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This study emphasizes the means by which field-based courses profoundly enrich geoscience education. Field-courses offered at Indiana University bridge the gap between the field and classroom by giving students hands-on experience with soil and rock description, hand lens petrography, Brunton compass and geologic mapping skills, and other field screening techniques. Field courses teach future geologists the foundational skills to be independent geoscientists post-graduation. Field trips to the Northern Appalachians in New England, the St. Francois Mountains of Missouri, the Tobacco Root Mountains in Montana, and the many world-class limestone exposures near the Bloomington campus give students the opportunity to interpret sedimentary, igneous, and metamorphic rocks produced by a wide range of geological processes that significantly add to their ongoing education, outside of the classroom. Students are encouraged to use critical thinking at planned outcrops in order to synthesize geological, chemical, mathematical, and logistical interpretations to better understand the environment/s they were once exposed to. With a set of tools (Brunton compass, rock hammer, hand lens, and guidebook) students can collaborate and apply the skills learned in the classroom to aid their discoveries/hypotheses found in the field. Instead of briefing students on what to expect at any outcrop, students are expected to make their own observations and develop their own interpretations. Students' observations of mineralogy, fabric elements, and brittle structures yield interpretations that can be tested while still on the outcrop. Students plot their structural measurements on a field stereonet to visualize inferred stresses and compare structures from other outcrops. Students then develop schematic diagrams, detailing, for example, the thermal or strain history of an outcrop. Integration of these observations over a multi-day field course ultimately leads to an understanding of regional geology that the students have generated themselves. Self-confidence, problem-solving, and scale are all emphasized in the field; understanding scale outside of the classroom is critical in being a fully immersed geoscientist. Our results corroborate the adage that the best geoscientists are those who see the most rocks.

CHANNEL HEAD INITIATION AS A FUNCTION OF GLACIAL AND FLUVIAL HISTORY

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The channel head is the place on a hillslope where water first flows through identifiable banks, marking the transition to a channel. Prior work has found that physical variables including lithology, climate, vegetation, and slope, control the channel head placement, but few studies have quantified the effect of glaciation. Moreover, prior work has used coarse (30-meter) resolution elevation models. We looked at non-glaciated fluvial hillslopes and glaciated hillslopes in the northern Sierra Nevadas and compared channel head initiation in two sites. We used high resolution lidar elevation models of the two sites to determine flow accumulation and slope data for each site. We resampled the rasters to find the flow accumulation and slope data for each site at 1-meter, 10-meter, and 30-meter resolutions. We then plotted the drainage area and slope to find the critical drainage area – the area from the ridge to the channel head – for each site. Results thus far have shown that at the glaciated site the channel head is initiated closer to the ridgeline and at a lower slope compared to the channel head at the fluvial site. Within the same study site, the different DEM resolutions caused a shift in the perceived critical drainage area by an order of magnitude. This implies that whether or not an area has been glaciated affects stream initiation and channel head placement and that the resolution of the DEM impacts the perceived critical drainage area, which may have implications for the accuracy of previous work. Future work will test more sites to examine the effects of glaciation on channel head placement and will involve testing different glaciated and fluvial sites both within the Sierra Nevadas and outside of it to determine whether or not other glaciated sites consistently have lower slopes and critical drainage areas than non-glaciated sites.

METAMORPHIC EVOLUTION AND METASOMATISM IN THE TSO MORARI UHP TERRANE, NW INDIA: CONSTRAINTS FROM GEOCHEMISTRY, FE ISOTOPES, AND THERMODYNAMIC MODELING

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The Himalayan orogen is associated with one of the largest subduction zones on Earth in terms of elemental cycling, crust-slab-mantle interactions, and areas of ultrahigh pressure (UHP) terranes. This project aims to examine the hypothesis that some microcontinents (MC) can be subducted to mantle depths surrounded by oceanic crust prior to the major Indo-Asian continental collision, which would allow for metasomatism to alter the subducted MC at high pressure through fluid-rock interactions (Kylander-Clark et al. 2012; Menold et al. 2016).

Mineral recrystallization in the presence of geofluids and changes of mineral phases in solid solution may occur at the UHP depths and during exhumation, and those processes can be identified by studying its geochemical and isotopic signatures and also through thermodynamic modeling. The Tso Morari UHP terrane, NW India, provides an ideal geologic site to examine the above suggested hypothesis. Petrographic investigation shows that the abundances of hydrous minerals formed through metasomatic reactions (e.g. amphiboles, talc and epidotes) increase markedly at the eclogite-gneiss contact. The whole-rock geochemistry shows that LILE (e.g. K, Rb, Cs, Sr, Ba) are enriched along the traverse and the Ba/Rb ratios are relatively lower at the contact. In addition, the whole-rock $\delta^{56}\text{Fe}$ slightly decrease and the $\Delta^{56}\text{Fe}_{\text{omp-grt}}$ fractionation dramatically decreases approaching the contact. The changes regarding mineral phases, LILE, trace elements, and Fe isotopes at the lithologic contact are thought to be caused by metasomatism deep in the subduction zone (Macris et al. 2016).

Metamorphic pseudosections and the corresponding mineral compositional isopleths in the eclogite and gneiss based on whole-rock XRF and EMPA data are constructed as to further constrain the metamorphic evolution. We found that the pressure and temperature increase from 508 °C and 22.6 kbar (garnet core), to 551.8 °C and 34.3kbar, and then to 620.6°C and 28.5 kbar (garnet rim) during its prograde metamorphism. Future work will focus on investigating the metasomatism and thermodynamic modelling in a high P-T aqueous environment.

References:

- Kylander-Clark et al., *Earth Planet Sci. Lett.* **321**, 115-120 (2012)
Macris et al., *GSA Abstract with Programs* **48**, 7 (2016)
Menold et al., *Earth Planet Sci. Lett.* **446**, 56-67 (2016)

MODELING POSTSEISMIC DEFORMATION AT NANKAI SUBDUCTION ZONE

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The Nankai subduction zone in southern Japan has been seismically quiet since the 1944 M8.1 Tonankai and 1946 M8.4 Nankai earthquakes, making it an ideal area to study postseismic mantle flow. Using a data set comprised of GPS, leveling, and tide gauge records of vertical motion spanning 1950 to 2015, we estimated the vertical velocity field of southern Japan from immediately after the 1944/46 events until near present day. Approximately 250 km inland from the trench we observe postseismic subsidence which decreases in rate from 1950 to 1995. Postseismic uplift is observed in a narrow belt along the coastline that diminishes and reverses to subsidence by the 1960s. Analysis of this data with 2D models shows that the observed inland subsidence pattern is diagnostic of viscoelastic mantle flow while the uplift at the coast is diagnostic of afterslip on the subduction interface. In this presentation we show results of 2D postseismic deformation models consisting of a linear Maxwell viscoelastic mantle and an elastic subducting slab and overriding plate. By adjusting rate-strengthening afterslip contribution, mantle flow relaxation times, and the geometry of the subduction zone, we were able to match the vertical velocity field patterns over time. We will also show preliminary efforts to expand the work to a 3D postseismic deformation model for the Nankai subduction zone.

ASSESSMENT OF EARTHQUAKE AND LANDSLIDE HAZARDS IN INDIANA
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We report on a contribution to the Indiana Department of Homeland Security (IDHS) five-year review of natural and anthropogenic hazards impacting the state. We focus on the subset of hazards associated with earthquakes and landslides facing Indiana residents. We used a combination of the US Geological Survey's *ShakeMap* and FEMA's *Hazus-MH* software packages to assess earthquake-triggered ground-shaking and their effects on the built environment, respectively. We applied two distinct approaches to analyze seismic hazards. The first approach uses a probabilistic earthquake hazard estimate from the U.S. Geological Survey's (USGS) national Probabilistic Earthquake Hazard Assessment. The second approach uses a "deterministic seismic hazard assessment" to illustrate the impacts of a series of specific possible future events that might affect residents of the State. The deterministic case studies are by definition arbitrary scenarios representing individual cases of a virtually infinite set of possible combinations of earthquake location, magnitude, source type, depth, and wave propagation characteristics that might influence the impact of earthquakes in Indiana's future. We performed five deterministic scenarios—three events occurring outside the borders of the state and two within the state that could affect Indiana residents; a M7.6 New Madrid event in southeastern Missouri, a M7.3 Wabash Valley event in southern Illinois, a M6.2 Anna, OH event in west-central Ohio, a M6.2 Darmstadt, IN event near Evansville, and a M5.8 Central Indiana event near Indianapolis. For each scenario we used a recently developed ground failure estimation tool to examine the spatial distribution of anticipated earthquake-induced landslide and liquefaction probabilities. We conclude that the most serious hazards may come from moderate-sized crustal earthquakes originating close to populated areas of the state. Much of the state's built environment is shown to be vulnerable to these moderate-sized urban earthquakes and their secondary effects.

In addition, we present, for the first time, a statewide review of non-seismic (mostly rainfall-induced) landslide hazards affecting the state, including observational review of historical landslides, recent landslide data from the Indiana Department of Transportation (INDOT), and geological landslide vulnerability assessment. Most historical landslides have been concentrated in the areas of high relief in south-central and southeastern Indiana. There is also significant correlation with bedrock type, as the highest density of landslide occurrence is associated with the Buffalo Wallow and Kope formations, dominated by fine-grained shale, mudstone and siltstone. The majority of recent landslide events have occurred in the southeastern part of the state, including areas of Dearborn, Ohio, and Switzerland counties. Neighboring areas of southwestern Ohio (Cincinnati area) and north-central Kentucky are also highly susceptible to landslide damage. Based on INDOT data on landslide losses, they are a chronic cause of roadway damage and their associated costs have been trending upward over the last five years, as a possible result of increasing vulnerability of new roadway systems and increased cost of roadway repair and renovation.

QUANTIFYING THE CONTROL OF BEDROCK STRENGTH ON KNICKPOINT MIGRATION RATES

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A growing body of literature has shown that the spatial distributions of bedrock river knickpoints and their migration (or erosion) rates are strongly linked to rock uplift rates, and therefore act as an archive for the tectonic activity within a region. However, the erosional resistance of bedrock has the potential to obscure this archive, yet scholars have not yet adequately addressed how variable bedrock strength influences erosion rates in tectonically active regions. I will fill this knowledge gap by quantifying how bedrock erodibility modulates transient channel response along the Eastern Margin of Bull Mountain, MT. My hypothesis is that the rate of knickpoint migration within the transient channels is faster within softer bedrock, so that knickpoints propagate faster in higher bedrock erodibility. I have performed a morphological analysis of the bedrock streams draining along the eastern margin of Bull Mountain using 10m DEMs. Through this analysis I have calculated the normalized steepness (K_{sn}) values, the spatial distribution of knickpoints, and the transient channel incision depth within the actively eroding bedrock channels. I have found that the transient channel incision depths decrease northward along the eastern Bull Mountain margin. The collection of field data will take place this Summer, where I will first gather bedrock strength values along a selected number of profiles using a Schmidt Hammer in the field as well as bringing samples back to IU for tensile strength analysis using the Brazilian split test. I will then extract sand samples from both the transient and relict profiles of the selected channels in order to estimate their erosion rates through Be-10 cosmogenic nuclide analysis. With all of these data, I will be able to test my hypothesis by correlating the incision rate and rock strength values with the spatial distributions of the knickpoints. Through this analysis, I will also be able to quantify the spatiotemporal uplift rates of the Eastern margin of Bull Mountain.

Poster Session 2

CHARACTERIZING OFF-FAULT DEFORMATION IN SOUTHERN CALIFORNIA

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The fault network that characterizes Pacific-North American plate boundary in southern California has been extensively studied through a variety of interdisciplinary techniques. Quaternary fault geometry is well constrained from numerous geologic studies and is compiled in the USGS-led Uniform California Earthquake Rupture Forecast (UCERF) report and the Southern California Earthquake Center's Community Fault Model (CFM). Present-day relative motions across these faults have been characterized by paleoseismology, geodesy, and geophysical deformation modeling. In the last decade, a number of mechanical modeling studies have sought to characterize fault slip rates in the southern San Andreas fault network by using geodetically measured displacements with mapped fault geometries to drive long-term slip. These models consistently show that a substantial amount of total strain accumulated from plate motion is not resolved along faults, with some methods estimating off-fault strain accounting for up to 30% of plate motion. Present modeling methods do not directly model permanent off-fault deformation but are able to observe it indirectly by taking the difference between applied displacement and slip resolved on faults. In this work we utilize the finite-element code PyLith, which can directly compute off-fault plastic strain, to explicitly model permanent off-fault deformation in Southern California. While this project is not complete, we anticipate that using PyLith will allow us to resolve off-fault deformation to a much higher spatial resolution than indirect techniques. We will be able to benchmark our results by comparing model-calculated slip distributions to both geologic slip rate estimates and geographic features associated with off-fault deformation, including the Western Transverse Ranges, Los Angeles Basin, and Eastern California Shear Zone. In this presentation we will show some preliminary models of off-fault deformation using idealized fault geometries.

A HIGH RESOLUTION STUDY OF NUTRIENT AND REDOX CYCLING IN THE KOPE FORMATION OF THE LATE ORDOVICIAN

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The Ordovician (485-444 Ma) was a highly dynamic time period, characterized by both significant evolutionary and climatic change. It began with the Great Ordovician Biodiversification Event (GOBE), during which the number of marine families tripled as new benthic fauna replaced Cambrian fauna. As rapidly as metazoans radiated and diversified, the Ordovician abruptly ended in biological crisis when 85% of marine species went extinct during the first of the “Big Five” major mass extinction events. The mass extinction is thought to have been caused by the Hirnantian glaciation, which dramatically switched the Ordovician climate from a “hot house” with elevated CO₂ levels to an “ice house” with decreased CO₂. Though several studies that document long time-scale changes in geochemistry exist, there is currently a lack of high resolution geochemical data that can elicit different interpretations concerning the Ordovician biosphere.

The Kope Formation, within the upper Ordovician Cincinnati series, contains a series of interbedded mudstone and fossiliferous limestone beds deposited within a shallow epeiric sea. C-isotope excursions, lithology, and biostratigraphy from this area are well studied and have been correlated across local and global regions. This provides an ideal backdrop for a high-resolution geochemical study. Preliminary N-isotope analysis of a high-resolution section of the Kope Formation shows an overall positive increase in N-isotope values up-section as well as systematic decreases in the N-isotope value within carbonates. These N-isotope values tied to lithology also appear to be concordant with meter-scale cycles, which are repeated patterns of lithological change that can be indicative of sea level rise and fall. Combined, these preliminary data may suggest sea level fluctuations are a control for N-isotope signatures. By encompassing drill core sections above and below this data set, it may be possible to find there is an overall shift in nutrient availability and cycling as the environment changed leading into the Hirnantian glaciation. Moreover, small cycles within lithological changes may be caused by sea level fluctuation or single events that temporarily perturbed the N-cycle.

DIVE INTO TAÍNO HISTORY: UNDERWATER ARCHAEOLOGY IN THE CAVERNS OF THE DOMINICAN REPUBLIC, PADRE NUESTRO

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Much of the Dominican Republic, and the island of Hispaniola overall, is composed of Pleistocene limestone which, through the process of dissolution, has turned into the karst topography that is so characteristic of the island. The caves, caverns, and sinkholes of the Dominican landscape are just as important to inhabitants of the island now as they were before colonial contact. These geological features served as sources of freshwater (a valuable resource on an island surrounded by the sea) as well as sacred spaces, a sort of connection between the world of the living and the world of the dead. In the Southeastern region of the Dominican Republic lies *Parque Nacional del Este* or East National Park. The park holds within it some of the richest cultural resources of the entire country including the 9th oldest site on the island of Hispaniola. That site, a cavern known as *Padre Nuestro* (Our Father), contains a long history of usage. The cavern's entrance is through a sinkhole; the ceiling, having collapsed some time ago, opened the underwater world up to the terrestrial one. Entering the cavern, one will see a large pile of rubble, from which Taíno ceramic artifacts, pre-ceramic lithic artifacts, and extinct faunal remains have been recovered. Descending into the cavern, one will see stalactites, stalagmites, and large merged columns indicating that the cavern flooded after the formation of these structures, some 6500 years ago. At the deepest depths of the cavern, the remains of three extinct species of mammal were recovered: A diurnal platyrrhine monkey: *Antillothrix bernensis*, and two medium-sized ground sloths: *Acratocnus ye* and *Parocnus serus*. Jenny Riley, in her dissertation, discovered the presence of possible cut marks on one of the *P. serus* specimens, indicating that it may have been prepared for consumption. Knapped stone artifacts, dated to 4-6kya by Nicolas Toth and Kathy Schick of the Stone Age Institute, were uncovered halfway up the rubble pile, indicating early, pre-ceramic human activity. Taíno ceramic artifacts, determined to be *potizas* or water gathering vessels, were recovered from the upper portions of the rubble pile. While there is no evidence that Padre Nuestro itself ever served a ritual or sacred purpose, other caves and sinkholes in the park do such as Cueva de Chicho and the Manantial de la Aleta. The importance of these caverns and sinkholes to those living on the island is highlighted by the material recovered from Padre Nuestro and other surrounding caves. These caves still serve as sources of freshwater to locals; however, much of the water is contaminated with coliform bacteria. This is why the protection of these submerged cultural resources is paramount, not only to document and preserve the cultural history of the island but also to protect a natural resource and geological feature so central to the topography of Hispaniola.

PRODUCTION OF SYNTHETIC METEORITE SPHERES USING AERODYNAMIC LEVITATION COMBINED WITH LASER HEATING

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Studies of the detailed chemistry, mineralogy, and isotopic compositions of meteorites provide invaluable clues to the range of chemical and physical processes and timing of events in the solar nebula. To study meteorites, scientists often use analytical methods that alter or destroy these valuable samples. The creation of synthetic meteorites helps alleviate this problem. This study uses a High Temperature Conical Nozzle Levitation (HT-CNL) system, combining laser heating with aerodynamic levitation, to create synthetic meteorites that reproduce the compositions and textures of natural meteorites.

We combined powdered compounds (e.g., MgO, SiO₂, Fe₂O₃, etc.) in proportions matching the compositions of natural EL and CI chondrites and in simplified analogues (e.g., Fe-free). The powder mixtures are weighed out, fused to form spheres in a Cu-hearth plate, and then levitated on a flow of gas above a conical nozzle while being heated with a 400 W CO₂ laser. The synthesis experiments were conducted at temperatures between 1600 and 2200 °C, heating times between 5-240 s, and in levitation gases of pure Ar, pure O₂, or a mixture of CO and CO₂. Each variable has an effect on the outcome of the experiment and can help inform the conditions attending meteorite formation and alteration.

Fe-bearing synthetic chondrite spheres have rough, metallic external surfaces and contain dendritic Fe-metal crystals inside. Visual comparisons of these synthetic spheres with some natural samples reveal striking similarities, suggesting that our technique likely produces good analogues. One application of our experiments is to investigate mass loss due to volatilization at high *T*. Preliminary evaporation experiments using Fe-bearing chondrite compositions resulted in <6% mass loss, whereas Fe-free compositions had up to 12% mass loss. Comparing the levitation conditions and results of both Fe-bearing and Fe-free experiments, we determined that Fe-bearing spheres had significantly less mass loss than Fe-free spheres, and that Fe-free spheres had a positive correlation with mass loss, heating time, and temperature. There is no apparent correlation between mass loss and levitation gas mixture for either composition. Future work will involve isotopic analyses of these experiments to learn about evaporation induced fractionation.

SALINITY INFORMATION FROM LIPID BIOMARKER ISOTOPE RATIOS IN A CENTRAL TROPICAL PACIFIC LAKE SEDIMENT RECORD

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Variability in tropical Pacific Walker Circulation and the nature of the Intertropical Convergence Zone (ITCZ) on centennial timescales over the last millennium remains uncertain given the diverse conclusions of paleohydrologic proxies across the tropical Pacific. Here we use biomarker stable isotope ratios from a lake sediment record taken from a brackish (28 ppt) lake on Kiritimati, in the central tropical Pacific, to reconstruct lake salinity and paleohydrology over the last millennium. Total lipid extracts (TLE) and specific biomarkers were extracted and the δD values were measured at decadal resolution over the last millennium. Preliminary results show lower $\delta DTLE$ values corresponding with thicker, darker microbial mats and more positive $\delta DTLE$ corresponding with gypsum rich units. A published transfer function relating salinity to $\delta DTLE$ indicates this latter period of high $\delta DTLE$ corresponds to lake water of 4.33-135 ppt. However, this transfer function also suggests modern salinity of 71.2 ppt, 43 ppt higher than measured. Thus, variations in $\delta DTLE$ likely reflect different microbial communities downcore, rather than the δD of lake water and its relationship with salinity. We plan future research on compound specific δD , paired with inorganic carbonate $\delta^{18}O$ and detailed isotope-based hydrologic balance modeling, to further define the relationship between biomarker δD and salinity.

DETECTING THE DAMAGE OF BEDROCK BY BEDLOAD IMPACTS

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Incision into bedrock drives landscape evolution and controls the topographic response to climate and tectonics. Bedrock resistance to incision (i.e. erodibility) is set by rock strength. Bedrock is weakened through a wide range of mechanical and chemical processes that damage rock by increasing the density of fractures. Here we consider the role in which sediment impacts propagate micro-fractures and weaken the bedrock surface thereby enhancing the efficiency of other processes to remove material. We examine distinct channel surfaces that are subject to a range of characteristic impact energies and weathering rates. These surfaces include upstream facing bedforms, downstream facing bedforms, and channel margins at a height above the bankfull waterline. The Prescott National Forest in Arizona has many bedrock streams in a variety of lithologies. Several streams are used to investigate the influence of different mineralogy and crystalline grain size. Cross-channel differences in bedrock erodibility are estimated with in-situ measurements of P-wave velocity and Schmidt hammer rebound as well as uniaxial strength tests of extracted cores. Sediment impact energy is characterized by the sediment impingement angle estimated from the surface-normal of channel bedforms. We quantify the degree of micro-fracturing with depth below the surface using image analysis on thin sections of samples collected from the bedrock surfaces.

Results show that the P-wave velocity of bedrock surfaces is slower than core samples by 200-3000 m/s and that micro-fractures are more prevalent in channel bed than the channel margins despite more extensive weathering in the margins. In coarse grained granitic rock and phyllite, as the impact angle steepens both the P-wave velocity and compressive strength of the impacted surface decreases in a statistically significant correlation ($p < 0.001$). In basalt and greenstone this relationship is not apparent, which we suspect is due to either greater weathering susceptibility of mafic minerals or fewer structural weaknesses. Thin section analyses reveal that in granitic rock and phyllite the density of micro-fractures tails off between 2.5 and 5 mm depth while basalt and greenstone have far fewer micro-fractures that are limited to the upper 0.5 mm. Our results imply that rock type has a strong influence the fundamental processes under which river erosion incises into bedrock.

Poster Session 3

NICHE DIFFERENTIATION IN EOCENE CARNIVORES: UNIQUE LUMBAR SPECIALIZATIONS IN THE OXYAENID *PATRIOFELIS*

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Oxyaenids were one of three diverse clades of terrestrial mammalian carnivores in the Eocene: carnivorans survive to the present day, hyaenodontids persisted into the Miocene, but oxyaenids became extinct in the Eocene. Key adaptations either inflexibly coupled oxyaenids to disappearing tropical environments or put them in direct competition with the emerging carnivorans. An almost complete specimen of *Patriofelis ulta*, one of the last oxyaenids in North America, shows that the lumbar vertebrae had highly specialized convolute zygapophyseal joints. We used geometric morphometrics to compare the shape of this joint with those of 20 extant mammals from 9 orders. Ten landmarks were used to measure overall shape of the vertebrae, and 30 semilandmarks were used to measure the curvature of the articulation surface of the prezygapophyses. For overall lumbar shape, PC1 explained 36.8% of the variance, and while a multiple linear regression of the log of centroid size compared to principal components 1-16 was not significant with a $p > 0.1$, a bivariate regression of PC1 with log of centroid size shows that centroid size varies significantly with PC1 with a $p < 0.01$. For shape of the articular surfaces, PC1 explained 77.2% of the variance, but no tested factors, including locomotor category, order, or size significantly correlated with the variation. Articular shape appears to correlate with lumbar stiffness, with animals such as the peccary, armadillo, and goat grouping together at the positive end of PC1 and otter, bobcat, and rabbit at the negative. *P. ulta* grouped with the stiff-backed species. Paradoxically, other features of *P. ulta*, such as its long body and tail, relatively short limbs, and plantigrade posture, are incongruent with other dorsostable mammals of comparable size in which stabilization is useful for jumping or running. *P. ulta* has no cursorial features, and although it lived in a forested environment where climbing and jumping may have been useful, it has no clear scansorial features either. Our results suggest that late oxyaenids may have had a combination of postcranial specializations that sharply distinguished them from the other carnivore groups.

BIOLOGICAL HEALTH DOCUMENTATION OF THE 1733 *SAN PEDRO* SHIPWRECK

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Today, the Spanish 1733 *San Pedro* shipwreck is a successful marine protected area which supports a diverse assemblage of marine organisms typical of an inshore patch reef community. After the ship sank in 1733, extensive salvage put it in the condition it is in today with its disarticulated ballast pile and unconsolidated substrate. Due to the salvage, the site is not conducive to long-term coral stability and growth. The last biological report conducted on the site was in 1988 which identified the sites varieties of segmented worms, crustacea, sea urchins, cnidarians, corals, fish, and shells. Although the establishment of the area into a state park has reduced the level of disturbance, the site continues to be impacted by constant visitors and environmental change. For this report, the invertebrates of the *San Pedro* site were identified and compared to 1988's report in order to determine how the biological health has changed over time.

QUANTIFYING TRIBUTARY RESPONSE TO CANYON INCISION IN THE CENTRAL ANDES, SOUTHERN PERU

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The rivers of southern Peru have carved some of the deepest canyons on earth and are essential to quantifying and constraining the timing of surface uplift in the Central Andes. Tributary basins within these larger watersheds contain a break in slope that separates high relief, adjusted canyons from low relief, relict surfaces that remain untouched by recent transience. The erosional history of these tributary basins can be used to constrain the style, rate and timing of uplift in this region. We will present erosion rates derived from ¹⁰Be cosmogenic radionuclide concentrations from five tributary basins in both the adjusted and relict reaches of these channels. We present these trends in erosion rates along with comparisons between a number of metrics including mean annual precipitation, channel steepness, knickpoint distribution, and incision depth. The patterns among these metrics will clarify the relative influence of climate and tectonics in this region as well establish a foundation for understanding the history of uplift in the Central Andes. Specifically, by focusing on tributaries, we can account for the control of climate on the transient response of the landscape and provide robust reconstructions of the spatiotemporal pattern of canyon incision. The study basins are located along a transect extending from the dry (<1 mm yr⁻¹), low elevation coast up to the high, wetter (700 mm yr⁻¹) Central Andean plateau. Erosion rates range from 0.003 – 0.35 mm yr⁻¹ and are consistent with longer-term estimates of exhumation from thermochronology. Relict and adjusted erosion rates both increase by more than an order of magnitude between low (dry) and high (wetter) elevation sites. Furthermore, we find that while knickpoint elevations simply increase with increasing elevation throughout the study area, incision depths are greatest in the northwest and decrease to the southeast along strike of the topography. This pattern suggests that there exists either a higher uplift rate, a climate driven increase in erosion, or a combination of the two, which has led to deeper incision in the northwest.

DIETARY ECOLOGICAL NICHE DISPERSION IN AN ECOMORPHOSPACE OF PLATYRRHINE PRIMATES AND ITS ASSOCIATION WITH CRANIAL INTEGRATION

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Morphological integration and modularity are concepts describing the degree of interdependence between traits in an organism. Integration describes a high degree of interdependence, while modularity describes relative independence of traits. A greater magnitude of interdependence (integration) among traits hampers evolutionary response, while trait independence (modularity) facilitates evolutionary flexibility, suggesting that modularity facilitates the evolution of ecological specializations and the ability for modular clades to occupy a wider array of niches. I tested this in platyrrhine primates by constructing a three-dimensional ecomorphospace based on dental topographic measures using principal component analysis (PCA). The breadth of dietary niche occupation in this ecomorphospace was measured using the Euclidean distance between each platyrrhine genus and a 'generalist' condition of the average dental shape of all genera. Indices measuring the degree of modularity (r^2 , ICV) were collected from the literature for each genus. Linear regression and correlation was used to assess the relationship between modularity and niche dispersion. No significant correlations between PCA Euclidean distance and each integration index was detected. This indicates modularity may not have a strong influence on dietary niche dispersion (at least not in platyrrhines). Alternatively, the potential for modularity to allow clades to exploit ecological opportunities occurs at broader phylogenetic and ecological scales than those considered here. This hypothesis can be tested by broadening the taxonomic scope of the analysis presented here.

DISCOVERY OF A EUPELYCOSAUR BODY FOSSIL IN THE LOWER PERMIAN YESO GROUP, CENTRAL NEW MEXICO

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The lower Permian (Leonardian) Yeso Group, which until recently was considered to have few fossils, records arid coastal plain, shallow marine, and evaporitic deposition northwest of the Permian basin, across much of central New Mexico. The recently discovered fossil record in Yeso strata includes marine micro-organisms (mostly algae and foraminiferans), terrestrial plants, and tetrapod footprints. In November of 2016, the first tetrapod body fossil of the Yeso Group was discovered at Salinas Pueblo Missions National Monument. This fossil is a partial skeleton of a basal synapsid, varanopid eupelycosaur, and is preserved as natural casts of the bones in part and counterpart in a lower sandstone bed of the Arroyo de Alamillo Formation in the southern Manzano Mountains. This quartz-rich sandstone is fine-grained and pale reddish brown to grayish red when unweathered, weathers to blackish red, and is partially encrusted with white caliche. The casts preserve in close articulation the lower half of a single individual including part of the pelvis(?), 18 caudal vertebral centra, both femora, tibiae, fibulae, and most of the pedes. With a femur length of 62 mm and a total length of the preserved cast from the pelvis to the tip of the incomplete tail of 325 mm, this skeleton is of a relatively small and gracile eupelycosaur most similar to *Varanops*. Older strata in New Mexico, including the Bursum Formation, Abo Formation, and Cutler Group are known to contain eupelycosaurs, but this discovery extends that fossil record into the younger part of the early Permian section. The arid coastal environment recorded in the Arroyo de Alamillo Formation must have cultivated a substantial terrestrial food chain in order to sustain a relatively large, early Permian predator like *Varanops*. This animal likely fed on smaller vertebrates and arthropods, which have yet to be discovered in the Yeso Group strata.

TEMPORAL TRENDS IN DEEP-SEA CORAL BIODIVERSITY AND BIOGEOGRAPHY, GULF OF MEXICO AND US WEST ATLANTIC

Zimmerman, A. N., Johnson, C. C., Bussberg, N., Roberson, R., and Dalkilic, M. M.

Characterizing deep-sea coral biodiversity is an integral step in evaluating the current state of the deep-sea ecosystem and in assessing vulnerability to anthropogenic factors.

Thousands of deep-sea coral records are compiled in the publicly accessible NOAA database, but no research has examined the how deep-sea coral biodiversity through time. This paper completes the first temporal analysis of deep-sea corals by examining regional US deep-sea coral biodiversity through time across multiple US marine ecoregions. Analyzed records consisted of deep-sea coral occurrences that were verifiable for taxonomy, depth, location, and time. Approximately 24,080 records of coral occurrences were gleaned, categorized to shelf (60-200 m) and to slope (201-2000 m) depths, subdivided into Caribbean, Gulf of Mexico, and US West Atlantic regions, and binned into time intervals of pre-1960, and decadal intervals thereafter to the 2010's.

Data were most robust across all time bins for slope depths in the Gulf and the US West Atlantic, and subsequent analyses focused on these subsets. In both regions, biodiversity decreased sharply through time following 1990 for all examined taxonomic levels (family, genus, and species), with a larger biodiversity decrease in the Gulf than in the US West Atlantic. Caryophylliidae and Oculinidae were the most persistent families in the Gulf and US West Atlantic, and *Lophelia pertusa* and *Madrepora oculata* were the most persistent species. Dendrophylliidae and *Enallopsammia profunda* were persistent in the US West Atlantic but not in the Gulf. Overall, Gulf slope corals exhibited a greater decrease in biodiversity than in the US West Atlantic.

This work illuminates novel quantitative temporal patterns of how and when deep-sea coral biodiversity has changed over the past 60 years in US waters. Results reveal deep-sea corals are highly susceptible to rapid biodiversity losses, fortunately diversity has stabilized, albeit at the lowest levels recorded. This temporal framework supplies a highly useful and much needed historical context of deep-sea coral biodiversity, compliments spatial niche modelling, and ultimately aids the collective effort to preserve these ecologically and economically important deep-sea ecosystems.

Oral Session 1

CARBON CYCLING IN THE KARST AQUIFERS OF SOUTH-CENTRAL INDIANA

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The classic karst landscape of the Mitchell Plateau in south-central Indiana is shaped by the dissolution of limestone by carbonate equilibrium reactions with water, resulting in subsurface drainage systems where meteoric, surface, and groundwater interact. Dissolution produces dissolved inorganic carbon (DIC), from both the atmosphere and bedrock, and the epikarst soils releases dissolved organic carbon (DOC), as delayed capture from the atmosphere. Both DIC and DOC in karst groundwater are therefore a sink for atmospheric carbon. The rate of carbon flux is dependent on geochemistry, biological productivity, climate, and land use. The juxtaposition of farmland on the epikarst of the Mitchell Plateau may contribute to excess carbon in groundwater via soil erosion, fertilizer application, and animal waste. As part of a larger research program into karst aquifer geochemistry and carbon systematics in the critical zone, this study will quantify carbon in water samples from sinking streams, caves, and springs across two karst basins. Each study site represents an inflow, throughflow, or outflow of the karst aquifer with unique hydrologic and geochemical characteristics. Stable isotopes of DIC, DOC, nitrogen, sulfur, hydrogen, and oxygen will be used to quantify the source contributions of water to the Lost River and Bluespring karst basins of Lawrence and Orange Counties, Indiana, in conjunction with continuous geochemical monitoring data collected from Orangeville Rise and Bluespring Caverns. The results of this study will be used to refine existing models of global carbon cycling and assess the effect of land use on the flux of carbon through karst aquifers.

RADICAL SHIFTS IN THE EVOLUTION TOWARDS THE SABERTOOTH CRANIAL MORPHOLOGY

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The sabertooth morphology has evolved independently in several different lineages. Besides hypertrophied maxillary canines, another shared characteristic of the sabertooth morphology, regardless of phylogeny, is a shortened distance between the craniomandibular joint and the upper carnassial. It has been hypothesized that the clouded leopard, *Neofelis nebulosa*, which has the longest canines of modern felids, might begin to show similar cranial morphologies as sabertooths. Here we test whether species with medium-sized canines, such as *Neofelis*, have an intermediary cranial form between modern felids and sabertooths. We took images of modern felids and nimravids, thylacosmilids, and machairodontids, all with varying canine lengths, and analyzed their skull morphology via landmarks using geometric morphometrics. We have found a bimodal distribution of skull morphologies consisting of species with short canines at one extreme and species with long canines at the other, and few species with an intermediary cranial form. This suggests that rather than there being a gradual shift towards the sabertooth morphotype as canine length increases, the evolution towards that morphology may consist of a rapid and permanent shift, with few species maintaining an intermediary morphology. *Neofelis* falls within the skull morphology of modern felids, and other species with medium-sized canines vary greatly in their morphologies between the two extremes.

USING PHENOCRYST COMPOSITION FROM REWORKED TEPHRA TO CORRELATE DRILL CORES TO THE OUTCROP IN OLDUVAI GORGE, TANZANIA

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Drill core studies in ancient hominin landscapes have greatly increased our knowledge of the climatic conditions that were present during the evolution of early humans. Such studies have led to interpretations of a variable climate having a crucial impact on the evolutionary and global success of our species. Olduvai Gorge, Tanzania is one of the most important paleoarchaeological sites in the world, and thus would contribute valuable data with drill cores. The Stone Age Institute funded the Olduvai Gorge Coring Project (OGCP) and collected 4 different drill cores from 3 distinct locations around the gorge. These cores can be correlated to the outcrop using the well-established tephrostratigraphic framework of Olduvai Gorge. The tephrostratigraphic framework is imperative for making correlations within the gorge, allowing for paleoenvironmental reconstructions of this hominin landscape. Marker tuffs throughout the stratigraphy have been used to link geologic and archaeological localities and enhance our understanding of when specific hominins existed and what stone tool industry they were utilizing. These marker tuffs were sourced from the numerous volcanoes of the Ngorongoro Volcanic Highlands just east of the gorge and can be chemically fingerprinted according to their unique volcanic source, giving them strong discriminative capabilities. This work has been done for the older Olduvai stratigraphic formations Bed I and Bed II using phenocrysts of anorthoclase, plagioclase, and augite. These same minerals are present in Bed III and younger, and thus can be fingerprinted using similar methodology in order to complete the chemical database of the Olduvai tuffs. Results show that anorthoclase can be used to distinguish tuffs of Bed III and younger from those of Bed I and Bed II. Anorthoclase found in Bed III and younger is more K₂O-enriched than anorthoclase found in Bed I and Bed II. Thus, anorthoclase can be analyzed from the drill cores in order to find the transition from Bed II to Bed III.

EAST SIDE STORY: COMPARING *PARANTHROPUS BOSEI* AND *HOMO HABILIS*
CARBON ISOTOPE DATA WITH PLANT WAX BIOMARKERS TO UNDERSTAND
HOMININ COMPETITION IN OLDUVAI GORGE, TANZANIA

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Ecosystems are a large networks of various species that work within equilibrium. In order to keep the state of equilibrium, each species occupies a specific niche. An ecological niche is the idea that every species has set of requirements (diet, habitat, climate, etc.) that have to be met to have population growth (Bear et al, 2016). At 4 Ma, hominins had diets rich in C3 plant matter that was very similar to modern day chimpanzees; however, at ~3.5 Ma, hominins began incorporating C4 plant matter into their diets (Sponheimer et al., 2013). *Paranthropus* is one of two catarrhines, and the only great ape genus, to have a diet that is C4 dominated (Sponheimer et al., 2013).

Olduvai Gorge is located in the Northern portion of Tanzania within the East African Rift System and is composed of five distinct beds named, in chronological order, Bed I, Bed II, Bed III, Bed IV, and Bed V (Hay, 1976). The beds range from the late Pliocene through Pleistocene and all five beds are fossil and lithic rich (Hay, 1976). Within Olduvai Gorge, Bed I is unique because both *Paranthropus bosei* and *Homo habilis* fossils have been discovered in upper Bed I within the shallow water/ floodplain deposits above the flood basalts (Leakey, 1961). The age dates for upper Bed I are retrieved from ⁴⁰Ar/³⁹Ar and are 1.9 Ma for the flood basalts and 1.8 Ma for the overlying layer of tuff called Tuff IF (Deino, 2012). Since *Paranthropus bosei* and *Homo habilis* are found within the same geologic unit that spans 100 Ka, it is unknown if the hominins were occupying the basin at the same time.

The Olduvai Gorge Coring Project is an ongoing project to understand small scale changes within the basin and consists of 3 cores spanning from below the Bed I flood basalt to the surface. The section of core that spans Bed I has a time resolution of ~300 years with plant wax biomarker data showing $\delta^{13}\text{C}$ values at this high resolution (Colcord et al, 2018). By correlating hominin $\delta^{13}\text{C}$ and total C4% values to the plant wax biomarker data, the timing of hominin occupation in the basin can be refined to a ~300 year resolution. With such a high timing resolution, it is possible to see the relationship between *Paranthropus bosei* and *Homo habilis* in Olduvai Gorge. If the hominins are occupying the basin at the same time, the competition between the *Paranthropus bosei* and *Homo habilis* could be a reason for *Paranthropus bosei* to be forced into this unique dietary niche; however, if the hominins are occupying the basin at different times, there has to be another outside force (climate, volcanism, predation, etc.) causing *Paranthropus* to shift into the C4 dietary niche.

VARIATION OF ROCK MECHANICAL PROPERTIES IN THE SEQUENCE
STRATIGRAPHIC CONTEXT OF THE UPPER DEVONIAN NEW ALBANY SHALE,
ILLINOIS BASIN

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Rock mechanical properties of unconventional tight shale reservoirs are key parameters in shale oil/gas exploration and development. Understanding the stratigraphic variation of rock mechanical properties in black shale successions is important for identifying target intervals for hydraulic stimulation. High-resolution hardness tests (6 cm spacing) using an Equotip Bambino 2 hardness tester and geochemical analyses (8 cm spacing) using a portable x-ray fluorescence spectrometer were conducted on a New Albany Shale core to study the stratigraphic variation of rock mechanical properties and the control of rock composition on the hardness of black shales.

The results show that the average quartz content in the New Albany Shale is 27.64%, out of which 12.88% is of biogenic origin, suggesting that biogenic silica accounts for approximately 47% of total quartz. Biogenic silica, mainly derived from siliceous planktonic organisms, occurs as recrystallized radiolaria, chemical precipitation of authigenic quartz in *Tasmanites* cysts, and microcrystalline quartz in the matrix. The hardness of shales is not controlled by quartz content, but by biogenic silica content because the latter forms an interconnecting stiff framework which increases the hardness of shales. Calcite cement also enhances hardness, but its influence can be masked by biogenic silica when its content is low. Dispersed grains in clay matrix such as detrital quartz, feldspar, and dolomite do not contribute to hardness. The negative correlation between hardness and Al₂O₃ content and differential compaction of clay minerals against rigid grains (e.g., quartz, dolomite, and pyrite) suggest that clay minerals are ductile components in shales. The influence of organic matter on hardness is counteracted by load-bearing biogenic silica because organic matter and biogenic silica content have similar stratigraphic distribution patterns. We propose a new mineral-composition-based brittleness index which considers the differential contribution of biogenic silica and calcite to characterize the brittleness of tight shale reservoirs.

Within the sequence stratigraphic context of the New Albany Shale, hardness increases in transgressive systems tracts, reaches a maximum at the maximum flooding surface, and decreases in highstand systems tracts except in the Blocher Member. The maximum flooding surface intervals have the highest potential for the development of natural fractures and could be potential zones for hydraulic stimulation.

SPATIALLY VARIABLE INCREASE IN ROCK UPLIFT IN THE NORTHERN U.S. CORDILLERA RECORDED IN THE DISTRIBUTION OF RIVER KNICKPOINTS AND INCISION DEPTHS

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The Earth's surface evolves over time, driven by factors such as tectonics, geodynamics, climate, and lithology. By studying landscape evolution, geomorphologists seek to unravel these factors and read the history recorded in landscape morphology. Here, we study the northern U.S. Cordillera. This region features a wide array of potential drivers of landscape evolution, such as the Yellowstone plume, the extrusion of a large igneous province, and the drainage of large lakes. Transient incision has carved deep canyons along the Salmon and Clearwater Rivers in central Idaho, and these steep canyons are in stark contrast with the low-relief, low erosion rate surfaces at high elevations. Amongst the region's complex geologic history, the drivers of this transient incision are not well understood. To constrain the pattern of regional incision and isolate the influence of rock properties on transient adjustment, we analyze the morphologies of 80 individual tributaries underlain by single lithologies (granite, basalt, gneiss, quartzite, and siltite). From north to south across our study area, knickpoint elevations increase from about 800 to 2200 m and incision depths increase from about 300 m to 1200 m. We present numerical model simulations and utilize a previously published analytical model to demonstrate that such a gradient could represent spatial variations in rock uplift. These findings suggest that transience is driven by a spatially variable increase in rock uplift that has disrupted a low-relief paleo-landscape, and the high steepness values of main drainages suggest that high rock-uplift rates are still maintained to the present. Changes in rock uplift may be related to interactions between the Yellowstone plume and the lithosphere, although base level fall from the drainage of the Lake Idaho down the proto-Snake River may be superimposed over these patterns in rock uplift. We show that careful, quantitative analyses of river profiles in geologically complex regions can differentiate between the influences of rock uplift and far-field base level changes.

BIOACCUMULATION OF LEGACY POLLUTANTS IN FRESHWATER SYSTEMS USING (*LONTRA CANADENSIS*) NORTH AMERICAN RIVER OTTER AS A BIOINDICATOR

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While environmental quality has improved significantly over the last 40 years, assessing water quality alone cannot predict the ecological impacts of metal pollution. In order to quantify these impacts, bioaccumulation and biomagnification in organisms must be studied. Because of their long environmental residence times, metals can remain in an environment for decades where they may be or may become bioavailable. Once introduced into a food web, these metals may bioaccumulate and biomagnify and can reach toxic levels very quickly. For example, fish tested in this study had average Pb = 3 to 6.5 ug/dL depending on trophic level. Fish maintain equilibrium with the water they inhabit, and they are pH, temperature, and most importantly, pollution tolerant. This allows fish to carry metal burdens throughout their lifespan.

Keystone species are often used to assess bioavailability of pollutants. The North American river otter, a piscivorous keystone species in fresh water systems, is an ideal choice as a surrogate for fish and a proxy from human fish consumption. As a pollution sensitive, apex predator, river otters hold the potential for both bioaccumulation and biomagnification. The purpose of this research is to evaluate the metal content of whole livers collected from otters that were surrendered to IN DNR during the 2017-2018 trapping season. Analysis of the livers revealed Pb levels 4Xs the levels found in fish, with average Pb = 23 ug/dL, suggesting bioaccumulation of Pb is occurring in freshwater systems in Indiana. In addition, elevated liver Pb concentrations were found in all counties where otters were trapped and surrendered.

Comparing lead results in the river otters to surface water monitoring by Indiana's Department of Environmental Management indicates much of the lead contamination is recycled in the food web of freshwater, exposing all organisms in the food web. The results of this research will provide an alternative assessment of potential metal exposure to humans through fish consumption.

DYNAMICS OF SEDIMENT TRANSPORT THROUGH A RIVER BIFURCATION

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Channel bifurcations are key nodes in rivers that distribute water and sediment into two or more channels downstream. Previous studies suggest the dynamics of sediment routing through a bifurcation influence bifurcation stability; when unequal amounts of sediment are routed into either channel a stable, asymmetric bifurcation develops. The unequal sediment distribution can arise from either the interaction of different grain sizes with a local bed ramp at bifurcate arm or upstream channel curvature. Yet, these two ideas have rarely been tested in the field and our understanding of the feedbacks between sediment routing and bifurcation stability remains theoretical. We present a combined field and numerical modeling study aimed at evaluating the controls on sediment routing through bifurcations. Our field site, the Jefferson River, MT, is a gravel-bed river with a long-lived bifurcation and bed ramp leading up to the shallower bifurcate channel. We deployed radio frequency identification (RFID) tagged gravel and cobble clasts along three upstream transects to track their routing through the bifurcation during a flood season. We recovered 204 clasts that had been transported through the bifurcation; almost half (46%) were routed into the shallower channel. The factors that most significantly control which clasts were routed into either channel were upstream flow dynamics and grain shape. Surprisingly, grain size had no control on sediment routing, suggesting the bed ramp played a minimal role. Calibrated numerical modeling reveals that clasts generally follow flow lines, resulting in equal routing between the bifurcate arms. Moreover, the shallower arm has smaller Shields Stresses than the other, indicating it will likely alleviate with time. Our results highlight the potential for using RFID-tagged clasts to study bifurcation mechanics and show that, in this case, upstream channel curvature is a more significant control on sediment routing than bed ramp mechanics.

Oral Session 2

YOU ARE WHAT YOU EAT, +/- 5‰ Patrick Griffin^{1*}

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The reconstruction of food webs remains a central challenge in the study of paleoecology. Several obstacles preclude researchers from accurately assessing food web dynamics, particularly the unavoidable incompleteness of the fossil record. Stable isotope geochemistry has proven to be a powerful tool in the analysis of ancient environments, and food web reconstruction is no exception.

Here, I will provide a nearly-live demonstration of how stable isotopes from hair can be used to construct inferences about an individual's diet and, indeed, the broader ecology of that person's life. Strands of hair, like fingernails, are made of the protein keratin, which is now known to persist over geological time. Because keratin is a protein, its monomer subunit is the amino acid. Each of the approximately twenty amino acids that constitute protein contain both carbon and nitrogen. The isotope ratios of these elements provide information on primary productivity within an environment and the trophic level of the specimen whose tissue has been sampled. In this manner, even a small number of specimens may provide a comprehensive assessment of ecological dynamics of relict environments.

Specimens of hair were donated by IU students, staff, and their family members, rinsed with 90:10 DCM:MeOH to remove oils, and subjected to elemental analysis (EA). From these data, we can distinguish the vegetarians from the carnivores, those who prefer rice over potatoes, and possibly who has returned from international travel. Such a demonstration serves as a vivid example of the principle of uniformitarianism and also provides confidence in the ability of researchers to reconstruct past environments from what, at first, appears to be a dearth of data.

AMINO ACID $\delta^2\text{H}$ FROM *E. COLI* TO ELEPHANTS

TRACERS OF METABOLIC, ECOLOGICAL, AND BIOGEOCHEMICAL PROCESS

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Hydrogen is the most abundant element in biogeochemical systems and its isotope systematics are perhaps the most complicated to understand, and therefore, to employ as an analytical tool. Due to the mass difference between the isotopes, H is more strongly fractionated than any other element, leading to a wider range of natural values. Also unlike the other elements, some H in biomolecules readily exchanges with ambient moisture, erasing the signal imparted during biosynthesis. Transient H-bonding is responsible for an array of molecular interactions, including the base pairing of nucleic acids and the transport of many compounds during membrane transport. Finally, a family of enzymes is dedicated to the transfer of H from activated carriers, both to provide energy for ATP production (from NADH) as well as reducing power during biosynthesis (NADPH). Most importantly, however, hydrogen is central to the fundamental interaction of living organisms with their geochemical milieu: the acquisition of food and nutrients to be turned into biological molecules and tissues. Understanding these interactions is central to understanding biogeochemical processes.

Despite the tremendous potential utility of H as a proxy for these processes, its application has so far yielded limited success. Largely, this owes to the difficulty inherent in the interpretation of $\delta^2\text{H}$ from bulk materials. Simply stated, bulk materials are complex chemical mixtures of many distinct chemical species, each with individual isotope ratios that vary by hundreds of mUr (or ‰), have undergone uncharacterized exchange, and bear the isotopic signal of unknown biological processes.

Compound specific isotope analysis of amino acids solves these problems. Amino acid derivatives are readily separated by GC, allowing for the “unmixing” of complex tissues. The metabolic pathways that produce them are well-studied, allowing researchers to develop an understanding of the physicochemical underpinnings that give rise to observed biochemical fractionations. Amino acids are also abundant, persist over geological time, and branch from central metabolism at multiple points. All of these features make them ideal candidates for the development of a new analytical framework for understanding biogeochemical fractionation of H.

Laboratory experiments with the model microorganism *Escherichia coli* give clues to the biochemical underpinnings that dictate how hydrogen from the environment – both as water and organic nutrients – is fractionated during metabolism. A comparison of the $\delta^2\text{H}$ distribution of amino acids from bacteria and animals also provides a basis for interpreting the ecological origin of amino acids obtained from unknown sources, as may occur in the sedimentary record. Finally, potential application to paleo-environmental reconstruction – both hydrology and geochemistry – are discussed.

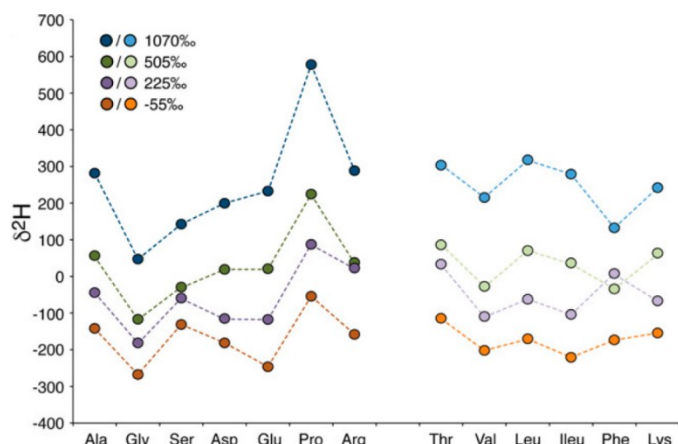


Fig. 1 - $\delta^2\text{H}$ of amino acids from *E. coli* cultured in ^2H -labeled water with glucose as its sole carbon source.

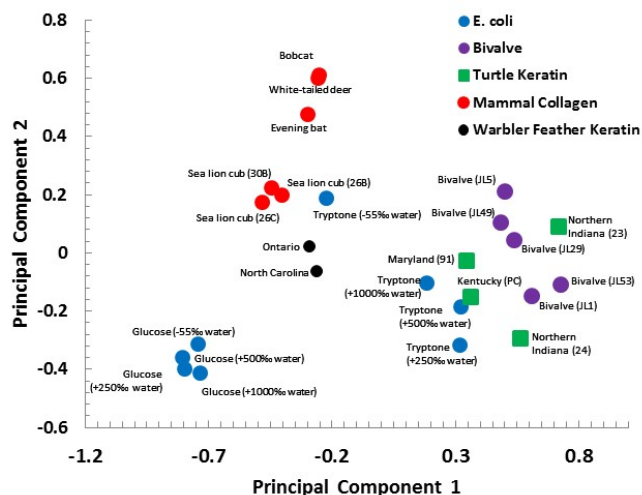


Fig. 2 - PCA of amino acid distributions from several mammals, turtles, bivalves, and *E. coli* grown on different nutrient substrates.

ALLUVIAL FAN GEOCHRONOLOGY AS A TOOL TO DISCRIMINATE HYDROCLIMATES IN THE VIZCAINO DESERT, CENTRAL BAJA CALIFORNIA, MEXICO

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Mexico's Vizcaino Desert on the Baja California Peninsula is a place of picturesque beauty and great geological variety, yet few studies have been conducted here to understand the Quaternary history of this magnificent landscape. This study aims to construct a more detailed alluvial fan stratigraphy and chronology in order to understand the climatic processes that control desert landscapes. To do this I will use a combination of field observations, optically stimulated luminescence (OSL) dating, and cosmogenic dating. Field observations indicate that there are four main Quaternary units, Q1 (oldest), Q2, Q3, and Q4 (youngest). Preliminary OSL dates suggest that the youngest unit, Q4 was deposited around 1 ka, and the two intermediate units, Q3 and Q2, were deposited around 15ka and 80 ka, respectively. These ages may suggest that there has been a combination of hydroclimates at work in the area during the Quaternary, but more data will be needed to corroborate these preliminary ages.

ANTHROPOGENIC IMPACTS ON HYDROLOGIC CYCLE EXTREMES MEDIATED BY LARGE-SCALE ATMOSPHERIC TURBULENCE

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While extremes in precipitation intensity or frequency, such as drought and flooding, have disproportionate economic and societal impacts, “state-of-the-art” climate models disagree on the response of these extremes to anthropogenic climate change. Recent literature has identified fluid dynamical differences as a leading cause of this inter-model uncertainty. In order to understand one aspect of these differences, we examine the role of large-scale turbulent eddies (hereafter, eddies) in transporting moisture, as they are a key contributor to precipitation extremes. To this end, we quantify poleward moist eddies and equatorward dry eddies using local finite-amplitude wave activity (LWA). By connecting these eddies to a simple hybrid Eulerian-Lagrangian budget which determines their evolution, LWA can be used to understand how changes in eddies and in the background flow influence precipitation extremes. Using the LWA budget, we analyze changes in frequency and intensity of precipitation extremes projected by the Community Earth System Model Large Ensemble (CESM LENS) under Representative Concentration Pathway (RCP) 8.5 forcing. Our early results suggest that previous studies may have neglected to fully account for changes in the advection of basic state moisture, changes which are significant in the mid-latitudes and are intimately connected to eddy characteristics.

S, PB, AND OS ISOTOPIC STUDIES OF MASSIVE NI-CU±PGE SULFIDES HOSTED IN
METASEDIMENTARY COUNTRY ROCKS OF THE MIDCONTINENT RIFT SYSTEM,
USA

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Country rock-hosted Ni-Cu±PGE massive sulfides are found near mafic-ultramafic intrusions of the 1.1 Ga Midcontinent Rift. Massive sulfides occur in Proterozoic country rocks beneath the sheet-style Duluth Complex and adjacent to and below the conduit-style Eagle and Tamarack intrusions. Locally, the intrusions and the massive sulfides are separated by several meters of country rock, and, until now, an igneous origin for the massive sulfides has not been confirmed.

Massive sulfides beneath the Duluth Complex have $\delta^{34}\text{S}$ of 10.2-17.4 ‰. Disseminated igneous-hosted sulfides have $\delta^{34}\text{S}$ from 6.0 to 13.0 ‰. Massive sulfides in country rocks at Eagle have $\delta^{34}\text{S}$ between 2.6 and 3.6 ‰. Igneous-hosted sulfides have $\delta^{34}\text{S}$ from 0.3 to 4.6 ‰. Country rock-hosted massive sulfides at Tamarack have $\delta^{34}\text{S}$ from 0.5 to 2.5 ‰, and igneous-hosted sulfides have $\delta^{34}\text{S}$ between -0.2 and 2.8 ‰. Country rock-hosted massive sulfides from all three sites have near-zero $\Delta^{33}\text{S}$. Massive sulfides from Eagle and Tamarack have identical $\delta^{34}\text{S}$ to samples of igneous-hosted mineralization, but massive sulfides from Duluth have heavier $\delta^{34}\text{S}$ values than igneous-hosted sulfides. Re-Os compositions of the massive sulfides at Eagle and Tamarack (average $\gamma_{\text{Os}_{1100\text{Ma}}} = +28$ and $+22$, respectively) are virtually identical to igneous-hosted sulfides (average $\gamma_{\text{Os}_{1100\text{Ma}}} = +35$ and $+25$, respectively). At Duluth, country rock-hosted massive sulfides are more radiogenic, with $\gamma_{\text{Os}_{1100\text{Ma}}}$ from $+800$ to $+1360$. Limited analyses of igneous-hosted sulfides have $\gamma_{\text{Os}_{1100\text{Ma}}}$ of $+3$ and $+557$.

Previous S and Os analyses of igneous-hosted sulfides from Tamarack and Eagle have suggested that sulfide saturation was achieved by crustal contamination of mantle melts by Proterozoic country rocks. The identical S and Os isotopes between country rock-hosted massive sulfides and igneous-hosted sulfides at Tamarack and Eagle indicate that the country rock-hosted sulfides are leaked igneous sulfide liquids. At Duluth, crustal contamination has been well documented by S, Pb, and Re-Os studies of igneous sulfides. Massive sulfides near Duluth are interpreted as leaked igneous sulfide liquids, but the heavier S and more radiogenic Pb and Re-Os compositions of the massive sulfides beneath the Duluth Complex suggest the sulfide liquid continued to incorporate sedimentary S after emplacement.

SULFURIZATION PATHWAYS AND METAL DISTRIBUTION IN MODERN EUXINIC LAKES: INSIGHTS FROM THE HYPER-EUXINIC SYSTEM OF MAHONEY LAKE, CANADA

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To better understand the fate of reduced sulfur (S) in waters and sediments, we focus on modern euxinic lakes where S isotopes can potentially differentiate the two competitive sulfurization pathways that lead to pyrite and organo-S compound (OSC) formation. Mahoney Lake contains a productive community of phototrophic S bacteria and sulfate-reducers that drive S cycling within the water column and sediments. The high levels of sulfate, sulfide and organic matter (OM) relative to other natural systems can help elucidate the parameters that influence sulfurization reactions. The isotopic offset between sulfate and sulfide ($\Delta^{34}\text{S}_{\text{SO}_4\text{-H}_2\text{S}}$) within water column is similar to other euxinic systems (~50‰). Dissolved trace element concentrations (e.g., Mo, U) show clear transitions from the oxic to euxinic waters. In order to examine the longer term history of redox and S cycling within the lake, a 3.7 m sediment core was collected. The $\delta^{34}\text{S}$ of pyrite and total organic sulfur (TOS) decreases with depth, which is opposite the expected increase that happens during diagenesis. The isotope offset between pyrite and TOS also changes from ~15‰ within the surficial sediments to ~0‰ at the base of the core. Based on solid phase trace metal chemistry, we suggest that the hyper-euxinic environment of Mahoney Lake has changed through time including changes in the Fe and OM availability, and the relative kinetic rates between pyrite and OSCs formation. These parameters influence the partitioning of reduced S in these two pools and their S isotope compositions. Ongoing kinetic modeling will evaluate the dominating pathway by varying the environmental parameters (C_{org} , H_2S , S_8 , Fe) of the system. Initial results show that only significant levels of labile organic carbon can trigger OM sulfurization rates in levels similar to those of pyritization. These kinetic rates potentially lead to the incorporation of an isotopically similar S inorganic source to pyrite and TOS during the same timescale, which could explain the zero isotope offset observed within sediments. FT-ICR-MS analysis of DOM in Mahoney water column revealed an abundant and diverse array of OSCs suggesting that rapid sulfurization of OM can occur syngenetically.

INFORMAL INTERCOMPARISON OF HO_x RADICAL MEASUREMENTS IN AN
INDIANA FOREST USING LASER-INDUCED FLUORESCENCE, CHEMICAL
IONIZATION MASS SPECTROMETRY AND CHEMICAL AMPLIFIER TECHNIQUES

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Oxidation is one of the key reactions controlling the lifetime of many species in the atmosphere, such as greenhouse gases and volatile organic compounds (VOCs). Hydroxyl (OH) radicals, as well as organic peroxy (RO₂) radicals, and (HO₂) hydroperoxyl radicals—collectively known as HO_x radicals—all play primary roles as oxidants in the atmosphere. In the presence of nitrogen oxides (NO_x), oxidation of VOCs may lead to the formation of ozone and secondary organic aerosols which contribute to photochemical smog, a significant contributor to ambient air pollution.

Previous measurements of HO_x radicals in areas influenced by high isoprene and low NO_x concentrations have shown discrepancies with respect to modeled predictions, which brings into question (1) our understanding of atmospheric chemical processes and (2) the accuracy of instrumental techniques at hand. To address these issues, an informal intercomparison of three instrumental techniques used to measure HO_x radicals— (1) Laser Induced Fluorescence- Fluorescence Assay by Gas Expansion (LIF-FAGE), (2) Chemical Ionization Mass Spectrometry (CIMS), and (3) Ethane Chemical Amplifier (ECHAMP) Technique—was performed at the Indiana University Research and Teaching Preserve (IURTP) in Bloomington, Indiana. The IURTP is a forested site located near the Indiana University campus. In addition, different calibration techniques, as well as auxiliary measurements, were also compared for the three techniques.

These results give way to further understanding the discrepancies between measured and modeled HO_x concentrations, as well as provide confidence in the accuracy of radical measurements using these three techniques.