# Crossroads Geology Conference 2015

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# CROSSROASDS GEOLOGY CONFERENCE 2015

## Welcome

We would like to extend a special thank you to all of those participating in this year's Crossroads Geology Conference at Indiana University. This conference is a rich tradition for the Department of Geological Sciences and we anticipate that this year's submissions will uphold previous standards of excellence. Additionally, we are excited to present our keynote speaker, Assistant Professor Paul W. Staten from Indiana University. Finally, we want to thank our sponsors, judges, the Department of Geological Sciences at Indiana University, and all of those who have volunteered their time for the preparation and execution of Crossroads 2015.

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Oral Sessions: 15-minute standard presentations (GY 126)

| Time | Presenter | Topic |
|---|---|---|
| 10:15 | Xiaotao Yang | Geophysics |
| 10:30 | Chen Chen | Geophysics |
| 1:00 | Ryan Wells | Geomorphology |
| 1:15 | Louis Wersan | Geomorphology |
| 1:30 | Ellen Reat | Sedimentology |
| 1:45 | Scott David | Geomorphology |
| 2:00 | Spencer Hellert | Paleontology |
| 3:00 | Bryan Wathen | Petrology |
| 3:15 | Gregory Welage | Hydrology/Geochemistry |
| 3:30 | Annie Ayre | Geochemistry |
| 3:45 | Cherie Achilles | Mineralogy |
| 4:00 | Patrick Griffin | Geomicrobiology |
| 4:15 | Sarah Cadieux | Geochemistry |

Poster Sessions: 2-hour standard poster presentation (Geology Lobby)

| **Session 1: Geophysics, Sedimentology, and Hydrology**<br>**9-11am** | **Session 2: Geochemistry**<br>**1-3pm** | **Session 3: Petrology, Paleontology, and Other**<br>**3-5pm** |
|---|---|---|
| Elizabeth Olliver | Mohammed Alrowaie | Patrick Cavanagh |
| Rebecca Caldwell | Michael Haluska | Shane Smallwood |
| Steven Davey | Amishi Kumar | Matt Lilley |
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| Anas Rabie | | Carley Gasaway |
| John Talley | | Silvia Ascari |

# Friday, March 27th, 2015

| | | |
|---|---|---|
| 8 am | Breakfast | |
| 9 am | Poster Session 1: Geophysics, Sedimentology, and Hydrology | Break |
| 10 am | | Oral Session 1: Geophysics |
| 11 am | Keynote Talk (GY 143) | |
| 12 pm | Lunch | |
| 1 pm | Poster Session 2: Geochemistry | Oral Session 2: Sedimentology, Geomorphology, Paleontology |
| 2 pm | | Break |
| 3 pm | Poster Session 3: Petrology, Paleontology, and Other | Oral Session 3: Petrology, Hydrology, Geochemistry, Mineralogy, and Geobiology |
| 4 pm | | |
| 5 pm | Break | |
| | Judges' Meeting | |

| | |
|---|---|
| 7 pm | Networking Social at the downstairs of the Video Saloon (105 W 7th St, Bloomington, IN 47404; Entrance on Walnut) |

**Note all oral presentations are in GY 126 and poster presentations in the Geology Lobby

| Saturday, March 28th, 2015 | |
|---|---|
| 8 am | Breakfast |
| 9 am | Awards Ceremony |
| | Career Panel Discussion |
| 10 am | |
| | IBA Presentations |
| 11 am | |
| | Career Skills Workshop |
| 12 pm | |
| 1 pm | Lunch |

# Keynote Speaker: Dr. Paul W. Staten

**Indiana's Climate, from a billion years ago, to a hundred years from now**

**Abstract:**

Over the past billion years, Indiana has experienced many climate extremes. In this talk, we will review some climate change events from Indiana's deep paleoclimate history, like ice ages and thermal maxima, along with more recent climate events like the year without a summer, and the recent cold winters in the Northeast. We will discuss why Bloomington enjoys the climate it does now, sample some current topics in climate science literature today, and explore what climate change means for us in Indiana.

# MARTIAN GLOBAL SOIL: INSIGHTS INTO AMORPHOUS PHASES

C. N. Achilles[1*], D. L. Bish[1], E. B. Rampe[2], R. V. Morris[3]

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Martian global soil and dust are the most widespread and comprehensively studied component of the planet's geology, yet after decades of robotic exploration, the amorphous materials, which comprise ~50 wt% of this global soil, remain poorly understood. Soils on Mars have been analyzed by the Mars Exploration Rovers (MER) and most recently by the Mars Science Laboratory (MSL) rover. The CheMin X-ray diffraction (XRD) instrument has revealed crystalline phases and a broad, elevated background, indicating the presence of amorphous or poorly ordered materials. Here, we explore the scattering profiles of potential amorphous materials comprising the global soil using pair distribution function (PDF) analysis to determine the short-range order of analog phases. These data will help better constrain the amorphous material detected by CheMin and build a thorough understanding of Mars's past geological processes.

# SULFUR CONTENTS AND GEOCHEMICAL CHARACTERIZATIONS OF THE MARINE, HIGH ORGANIC MATTER, HIGH GAMMA RAY SHALE: NEW ALBANY, USA

Alrowaie, M. A[1], Pratt, L.M.[1], and Haluska, M.A[1]

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During early diagenesis and the deposition of the Devonian-Early Mississippian New Albany Shale, complex biological processes occurred including sulfate reduction, disproportionation, and sulfide oxidation. These processes are strongly influenced by the change in the depositional environment including redox condition, reactivity of organic matter and metals. Organic geochemistry, photomicroscopic, and sulfur geochemistry for whole rock samples that were obtained from well cores drilled in 2006 in Pike County, Indiana, were used to (i) understand the depositional environment of the New Albany Shale "Hot Shale interval", (ii) to understand the role of sulfur in OM preservation, (iii) to investigate the proportion of the metallic sulfides and organic-sulfur and their relationship to the depositional environment.

Camp Run and Clegg Creek Members of the NAS show linear $C_{org}$ to $S_{tot}$ correlation in the studied core. Camp Run Mbr shows wider isotope fractionation for $\delta^{34}S_{pyrite}$ compared to the overlying Clegg Creek Mbr which might indicate more varied environments for Camp Run Mbr. The most depleted values of $\delta^{34}S_{pyrite}$ are −27.9 ‰ and −23.4 ‰, for Camp Run Mbr and occur at 2804 ft and 2812 ft respectively. At 2757 ft of the Clegg Creek Mbr, sulfide is characterized by extremely depleted value, −38.2 ‰ $\delta^{34}S_{pyrite}$. These depleted values in both members could be resulted from the process of repeated microbial disproportionation. Evidences from microscopic analysis indicate that the sample from 2757 ft is characterized by more opened marine condition compared to other analyzed samples. High fractionation in $\delta^{34}S_{pyrite}$ of the repeated chrome reducible sulfides, CRS, extraction for the same samples could be as a result of different processes of pyritization at different time. The presence of sulfate in the New Albany shale is due to the oxidation of disulfides and monosulfides. The smallest $\Delta^{34}S_{sulfate\text{-}pyrite}$ values are 5.7 ‰ at 2755 ft and 2.7‰ at 2785 ft respectively. These values are in corresponding to the highest absolute gamma ray values measured for the studied interval. The correlation between low $\Delta^{34}S_{sulfate\text{-}pyrite}$ and the high gamma ray might indicate abiotic oxidation of pyrite from radiation sourced from decaying of uranium in the presence of water. The overlying Ellsworth Mbr is dominated by sulfate originated from carbonate-associated sulfate, CAS, which gives extremely heavy $\delta^{34}S_{sulfate}$ value of + 27.8 ‰.

# RECONSTRUCTION OF EAST AFRICAN PALEOENVIRONMENT BASED ON STABLE ISOTOPES

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The Olduvai Gorge is a valley situated along the East African Rift Valley where many early hominin fossils have been exposed and found due to the rifting. The paleoenvironment of the Olduvai Gorge is important for determining what factors influenced early human evolution. One way of determining the paleoenvironmnet of a given region is by conducting isotopic studies on the bones of animals that lived in that region. Animals tend to incorporate the isotopic composition of what they eat and drink into their tissues. Trees and shrubs have lower concentrations of 13C whilst grasses, which can tolerate hotter, arid climates with low atmospheric CO2 levels, have higher $^{13}C$ concentrations. Higher $^{18}O$ concentrations from the water that the animals drink are likewise associated with aridity. We can use the collagen from fossil bones and teeth to analyze their isotopic composition and thereby reconstruct the paleoenvironments that the animals lived in. For this study we used both fossil and modern teeth and bones from the Olduvai Gorge to determine their isotopic compositions. We used 32 modern and fossil crocodile teeth and herbivore bones and teeth. The fossil specimens were from beds aged 1.8 and 1.85 Ma. We were able to do a comparative analysis between the modern and fossil bones and teeth to determine how the climate in East Africa was different in the past. The oxygen isotope composition of the samples indicate that the paleoenvironment at 1.8 and 1.85 Ma had higher precipitation levels than in the present, with slightly higher levels at 1.85 than at 1.8, indicating an overall increase in aridity through time. The carbon isotope composition of both crocodiles and mammal herbivores indicate that the environment in the past was dominated by woodlands, whereas in the present it is dominated by arid grasslands.

# Multiple Sulfur Isotope Studies of the Stillwater Complex, Montana

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Indiana University, Bloomington, Indiana, 47405 U.S.A.

Models for the genesis of the J-M Reef of the Stillwater Complex include magma mixing and the attainment of high R-factors to produce PGE-rich immiscible sulfide droplets (e.g., Campbell et al., 1983), leaching of trace sulfides in the Ultramafic Series and concentration at the level of the Reef by magmatic fluids (e.g., Boudreau and McCallum, 1992; Boudreau and Meurer, 1999), and the emplacement of PGE-rich magmas that had been upgraded via sulfide dissolution at depth (e.g., Keays and Lightfoot, 2013). In order to better evaluate the extent to which crustal sulfur was key for PGE enrichment we have initiated a multiple sulfur isotope study of the Complex. The work compliments the early S isotope studies of the Complex by Zientek and Ripley (1990), but the utilization of both $^{33}S$ and $^{34}S$ permits the detection of deviation from the terrestrial fractionation line that may be due to assimilation of S from Archean country rocks and was previously undetectable.

We have measured $\Delta^{33}S$ values for samples of country rocks and sulfides within country rocks, as well as rocks of the Reef Package in the area of the Stillwater Mine. $\Delta^{33}S$ values for both massive sulfides in country rocks and pyroxene-hornfels below the Basal Series range from 0 to 0.25 ‰. $\delta^{34}S$ values generally range from -1.3 to +1.3 ‰, with one massive sulfide sample having a value of 3.9 ‰ Samples of sulfides from the J-M Reef have $\delta^{34}S$ values from -1 to +1.5 ‰. J-M Reef samples have $\Delta^{33}S$ values from 0.005 to 0.05 ‰. The $\Delta^{33}S$ values of sulfides so far measured from the J-M Reef are not considered to be anomalous, however the range of sulfur isotopic values found in the metasedimentary country rocks does not preclude a contribution of country rock sulfur to the magmas that produced the Stillwater Complex. The relative uniformity of $\Delta^{33}S$ values in the igneous rocks of the Reef is consistent with no country rock contribution of sulfur, and exclusive incorporation of mantle S or, alternatively, contribution of country rock S characterized by similar $\Delta^{33}S$ values. A multi-component mixing process involving sulfur from various country rocks and that of mantle derivation remains feasible. Samples of Archean gneisses and other intrusive rock types are being analyzed to further constrain the involvement of country rock S in the formation of the J-M Reef.

# EXPLORING THE DALY GAP THROUGH A ONE ATMOSPHERE EXPERIMENTAL STUDY OF BASALTS FROM THE HUE-HUE FLOW OF 1801, HUALALAI VOLCANO, HAWAII

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Oceanic islands formed from hot spots are characterized by lavas that range from basalt to trachyte in composition. This range is believed to be produced by progressive fractional crystallization of magmas prior to eruption. However, a bimodal distribution of these rocks is often observed; most rocks fall in the basaltic or trachytic with very few intermediate composition lavas. These missing compositions is referred to as the Daly Gap. Clague (1978) proposed that silica content varies non-linearly with increasing fractionation with an initial period of essentially constant low Si02 (basalt), followed by a rapid rise in SiO2 (intermediate), and ending with another period of constant, higher SiO2 (trachyte). This means that there is less opportunity for intermediate magmas to erupt onto the surface which explains the observed gap. The purpose of this research is to experimentally evaluate Clague's model through a series of crystallization experiments using the 1801 Hue-Hue basaltic lava from the Hualalai Volcano, Hawaii, as a starting composition. Samples were melted at successively lower temperatures using a 1 bar, controlled atmosphere, high temperature furnace. After each experiment, samples were made into thin section and examined in an electron microprobe to determine the percent crystallinity and the composition of the minerals and glass formed at each temperature.

To date, five successful experiments have been conducted at temperatures ranging from 1200 °C to 1120°C. As expected during fractional crystallization, the samples show a systematic decrease in olivine forsterite content and plagioclase anorthite content with decreasing temperature. The data are sufficient to begin corroborating Clague's theory. As hypothesized, a non-linear rate is observed in increasing percent crystallinity with decreasing temperature. In fact, so far the trend appears to be exponential. Liquid compositions over this range of temperatures show very little variance in SiO2 compositions in the basaltic realm,. In Clague's model this implies that the Daly Gap has not yet been passed. Future experiments will be run at lower temperature in order to detect at which temperature the Daly Gap occurs. Results from these runs will be evaluated soon.

# FLUVIO-DELTAIC RESPONSE TO TECTONIC AND SEA-LEVEL PERTURBATIONS

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Fluvio-deltaic deposits result from the interplay of upstream and downstream environmental conditions, such as upstream tectonic and downstream sea-level settings, making them prime records of past environments. Environmental conditions are far from static, and changes to these conditions create perturbations, or signals, that can propagate from both the upstream hinterlands and from the downstream receiving basin to the fluvio-deltaic realm. Our ability to interpret past environmental conditions from fluvio-deltaic deposits thus hinges on our understanding of fluvio-deltaic response to, and preservation of, environmental perturbations. Recent work suggests the internal dynamics of fluvio-deltaic systems can modify or completely destroy these signals, making them difficult or impossible to interpret from the sedimentary deposits. It has been shown that such signal modification or destruction is a function of both the signal timescales and system response timescales. However, it remains unclear which aspects of the fluvio-deltaic system most significantly control the interaction of these timescales and the extent to which the environmental signals are ultimately preserved in the deposits. To answer these questions, we numerically simulate fluvio-deltaic growth using a source-to-sink model of sediment transfer from upland source areas to coastal depositional basins. Preliminary results demonstrate that grain size of the fluvial system affects propagation of both tectonic and sea-level forcings, as well as the preservation style of the resulting signal in the architecture of the fluvio-deltaic deposits. Future work will focus on determining if these results are set by a relationship between grain size with system response time.

**MICROBIAL SULFUR ISOTOPE DEPLETION AND MINERALOGY OF PROSPECT MESA FORMATION SOIL PIT, DRY VALLEYS, ANTARCTICA.**

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**Introduction:** A soil pit from the Prospect Mesa Formation (PMF) near Wright Valley, Antarctica, was investigated using sequential sulfur extraction, stable isotope analysis, and X-ray diffraction (XRD). The Antarctic Dry Valleys (ADV) have previously been used as a potential Mars analog due to their cold and dry environment. The PMF exhibits a varied stratigraphy with layers ranging from morainal gravel deposits, lodgement till, and fossil-rich marine sediments [1]. Seven samples, from the Pit #1, Core 72 Site in the PMF and collected during a 1979/1980 Antarctic campaign [2], were analyzed. Samples were taken at 2-4 cm intervals from the surface sediment layer down to 12-16 cm in depth. These samples have high sulfate and evaporite mineral abundances, and their sulfur isotopic compositions were analyzed to assess the origin of the sulfate and potential sources of depletion of $\delta^{34}S$. We present a potential depletion process that supports the hypothesis that the sulfate was deposited from atmospheric sources that have experienced microbial interactions.

**Results:** Isotopic analysis of each of the leachates revealed a depletion in $^{34}S$ from ~21‰ (value for ocean sulfate) to ~17‰ in the top layers. Lower depth samples were consistently ~15-16‰

**Discussion:** The depletion in $^{34}S$ rules out purely oceanic to atmospheric transfer mechanisms. An intermediary mechanism must be contributing to the depletion in $^{34}S$. We propose that the DMSP/DMS

pathway is partially responsible for the depletion in $^{34}S$ compared with that of ocean sulfate. In this scenario, seawater sulfate is initially taken up by macroalgae, reduced, and used to synthesize dimethylsulfoniopropionate (DMSP). This pathway ultimately synthesizes dimethylsulfide (DMS), which is released into the atmosphere and oxidized into non-seawater sulfate [5]. The DMSP/DMS process has been shown to account for a depletion from ~21‰ to ~17-19‰ in DMSP and in subsequent degradation products DMS and NSS-$SO_4^{2-}$ [5]. High concentrations of DMSP and DMS have been documented in the Antarctic and can be correlated to algal blooms [6]. The DMSP/DMS process does not fully account for an additional depletion in $^{34}S$ shown at lower depths.

**Conclusions:** Preliminary analysis of the PMF sediments is consistent with previously observed depletion in $^{34}S$ in sediment from the Antarctic Dry Valleys compared to marine sulfate in the Antarctic Ocean. Our data are consistent with a microbial process in which volatile products from marine algae, such as DMSP and DMS, may be responsible for the observed depletion in $^{34}S$ with sulfur oxidized and transferred via atmospheric processes.

**Acknowledgements:** Research funded by the Indiana Space Grant Consortium Fellowship and NASA ASTEP NNX11AJ01G.

**References:** [1] S.A. Arcone & A.J. Delaney (2000), SPIE, 4084, 772-777. [2] E. Gibson et al. (1983), JGR, 88(S02), A912. [3] Zaback & Pratt (1992), Geochim. Cosm. Acta, v56, 763-774. [4] Canfield et al. (1986), Chemical Geology, v54, 149-155. [5] Oduro et al. (2012) PNAS, 109(23), 9012-9016. [6] J.A.E. Gibson et al. (1990) Marine Biology, 104, 339-346. [7] Bishop et al. (1996) GCA, 60, 765-785. [8] Bishop et al. (2014) Phil. Trans. R. Soc. A 372, 20140198.

# SHEAR VELOCITY STRUCTURE BENEATH THE CENTRAL UNITED STATES: IMPLICATIONS FOR ILLINOIS BASIN ORIGIN AND THE MECHANISM OF INTRAPLATE SEISMICITY

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The US midcontinent contains several interesting geological features, including the Illinois Basin and two intraplate seismic zones, the New Madrid Seismic Zone (NMSZ) and the Wabash Valley Seismic Zone (WVSZ). This study provides a new estimate of the velocity structure beneath the area constructed by measuring phase velocities of fundamental mode Rayleigh waves recorded at USArray Transportable Array and OIINK (Ozarks-Illinois-INdiana-Kentucky) Flexible Array stations. We find that the southern part of the basin possesses high mid-crustal velocities at depths between 25 km and 35 km. A failed rift arm, known as the Reelfoot Rift, extends into the southern Illinois Basin. The observed high velocities at mid-crustal depths beneath the southern basin may correspond to high velocity mafic material that was emplaced into the crust during rifting. High-density mafic intrusions may have contributed to the subsidence of the Illinois Basin. We also observe that low velocities exist in the mantle beneath the NMSZ at depths between 90 and 125 km. The low upper mantle velocities extend to the north and reach the WVSZ. Our lithology modeling shows that the low velocity beneath the NMSZ is similar to the velocity of a pyrolite and the velocity of the surrounding mantle resembles the velocity of a dunite (> 90% olivine). Thus, we propose that the low velocity zone observed beneath the two seismic zones results from re-fertilization of depleted mantle along the Reelfoot rift during the rift development. Depleted mantle generally has higher strength, compared to relatively enriched mantle. The two seismic zones may mark locations where deformation has been localized in the crust above a weak mantle due to their lower integrated lithospheric strength.

# TELESEISMIC P WAVE RESIDUAL MEASUREMENTS OF THE ILLINOIS BASIN

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The experiment was designed to answer fundamental questions on lithospheric-scale structure connections to the origin of the Illinois Basin. The project deployed a passive seismic array of seismometers centered over the Illinois Basin but spanning the westward transition to the Ozark Plateau and the eastward transition spanning most of the state of Kentucky. I am measuring teleseismic P wave residuals from newly acquired data in the Kentucky section of the experiment using an array cross-correlation program. We checked the measurements for consistency using contour maps of residuals measured for each of the 116 events measured to date. Our preliminary results from the residual maps show a delay in arrival time of approximately 0.5 seconds in the region over the Rough Creek Graben in Kentucky. These data will be used as input for teleseismic P wave tomography to image upper mantle structure.

# MODELING THE SIZE, SHAPE, AND CONNECTIVITY OF STRATAL BODIES IN RIVER, WAVE, AND TIDE-DOMINATED DELTAS

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Modeling the size, shape, and connectivity of deltaic stratal bodies has important implications for hydrocarbon reservoir assessment and prediction. Here, we present initial results from depth-averaged simulations of river, tide, and wave-dominated deltaic systems in Delft3D. All runs were computed on a 24 x 18.75 km grid with 75 x 75 m cell size. For the offshore boundary conditions, we specified time-varying wave conditions, and/or constant semidiurnal tidal forcing. For the upstream boundary condition we specified a steady river discharge of at or near 11,000 $m^3/s$, carrying an initial sand to cohesive mud ratio of approximately 2:1. Results show that river-dominated delta sand bodies are predominantly composed of elongate levees and mouth bars, which together create digitate deposits with long axes parallel to local flow. Fluvial sand bodies have limited connectivity due to intervening interdistributary muds. Depending on proximity to fluvial and tidal discharge, tide-dominated delta deposits are characterized by differing morphologies: near fluvial channels there are elongate levee and reworked triangular mouth bar deposits, while in regions of low fluvial discharge tidal flats and flow-parallel sandy tidal shoals develop. Overall, lateral and vertical sand body connectivity in tide-dominated deltas is low, due to mud being distributed between mouth bars and capping much of the delta plain. Early in the development of wave-dominated deltas, sand bodies are similar to those of river-dominated deltas. However, as deltas prograde into deeper water where wave influence is higher, levees and mouth bars are replaced by spits and sand ridges. In shallow water in lower bed elevation regions between sandy spits, sand body connectivity is low due to the presence of intervening mud deposits. Initial analysis suggests that small-scale gyres trap mud leading to enhanced deposition in these regions. At the delta front, sediment distribution by longshore transport leads to the formation of laterally continuous sand ridges forming sheet-like sand bodies.

# MAPPING FLOODPLAIN MORPHOLOGICAL VARIABILITY: IMPLICATIONS FOR CONTROLS ON FLOODPLAIN CHANNEL DEVELOPMENT

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Understanding how floodplain morphology develops is critical for understanding flood wave conveyance, sediment transport during flood, and the mechanics of the main river channel. Given the importance of floodplains, surprisingly little is known about their topographic and morphologic variability. Towards this end, we use 1.5 m resolution digital elevation models (DEMs) derived from Light Detection and Ranging (LiDAR) elevation data to explore the variability of floodplain morphologies in Indiana, USA. In total, we mapped 3,064 $km^2$ of floodplain landforms, where floodplain is defined as the lowest elevation surface relative to the banks of the main channel. We find three distinct types of floodplains in Indiana: 6.7% of floodplains are relatively flat and featureless (type 1), 55.9% of floodplains are dominated by topography derived from river meandering (e.g. oxbow lakes, scroll bar topography, type 2), and 37.3% of floodplains contain channels that are long, coherent down valley pathways active only during overbank discharge (type 3). The first two types of floodplains are relatively well studied, whereas only a few studies have recognized the existence of floodplain channels, underscoring how surprising their prevalence is within Indiana. To understand how floodplain channels arise, we calculated the following metrics for all floodplain reaches: floodplain width, floodplain slope, river width, river meander rate, sinuosity index, and 10 year flood discharge. We find that floodplains exhibiting floodplain channels are characterized by high river meander rates, large floodplain width to river width ratios, and relatively high 10 year flood discharges. Geomorphic analysis of select floodplains reveals that up to 75% of channel reaches within floodplain channels are likely paleo-meander cutoffs. The remainder of the channels are herein called secondary channels. Meander cutoff segments are geomorphologically distinct from secondary channels; they are generally much wider (~44 m) compared to the secondary channels (~27 m), suggesting they have different origins. However, more interestingly, we find that the secondary channels interconnect the meander cutoffs and other topographic lows. From our analyses we hypothesize that floodplain channels form by differential erosion across the floodplain, developing channels that link pre-existing topographic lows in the floodplain created primarily by meander cutoffs. The resulting floodplain channels may have important implications on incisional avulsions and may provide insight on how streams transition from a single thread to multi-thread streams (anabranching).

# TWO DISTINCT OCEANIC TRACTS PRESERVED BETWEEN PERI-LAURENTIAN AND PERI-GONDWANAN TERRANES IN SOUTH CENTRAL CONNECTICUT

Bedrock geological map of western New Haven quadrangle, Connecticut

Deasy, R. & Wintsch, R.

The western third of the New Haven quadrangle in Connecticut exposes some of the best outcrops of the Orange Milford Belt (OMB), a tectonic sliver of meta-argillites and metabasalts wedged between peri-Laurentian and peri-Gondwanan terranes. The area hosts two temporally distinct bodies of mafic rocks. The older Maltby Lakes Complex (O?m) includes gneissic amphibolite enveloped by epidote-amphibole mylonite. Increasing concentrations of Al and Ti from core to rim and into beards and necks of broken grains indicate the fine-grained fabric developed from the gneissic fabric under prograde metamorphic conditions.

Both the gneissic fabric and the mylonite are intruded by 0.04-10.0 m dykes of the Allingtown basalt porphyry (S?a). The magmatic assemblage of Sa has been wholly replaced by amphibole + clinozoisite-epidote + sodic plagioclase ± chlorite. In most localities the unit has developed a moderate to strong foliation, and contact with the country rock is commonly transposed to near parallel with the regional foliation. Structural regional correlation suggests this deformation may be Devonian. Nevertheless, primary structures are commonly preserved in Sa. These include massive textures with ≤7 mm plagioclase phenocrysts as much as 75 volume % of the rock, and ≤5 cm uralitized oikocrysts. In some few outcrops, dykes of Sa are observed to intrude earlier Sa dykes, with chill margins increasing in phenocryst density with distance from the contact before being truncated again by another dyke. These structures are characteristic of sheeted dyke complexes.

Tectonomagmatic discrimination based on high field strength elements (Zr, Ti, V) reveals fractionation trends in Sa that are consistent with origination at a mid-ocean ridge or back-arc basin. The gneissic unit of Om is depleted in incompatible elements (Ti, P, Zr, Y, etc.) to a degree known only in forearc deposits of juvenile arcs.

The Allingtown porphyry may correlate with the Comerford dykes in Vermont and New Hampshire (Rankin et al., 2007), which are associated with a brief period of Silurian extension. The MLC may then correlate with Ammonoosuc volcanics, with the latter representing more evolved, extrusive expressions of the former.

The MLC is in ductile fault contact with the Savin Schist (O?s) to the southeast. This contact is intruded by Sa and thus must be pre-Acadian. To the north, the MLC is in ductile fault contact with the Wepawaug Formation (SD?w), which may correlate with the Waits River Fm. in northern New England. Dykes of Sa are not observed to intrude SDw. Thus the fault contact between the MLC and SDw may represent the southernmost expression of the Monroe Thrust yet identified.

# The Use of Ecological Niche Modeling to Reconstruct the Paleoclimate of Pleistocene Hominin Landscapes in the Olduvai Basin in Northern Tanzania

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The modern geographic occurrence of any particular faunal species and associated climatic conditions can be a proxy indicator for constraining the spatio-temporal reconstructions of paleoenvironmental and paleoecological conditions. The ecological niche of a species consists of the environmental factors, both biotic and abiotic, within which a species can survive and flourish. Ecological niche modeling involves the construction of a climate envelope using the correlation of a species modern occurrence and associated climate variables, e.g., temperature and precipitation. The envelope describes the climate limits within which a particular species can live. Ecological niche modeling can been used to predict the past, present, or future distribution of a species. This method of examining the ecology of a species is a relatively novel approach to assessing and reconstructing the paleoecology of Pleistocene landscapes and environments inhabited by hominins in the Olduvai Basin in northern Tanzania.

Here, we present new data for climate tolerances of selected modern African reptilian and mammalian species that are also found in the Olduvai fossil record. Using ecological niche modeling, we constructed climate envelopes based on the modern geographic ranges and associated modern climatic conditions of a particular species. Using the envelopes we provide a preliminary reconstruction of the paleoclimate of the Olduvai Basin. Comparisons between the two animal groups further constrain variability of the paleoclimatic reconstructions of the basin and conform to the data available from studies of pollen and isotopes of paleosol carbonates.

# TEASING OUT PARASEQUENCES IN HIGHLY SEDIMENT STARVED DEVONIAN BLACK SHALES

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Careful petrographic examination of centimeter scale stratigraphic stacking patterns in conjunction with elemental analysis of total organic carbon (TOC) create an interesting story for better understanding parasequences and sequence boundaries in distal Devonian black shales. Detailed outcrop, drill core, and thin section petrographic observations were conducted on the Upper Gassaway Member of the Chattanooga Shale (Tennessee), the Bakken Shale (North Dakota), and the Clegg Creek Member of the New Albany Shale (Kentucky) to find commonalities in sedimentary rhythms and their significance for sequence stratigraphic analysis. In thin sections, starvation surfaces are marked by winnowed and reworked silt with calcite cement, and alternate with cm-thick intervals of banded shale. The latter show disrupted silt laminae, benthic fecal pellets, and remains of agglutinated benthic foraminifera and probably accumulated under suboxic conditions. Uncompressed and internally mineralized (pyrite, chalcedony) algal cysts attest to very small rates of net sediment accumulation.

The presumed parasequences identified in outcrop and core, vary in thickness depending on distance from the Acadian sediment source in the east. Following the cycles westward from the Appalachian into the Illinois Basin, they thin progressively. Whereas in eastern Kentucky cycles in the study interval are on the order of ~20 cm thick, they thin to an average of ~10 cm thick near the crest of the Cincinnati Arch. Further west, near Louisville, Kentucky, the cycles have thinned to less than 5 cm thickness.

Powdered samples of the Clegg Creek Member of the New Albany Shale and the Bakken Shale were collected at the centimeter interval for geochemical analysis of TOC. TOC analysis shows a complementary pattern of increasing and decreasing TOC with cycles about 3 – 4 cm thick. The starved-reworked portion of the cycle has the lowest TOC values, and the highest TOC values are found in the intervening banded shale. Comparing these combined petrographic and geochemical analyses between the Bakken, New Albany, and Chattanooga Shale will show whether comparable patterns exist and how depositional conditions may have differed (or not) over large distances (up to 1000 miles) in the Late Devonian inland sea.

# ANALYSIS OF ORGANIC MATTER CONNECTIVITY IN UPPER DEVONIAN & LOWER MISSISSIPPIAN NEW ALBANY AND BAKKEN SHALE

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High-resolution imaging with micro-FTIR (Fourier Transform Infra-red spectroscopy) allows users to distinguish mineralogical compositions as well as different organic matter (OM) types in a nondestructive manner. FTIR spectra of a suite of Devonian and Mississippian New Albany Shale (NAS) and Bakken Shale were obtained via reflectance micro-FTIR mapping of 50 × 50 µm sections and assembling connected maps measuring about 1 × 1 mm. After successfully mapping a single random plane in samples during previous work, we now analyzed two planes, parallel and perpendicular to the bedding of the NAS samples, to further understand the applications of micro-FTIR mapping for constraining OM connectivity in two dimensions. Micro-FTIR's capability of exploring interconnected OM pore networks in a highly heterogeneous shale matrix may prove useful for studying the flow of gas and oil through pore networks. ImageJ processing and analysis software was utilized for node-strut analysis to further evaluate the potential of micro-FTIR for characterizing the distribution and connectivity of OM. Future work on this project will include concluding the same analyses across a suite of Bakken Shale. We hope to arrive at answers to the following questions: (1) Is the connectivity of mineral and OM domains isotropic or anisotropic in laminated shales? (2) Will mapping of OM parallel to bedding reveal a more homogeneous picture than mapping perpendicular to bedding? (3) Will analytical parameters from Bakken Shale be similar to results from NAS? (4) How can micro-FTIR mapping be used to relate OM connectivity to permeability in shales?

# EVALUATION OF REDOX CONDITIONS OF THE ORDOVICIAN MAQUOKETA GROUP, ILLINOIS BASIN

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## Abstract

The sulfur isotopic signatures of the Ordovician Maquoketa Group, Illinois Basin, have been studied to characterize the redox processes occurring at the sediment-water interface. Total organic carbon content varies independently from sulfur content through the 60 foot core studied, suggesting that reducing conditions may have been invariant while productivity in the water column was variable. Analysis of sulfur speciation (mono/disulfides, elemental/bitumen sulfur, and carbonate associated sulfate) coupled with metal concentrations are used to resolve the degree of anoxia and thus the preservation potential versus the productivity in the water column during deposition of the Maquoketa. Metal concentrations including those of U and Mg are helpful redox proxies indicating the authigenic uptake of metals in seawater and thus the degree of anoxia. Pending assessment of $\Delta^{34}S$ ($\delta^{34}S_{CAS} - \delta^{34}S_{pyrite}$) will provide insight as to the processes of microbial sulfate reduction or sulfide oxidation occurring in sediment pore waters which influences the preservation of organic matter. Additionally, the yield of water-soluble sulfate may indicate oxidative processes occurring post-diagenesis.

# EVOLUTIONARY DYNAMICS OF THE LIMBS OF BIRDS AND THEROPOD DINOSAURS: TESTING THE INFLUENCE OF FUNCTIONAL CONSTRAINT

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The origin of birds and associated transition to flight fundamentally changed fore- and hind limb function. As the forelimbs became dedicated to locomotion, the biomechanical requirements of powered flight likely placed substantially different selective regimes on the skeletal elements of the limbs. This pattern suggests a tight link between locomotor function and wing skeletal morphology, and potentially a constraint on the evolution of these elements. In contrast, non-avian theropods and flightless birds likely had more relaxed biomechanical constraints on these elements, and therefore the potential for greater evolutionary lability. We tested whether the relationships among limb elements show different evolutionary dynamics in flying and flightless theropods (including birds).

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# TRACKING THE SOURCE OF ANTHROPOGENIC CONTAMINATION USING BIO INDICATORS

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Abstract Content

Chain O' Lakes State Park, located in northern Indiana, consists of nine interconnected lakes and four satellite lakes, with depths that range from 1-20 m. Chain O' Lakes State Park is bordered by farmland in the northeast and southwest corners, and a correctional facility in the eastern-most section of the park. Park managers have reported increasing cyanobacteria blooms throughout the last decade, which has resulted in periodic closure of recreational facilities. Park managers are concerned about the impact on the lake ecosystems and tourism to the park.

Our project is designed to explore the impact of eutrophication through a chain of interconnected lakes, and the impacts of development and agriculture on the system of lakes over the last two centuries. We analyzed diatom assemblages from short cores from each lake in the system. One long (2m) core was taken from Long Lake in order to establish a long-term baseline nutrient level for the lake systems. We ultimately found that diatoms provided a useful tool to track nutrients and organic pollutants through the interconnect lake system back to the corrections facility as a point source for contamination.

# DISTRIBUTION AND SOURCES OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) IN THE SANTA BARBARA BASIN

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Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous organic pollutants originating from both natural and anthropogenic sources. Traditionally PAHs are classified as either petrogenic or pyrogenic but can also be produced through other natural non-combustion processes such as degradation. The EPA has listed 16 PAHs as priority pollutants for to their carcinogenic and mutagenic traits. Their persistence, toxicity, and use as a proxy to trace the anthropogenic impact of fossil fuel combustion makes PAHs widely studied.

The Santa Barbara basin is a geologically active location with natural oil seepages, high sedimentation rates ≈ 4 mm/yr, and high primary productive from the upwelling of nutrient rich waters. A thick, anaerobic microbial mat covers the ocean floor limiting sediment redistribution and diminishing bioturbation, causing an annually laminated or varved sediment record. The varved nature of the sediments allow for a precise reconstruction of paleocharacteristics. Distinguishable terrestrially based flooding layers and turbidite flows are found within the sediment record of the basin. Selected varves, turbidites, and flood layers were sampled to determine TOC and PAH concentrations.

A total of 25 parent and alkylated PAHs were identified and quantified by gas chromatography/mass spectrometry (GC/MS) in selected ion mode. PAH quantities were normalized to TOC as samples were selected from multiple cores drilled from 1987 to 2009. Concentrations of perylene, a PAH derived from the *in situ* degradation of organic matter, increased in older sediments. Varve layers spanning the last 2,000 years reflected a shift in diagnostic ratios and total concentration data. Key diagnostic ratios revealed the dominant presence of petroleum PAHs in older sediments changed to a strong combustion and petroleum combustion signal starting in the latter half of the 20$^{th}$ century.

# SULFIDE DISTRIBUTION AND OXYGEN ISOTOPIC VARIATION WITHIN THE J-M REEF, STILLWATER COMPLEX, MONTANA

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The J-M Reef of the Stillwater Complex, Montana is one of the world's premier platinum-group element (PGE) deposits. The Reef is stratigraphically located in what is known as the Olivine-bearing Zone I (OB I) of the Lower Banded Series of the Complex The Reef extends over 40 km in strike length and averages 1 to 3 m in thickness. Rock types present within the Reef include dunite, troctolite, norite, and anorthosite. The origin of the J-M Reef remains controversial, and theories are broadly divided between those which favor downward collection of PGE-bearing immiscible sulfide liquids and those that favor an upward accumulation of PGEs controlled by magmatic hydrothermal fluids In addition to the very high concentration of Pd in the Reef, the distribution of PGE-rich sulfides remains enigmatic. We have examined interfaces between sulfide-bearing units of the J-M Reef and sulfide-poor units above, below, and within the Reef itself. PGE-rich and sulfide-rich lenses show vertical separation as well as horizontal discontinuities. The downward extent of the mineralization is defined by the presence of sulfide minerals and is not controlled by variations in host lithologies. Neither downward drainage of immiscible sulfide liquid through a fractionation/differentiation sequence nor upward fluid infiltration can readily explain these features. Some of the distribution of sulfide minerals in the Reef and associated ballrooms may be a function of low-T hydrothermal fluid mobilization. Oxygen and hydrogen isotopic studies show that the J-M Reef behaved as a horizon of relatively high permeability compared to other stratigraphic units in the Complex. The presence of plagioclase feldspar with $\delta$18O values as low as 4.0 ‰ and olivine with normal mantle values of 5.4 ‰ suppressed to 4.8 ‰ when partially serpentinized are indicative of kinetically controlled oxygen isotopic exchange between silicate minerals and a low-temperature and low-18O fluid. The elevated concentrations of Pd in pentlandite (5.6 to 9.8 wt. %) associated with the desulfurization of braggite and cooperite to isoferroplatinum-sulfide intergrowths indicates that Pd was transported within late-stage fluids.

# Testing marine shales' ability to generate catalytic gas at low temperature

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Hydrocarbon gases are generally thought to originate via low-temperature microbial or high-temperature thermogenic pathways (Whiticar, 1996) that can be distinguished by compound-specific hydrogen and carbon stable isotope ratios. An alternative low-temperature catalytic pathway for hydrocarbon generation from sedimentary organic matter has been proposed to be active at temperatures as low as 50°C (e.g., Mango and Jarvie,2009,2010; Mango et al., 2010; Bartholomew et al., 1999). This hypothesis, however, still requires rigorous testing by independent laboratory experiments. The possibility of catalytic generation of hydrocarbons in some source rocks (most likely in relatively impermeable and organic-rich shales where reduced catalytic centers can be best preserved) would offer an explanation for the finding of gas of non-microbial origin in formations that lack the thermal maturity for generating thermogenic gas.It is unknown whether catalytically generated methane would be isotopically different from thermogenic methane ($\delta^{13}C_{CH4}$>-50‰, $\delta^{2}H_{CH4}$from -275‰ to -100‰) or microbially generated methane ($\delta^{13}C_{CH4}$from -40‰ to -110‰, $\delta^{2}H_{CH4}$from -400‰to -150‰) (Whiticar, 1998).

In order to test for catalytic gas generation in water-wet shales and coals, we are conducting laboratory experiments at three temperatures (60°C, 100°C, 200°C)and three pressures (ambient pressure, $10^7$ Pa, $3x10^7$ Pa)over periods of six months to several years. So far, our longest running experiments have reached one year. We sealed different types of thermally immature, pre-evacuated shales (Mowry, New Albany, and Mahogany shales) and coals (Springfield Coal and Wilcox lignite) with isotopically defined waters in gold cells in the absence of elemental oxygen. Preliminary results show that these samples, depending on conditions, can generate light hydrocarbon gases (methane, ethane and propane) and $CO_2$. Methane, $CO_2$, and traces of $H_2$havebeen generated at 60°C, whereas experiments at 100°C and 200°C also yielded ethane and propane. As of July 2013, our preliminary data indicate that the amount of light hydrocarbon gases increases with temperature and decreases with increasing pressure. Gas yields after 1 year are typically about twice as large as after 6 months. Decreasing the pressure from $3x10^7$ Pato $10^7$ Payields 3 to 6 times more gases, all other factors being equal. A temperature increase from 60°C to 200°C increases gas yields by a factor of ~40. For example, at 60°C over 6 months at $10^7$ Pa, Mowry Shale can generate 0.4 μmol methane per gram TOC, and the yield decreases to 0.06 μmolat$3x10^7$ Pa..$\delta^{2}H_{CH4}$ from Springfield Coal and Mowry Shale decreases with time and temperature, whereas pressure's influence on $\delta^{2}H_{CH4}$value seems to vary among source rocks.$\delta^{2}H_{CH4}$from Mowry, Wilcox and Mahogany shales and$\delta^{2}H_{H2O}$are not correlated, which stands in contrast to the results of traditional hydrous pyrolysis experiment sat temperatures above 300°C (Schimmelmann et al., 1999). If the methane from gold cells was indeed generated via catalysis, the hydrogen isotope data would suggest that the mechanism of catalytic gas generation is different from thermogenesis.

# Evacuation Behavior of 2011 Earthquake and Tsunami Survivors

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After the March 11th, 2011 Tōhoku Earthquake and Tsunami, parts of the coast of Japan near the small town of Watari suffered. At Magnitude 9.0, this earthquake remains the largest recorded earthquake to have ever hit Japan, a horrific surprise to the unprepared residents. Despite various warnings, the residents Watari responded in ways that often strayed from official expectations. Some remained behind; others were rescued or they fled based on a variety of variables. Since the 2011 disaster, Watari town officials revamped their emergency plan in the case of another large tsunami. The purpose of this study is to identify the most influential variables, and to see if the town's new evacuation plan addresses them. Given Japan's location in the infamously active Pacific Ring of Fire and the potential effects of global climate change, these hazardous events may intensify. Thus, It is crucial to understanding evacuation behavior in order to implement effective safety procedures in the future. After gathering information from personal interviews conducted from some 60 Watari survivors, extracting GPS coordinates from their individual evacuation route maps, observing post-event soil moisture via Google Earth Historical Imagery, and locating the tsunami's inundation extent via Harvard's Interactive JapanMap, the initial results of our analysis indicate that distance from the coast did not play as large role in the immediacy of evacuation as other factors. Through further data analysis I seek to gain a better understanding of the evacuation patterns during the tsunami.

# INSIGHTS INTO SUBDUCTION ZONE COUPLING AND STRAIN PARTITIONING IN THE PHILIPPINE MOBILE BELT BASED ON GPS OBSERVATIONS AND DEFORMATION MODELING

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I present a suite of crustal deformation models for the Philippine Mobile Belt, a seismically active, rapidly deforming plate boundary zone situated along the convergent Philippine Sea/Eurasian plate boundary. These models are based on a newly available suite of GPS data from a dense nationwide network. The Philippine Mobile Belt is represented by 14 independently moving rigid tectonic blocks, separated by active faults and subduction zones. These elastic deforming block models are constrained by observed GPS observations, geologic fault rates, and known fault geometries, which are used to invert for an estimate of block rotations and fault coupling. In these block models, interseismic distortion along faults is introduced using a model of uniform slip along block boundaries, combined with backslip along locked plate boundary segments. I model block interaction using various kinematic approaches: (1) uniform backslip above a (solved-for) locking depth; (2) distributed backslip with laplacian smoothing; or (3) unregularized backslip (no smoothing) using Markov chain Monte Carlo (MCMC) methods. Models that minimize misfit between observed and predicted geodetic velocity vectors are chosen as best-fit, preliminary models, which can then be used to examine the spatial variation of subduction zone coupling along the five active subduction zones surrounding the Philippine plate boundary zone. This is accomplished through dynamic modeling of subduction-zone creeping and locked segments, while solving for the minimum and maximum amounts of moment accumulation on each trench that fits the observed data. These preliminary models of subduction zone coupling provide critical constraints on the potential for large earthquakes and tsunamis along these subduction zones, which can be used to further understand and mitigate the seismic hazard in the Philippines.

# The ecogeomorphic development of the coastal freshwater deltaic system of Wax Lake Delta

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The world's coastal deltaic wetlands are threatened by relative sea level rise. Protecting these ecosystems requires understanding deltaic growth. Here we explore the ecogeomorphic evolution of Wax Lake Delta (WLD) using a remote sensing database consisting of 1083 Landsat 5 and 7 images (30 m resolution) from 1983 to 2012 and 23 high-resolution images (1.5 m resolution) from 2001 to 2002. We calculate each Landsat image to the normalized difference vegetation index (NDVI), which indicates the relative above ground vegetation biomass. We also use the high-resolution images and spectral signatures from Landsat images to classify land cover into vegetation, sediment, and water. An imagery subset from peak biomass season, August to October for this subtropical ecosystem, was analyzed to control for the effects of interannual variability in growing season and growth rates on the estimates of vegetated areas. An imagery subset from minimum biomass season, February to early May, was analyzed with the peak biomass imagery to study annual land cover behavior on the various islands of the delta as they develop. Our results show from 1984 to ~2001 WLD experiences a period of emergence where total delta area and the vegetated percent (at peak biomass) increases rapidly. After 2001, the delta reaches a dynamic steady state as vegetated percent fluctuates between 28% and 49%. At individual island scale the majority of the islands reach dynamic steady state, but at differing times and percentages of vegetation cover. More proximal (or older) islands reach dynamic steady state as soon as 1993 at ~90% vegetation cover, while more distal (or younger) islands do so as late as 2001 at ~30%. Annual land cover behavior analysis of the islands also shows all islands, upon reaching a sufficient subaqueous elevation, are initially dominated by aquatic vegetation. However, certain areas of some of the islands see an increase in elevation over time and develop into subaerial, permanently vegetated levees, while other islands do not undergo this progression. It is unclear why the various differences in date of reaching dynamic steady state, percent vegetation cover, and annual land cover behavior occur, but we conjecture it is caused by the lower elevation of the distal islands or their aggrading slower than proximal ones as the incoming sediment volume spreads over a larger deltaic area.

# AN INSIGHT ON BISLEY WATERSHED CRITICAL ZONE USING ECO-HYDROLOGY MODELING

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ABSTRACT: A critical zone is the outer skin of earth, it is the permeable layer from the tops of the trees to the bottom of groundwater. A Critical Zone is the environment where rock, soil, water, air, and living organisms interact and shape the Earth's surface. Despite the Critical Zone's importance to terrestrial life, it remains poorly understood. Too little is known about how physical, chemical, and biological processes in the Critical Zone are coupled and at what spatial and temporal scales. Many of these processes are highly nonlinear and can range across scales from atomic to global, and from seconds to aeons. Understanding the complex web of physical, chemical, and biological processes of the Critical Zone requires a systems approach across a broad array of sciences: hydrology, geology, soil science, biology, ecology, geochemistry, geomorphology, and more (http://criticalzone.org/).

This study is taking place in Bisley watershed, which is located in the Rio Mameyes area with the Luquillo Mountains in northeastern Puerto Rico. Bisley watershed is within one of NSF funded Critical Zone Observatories. Multiple computerized modeling software packages are in use in the current Eco-Hydrology modeling of Bisley watershed. For instance, VELMA (Visualizing Ecosystems for Land Management Assessments) which is a spatially distributed, physically based, eco-hydrological model that is both computationally efficient and relatively easy to implement and develop. VELMA has real-time visualization tools that shows temporal and spatial patterns of state and flux variables, and is used to address the effects of changes in climate, land-use, and other interacting stressors on multiple ecosystem services such as timber production, carbon sequestration, regulation of water quality and quantity and reduction of greenhouse gases at scales relevant to formulating management decisions (From Velma User's Manual of Nov. 2009). Another software in use is GRASS GIS (Geographic Resources Analysis Support System), which is a free and open source Geographic Information System (GIS) software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modeling, and visualization (from the official GRASS GIS site http://grass.osgeo.org). It is currently being used in extracting and interpolating vegetation and other environmental aspects of Bisley watershed.

This is still a dissertation project in the pre-processing stages. The current information provided may be changed/modified as the project progression requires.

# EARLY EVOULTION OF THE BERMEJO BASIN, ARGENTINA: IMPLICATIONS FOR OROGENIC TIMING AND PALEOGEOGRAPHY

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Miocene paleogeographic reconstructions of the Central Andes show a structurally thickened retroarc thrust belt that constituted a large tectonic load on the lithosphere. The resulting foreland basin system records the deformational history of the orogeny, manifested as stratigraphic stacking of distinct depositional geometries and facies patterns. Variations depend on the nature of uplifted sediment sources and lithospheric bending properties, as well as the morphology and rate of the thrust front migration. Workers have previously dated the onset of Andean retroarc deformation at this latitude at the Oligocene-Miocene transition, based on provenance and geochronology of foredeep sediments unconformably overlying Paleozoic strata. However, foredeep deposits may not hold a complete record of early basin sedimentation resulting from the first stages of lithospheric flexure. Investigations of the timing and significance of Eocene and older strata, once considered Paleozoic in age, may shed light on the earlier history of Andean deformation and foreland basin initiation.

This study proposes that a poorly studied succession of redbeds, located in the Bermejo Basin at ~30°S and sandwiched between potentially Cretaceous sediments and the Upper Oligocene Vallecito Formation, represents forebulge subsidence and may signal the initial stages of foreland basin development in the Precordillera region. Preliminary data from these redbeds suggest they are Cenozoic in age, linking them to the younger Andean deformational history. By tracking the flexure of the lithosphere, the potential forebulge deposits would reflect the age of initial loading and thus suggest that Andean deformation began earlier than the Oligocene-Miocene transition. Alternatively, if these Paleogene redbeds are the result of post-rift subsidence from Mesozoic extension, they could provide important insight into the paleogeography, local structures, and paleoclimate of the area during Eocene and Oligocene time. Through structural mapping, development of detailed stratigraphic sections, and detrital thermochronology and geochronology, this research aims to characterize and model the forebulge formation and migration eastward into the South American craton as well as characterize pre-Andean paleogeography.

This research is timely and potentially transformative for improving our knowledge of an early stage of basin development that has been previously overlooked. The Andes Mountains and their genetically linked basin systems are a modern analogue for many economically and academically important ancient foreland basin systems, including the Rocky Mountains of the United States. A more complete understanding of the Andean region during the Eocene, Oligocene, and early Miocene will inform research into early stages of basin development in other ancient systems. This project will also further collaboration between researchers from the US and Argentina and will provide a more complete geologic interpretation of the Ciénaga del Rio Huaco ecological preserve in NW Argentina.

# Tungsten Isotopic Fractionation during Adsorption to Birnessite

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Tungsten is a metal that has been used in military and hunting ammunition as a substitute for lead, yet little is known about how tungsten contamination affects soil and water systems, nor about the effects of tungsten poisoning on humans and wildlife. Between 1997 and 2002 there were 16 reported cases of childhood leukemia near Fallon, Nevada (Sheppard et al. 2007). These cases were linked to high levels of tungsten in airborne particles and drinking water, and as a result tungsten has become a contaminant of interest. A major control on how a contaminant interacts with water and soil is adsorption to clays and other minerals. In order to better constrain the way in which tungsten migrates in water systems and interacts with soil, the adsorption mechanisms of tungsten need to be understood.

Recent research has led to the discovery of metal isotope fractionation during reactions that are relevant to the transport and immobilization of heavy metals and that this fractionation can be used to track the extent of the reactions. Little is known about tungsten isotope fractionation while adsorbing to minerals, such as birnessite, that are commonly found in soil. The goals of this experiment were to determine if there is a measurable fractionation when tungsten adsorbs to synthetic birnessite, to quantify the amount of fractionation, and to determine the manner in which it fractionates (Rayleigh or equilibrium). Birnessite (MnOx) is a common mineral in soil and has a large adsorption capacity, making it an ideal mineral to use for this study. The experiment was set up by mixing birnessite suspension with a 5 ppm tungsten solution and fixing the mixture to a pH of approximately 8. These samples were then left on a shaker for 24 hours before being filtered to separate the adsorbed and aqueous fractions. Preliminary isotopic analysis data show that tungsten has a small fractionation ($\sim$0.3‰), which is consistent with an equilibrium isotope effect, with lighter isotopes preferentially adsorbing to birnessite. Future experiments will include adsorption to different minerals and analysis of soils in which the timing and amount of tungsten input are well constrained. These results may help us analyze the extent to which adsorption reactions are attenuating tungsten migration in contaminant plumes.

# Stratigraphic Distribution of Pennsylvanian Coals and their Associated Lithologies in Sullivan County, IN: Effects on Coalbed Methane Production

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Abstract

The Carbondale Group of Pennsylvanian coals is one of the most widely utilized sections for Coalbed Methane (CBM) recovery in Indiana. Coal member beds Springfield, Survant, and Seelyville are particularly important due to their thickness and depth. In Sullivan County, IN CBM production is hindered by the varying/discontinuous thicknesses of these coal beds. Furthermore, low production rates have led to the hypothesis that CBM has locally migrated in to overlying, discontinuous sand bodies. Already available National Coal Resources Data System (NCRDS) data was combined with regional well log records from the Indiana Geological Survey. Using basic well logging techniques from these resources the coals and their associated lithologies were correlated from 556 wells using the software package Petra. Ultimately, structure and isopach maps for the coals and their associated lithologies will be produced using ArcGIS software. This study should give a better understanding of: (1) The effects regional paleotopography has on the structure and thicknesses of these coals. (2) The discontinuous nature of the overlying lithologies.

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# Sedimentary pyrite in the Campagnian Mooreville Chalk of the Late Cretaceous Mississippi Embayment

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Framboidal pyrite persists in the talus throughout the Mooreville Chalk Formation at the Harrell Station Paleontological Site in many shapes and sizes; however, original the source of the pyrite is unclear. These concretions are attributed to be either *thalassinoides* ichnofossils left behind by burrowing annelids or the fossilized dung of marine animals. Samples were collected and analyzed for bulk sulfur and isotopic signature. Preliminary results indicate that the two morphologies do contain different content and species of sulfur.

# MAPPING AND CORRELATION OF INDIANA TERRACES WITH IMPLICATIONS FOR UNDERSTANDING RATES OF GLACIAL ADVANCE AND RETREAT

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The Laurentide ice sheet (LIS) contributed immensely to global climate change during deglaciation in the late Holocene. Melting ice contributed as much as 1.3 cm of sea levelrise per year (Carlson et. al 2008). As deglaciation continued, freshwater from Lake Agassiz released into the North Atlantic, upsetting global ocean currents, and leading to an abrupt cooling in the Northern Hemisphere around 8200 years ago (Torbjörn and Hijma 2012). The fundamental process of deglaciation is important for understanding climate shifts, yet not much is known about the details of that process at the ice margin, especially in Indiana. Where other states such as Ohio and Michigan have mapped and dated numerous ice-margin glacial features, glacial topography in Indiana is scarce and discontinuous. The recent acquisition of state-wide high resolution topography (LiDAR) in Indiana has allowed a reassessment of these glacial features. For instance, based on my preliminary work, I have identified different glaciofluvial terrace flights grading to the Knightstown moraine located north of Franklin, Indiana using USDA official soil descriptions and LiDAR. This recessional moraine has been placed into a regional chronology (Wayne 1965), yet has never been dated using modern methods. Knowing the age of formation of the moraine furthers the knowledge of the extent of Laurentide ice at a specific moment in geologic time. This knowledge can help refine and further our understanding of deglaciation rates for the LIS and its impact on global, regional, and local climate change during the last interglacial. Glaciofluvial terrace correlation to the recessional moraine can provide a better understanding of LIS advancement and retreat (Ray 1940).

# EVALUATION OF THE HISTORY OF LOCAL LANDSCAPE FLUXES USING DETAILED PHOSPHORUS GEOCHEMISTRY FOR TWO LAKES IN GLACIER NATIONAL PARK, MONTANA, UNITED STATES

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In 1910, President William Howard Taft passed a bill making Glacier National Park the 10th established national park in the country. Glacier National Park (GNP) is located along a portion of the Rocky Mountains in Montana in the Western United States. The glacial activity in GNP has fluctuated considerably, primarily due to climate changes since the Little Ice Age. Using geochemical and diatom proxies, we hope to reconstruct a history of glacial advance and retreat for the region using lake sediment core records that were collected during summer 2013. For this study, two sites within the GNP area were chosen. Cosley Lake and Glenns Lake are located in the upper Northeastern corner of the park close to the Montana-Canadian border. This research will focus on the use of detailed phosphorus geochemistry within the lake sediment cores and soils surrounding the lakes to better understand P biogeochemical cycling on the landscape and within the lakes themselves. As glaciers retreat, fresh unweathered minerals (apatite) are exposed at the surface. As the landscape matures and soil develops, total phosphorus generally decreases with a concomitant change from the dominance of mineral P to organic and oxide associated P, which should be observable in the lake geochemical records. Sequential chemical extractions for phosphorus isolates the phosphorus adsorbed to particles and associated with oxides, phosphorus bound in mineral phases, and phosphorus associated with organic matter. Evaluating these temporal variations in phosphorus geochemistry coupled with fossil diatom assemblages and other geochemical proxies will ultimately provide a history of landscape nutrient status, weathering fluxes, and glacial activity.

# GENERALIZED ITERATIVE DECONVOLUTION OF PASSIVE SEISMIC ARRAY DATA

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We developed a frequency-domain iterative deconvolution approach, which is demonstrated as the generalization of conventional iterative deconvolution, and applied it to receiver function estimation. Generalized iterative deconvolution improves the resolution of receiver function estimation by using an inverse operator instead of the conventional cross-correlation operator. It also provides better control of the signal to noise ratio on the result by applying a different convergence criterion. The efficiency and constraint of this approach is illustrated by the synthetic experiment and pure noise test. In order to test the reliability of it, we applied this approach to the seismic data from the USArray and statistically proved its consistency by comparing with results from EarthScope Automated Receiver Survey. Application to the wavefield imaging showed this new method is capable of further improving the resolution of the seismic image.

# Strain Induced Retrograde Metamorphism in an Alleghanian Fault in South Central Connecticut

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Abstract:

New field studies of the East Derby Shear Zone (EDSZ) of Rodgers (1985) confirm the presence of a major zone of retrogression and overprinting fabrics at the western margin of the Orange-Milford Belt (OMB) in south-central Connecticut. Mapping along three transects across the fault zone shows a ~500 meter wide belt of chlorite/muscovite (lower greenschist facies) phyllites interior to amphibolite facies metamorphic rocks. Fabrics trending 015 in the eastern staurolite/kyanite bearing Wepawaug Schist are transposed and retrogressed to ~030 in the EDSZ. Progressive partial and then complete replacement of porphyroblasts of biotite, garnet and staurolite by chlorite and muscovite follows this transposition. The west side of the EDSZ is marked by greenschist facies mylonitic Wepawaug schist against the stronger Silurian Pumpkin Ground granodioritic gneiss, except along intervening slivers of high grade Wepawaug Schist where the eastern fabric transposition is mirrored. Existing geochronology (Lanzirotti and Hanson, 1996; Growdon et al. 2013) shows that the Middle Devonian metamorphism of the Wepawaug Schist with muscovite cooling ages >360 Ma are replaced by greenschist facies muscovite with crystallization ages < 300 Ma.

Kinematic indicators along the EDSZ such as S-C fabrics, asymmetric quartz and chlorite beards, and transposed quartz veins show dextral displacement. The relatively stronger Pumpkin Ground orthogneiss, which was on the edge of the Laurentian plate, acted as a buttress during lower green-schist facies Permian faulting. The EDSZ trends northeast beneath Triassic sediments of the Hartford basin, and may reemerge as the Westminster West Fault (WWF) (McWilliams et al. 2010; Walsh et al. 2012) in western New Hampshire. Together these results support the escape tectonics model proposed by Growdon et al. (2013).

**Seasonal Fluctuations in the Stable Isotopic Composition and Concentration of Methane and Carbon Dioxide in the Air of Buckner Cave, Southern Indiana, USA**

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The greenhouse gas methane ($CH_4$) has accumulated at 1.8 times the rate of carbon dioxide ($CO_2$) in earth's atmosphere since the start of the industrial revolution. One molecule of methane ($CH_4$) contributes about 20 times the amount of greenhouse warming to Earth's atmosphere compared to one molecule of carbon dioxide ($CO_2$). Despite significant improvements in our knowledge of the sources and sinks of $CH_4$ to and from earth's atmosphere, the $CH_4$ dynamics at the rock-atmosphere interface are poorly understood. Karst environments which can expose significant amounts of rock to the atmosphere provide a unique environment to learn about the $CH_4$ flux at this interface. To better understand the $CH_4$ dynamics in karst environments, air samples from Buckner Cave in southern Indiana were obtained on a monthly basis.

Six locations in Buckner Cave were chosen for atmospheric monitoring. *In-situ* measurements of the composition of the air of concentration of $CO_2$ in the air of Buckner Cave were made with a portable gas monitor. Discrete air samples were acquired from 5 of the 6 locations used for *in-situ* monitoring. $CH_4$ and $CO_2$ concentrations from discrete samples were measured using gas chromatography. The stable isotopic composition of $CH_4$ from cave air samples was measured using a Delta Plus XP mass spectrometer.

$CH_4$ concentrations in Buckner Cave ranged from 1.8 parts per million by volume (ppmv) to < 0.1 ppmv. $CO_2$ concentrations ranged from 400 ppmv to 10,000 ppmv. $CH_4$ concentrations were lowest in Buckner Cave during the summer and the highest during the winter whereas $CO_2$ concentrations were highest in the summer and the lowest during the winter. The $\delta^2H_{CH_4}$ values ranged from 10 to -138 ‰ and exhibited the greatest variance at low concentrations. The $\delta^{13}C_{CH_4}$ values ranged from 7 to -55 ‰ and exhibited the greatest variance at low concentrations. The $\delta^{13}C_{CO_2}$ values ranged from -9 to -23 ‰ and exhibited a similar variance at all concentrations. High $CO_2$ concentrations had $\delta^{13}C_{CO_2}$ values of about –23 ‰.

The shift between relatively high $CH_4$ concentrations in the rooms of Buckner Cave during the winter and relatively low $CH_4$ concentrations during the summer appears to be related to changing airflow patterns in Buckner Cave. During the winter the concentrations of $CO_2$ and $CH_4$ plot near the open atmospheric mixing ratios of 400 ppm and 1.8 ppm respectively. The low $CH_4$ concentrations measured in Buckner Cave appear to be related to the consumption of $CH_4$ by microoorganisms in the cave. The high $CO_2$ concentrations are consistent with a source of $CO_2$ derived from plant material. These data suggest karst environments are operating as a $CH_4$ sink and may be playing an important role in mediating the $CH_4$ concentration of the atmosphere.

# Abiotic changes within a reservoir after a complete drawdown: a case study of Griffy Lake

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Aquatic ecosystems are created and dictated by their physical and chemical environment; when catastrophic events cause an ecosystem shift, such as the draining and refilling of a reservoir, the composition and quality of the ecosystem state can change based on the new, physical and chemical environment.

This research project examines the physical and chemical limnological changes in Griffy Lake after the complete drawdown of water for the purpose of dam reconstruction. After two years of sediment oxidation and terrestrial plant growth, the reservoir naturally refilled. This study will summarize recovery results from data collected on a monthly basis; the results will focus on the variables of temperature, dissolved oxygen, alkalinity, pH, specific conductance, and nutrient concentrations.

After analysis of the data, this project will allow for better understanding of the effects of complete drawdowns on abiotic variables. This senior thesis is part of a larger project that will examine how aquatic ecosystems recover and ecosystem states may shift within reservoirs after complete drawdowns. With more than 75,000 dams across the Unites States, many of which are approaching the end of their life span in the near future, it is important to understand how such events affect the quality of the water, in addition to aquatic ecosystems.

# Constraining the variable that controls rill formation at a reclaimed mine site

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The remediation process at abandoned mine land (AML) sites can be costly and lengthy. Since reclaimed AML sites rarely start out in perfect equilibrium with their surroundings, most evolve after the initial construction has been completed. If a site does not reach an acceptable degree of stability, then monitoring, material purchasing, and construction must continue in order to effectively treat the recurring problems. Incorporating the concept of long-term stability in the remediation design for an AML site is one way to limit environmental and economic risk.

Geomorphic stability was the primary issue addressed in the remediation design for the Minnehaha AML site, located in southwestern IN. Now reclaimed, Minnehaha is currently experiencing a modest outbreak of rills in the silt loam soil cap, which serves as a critical barrier in reducing groundwater recharge to the pyritic coal sediments underneath. Here, we explore the physical variables that contribute to the erosion of the soil cap due to channelized overland flow, using forward modelling and field measurements.

The model is based on Hortonian theory of overland flow. Soil is assumed to have a certain resistivity to erosional forces; when erosional forces exceed the "critical resistivity" of the soil, rills begin to form. Shear stress and stream power resulting from channelized overland flow were calculated using an adapted version of the Manning's equation. Using 1.5 m resolution elevation (DEM) data of the current site topography, rasterized solutions were generated that span the entire site. The solution matrices were then imported into ArcMap, and field-collected GPS points of rill locations were superimposed on top of that data layer. Preliminary results suggest that stream power is the better predictor of rill development at Minnehaha, and that the critical resistivity of the soil cap does not greatly vary across the field site. The effectiveness of any physical alteration to the site, in regards to erosion prevention, can now be predicted based upon the estimated critical resistivity values derived from the model.

# Reinvestigating the Mission Creek Fault: Holocene slip rates in the Northern Coachella Valley and implications for Southern California earthquake hazard assessment

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Near San Gorgonio Pass the San Andreas Fault Zone encounters a structural knot which causes strain to be distributed laterally onto the San Jacinto Fault and Eastern California Shear Zone and locally onto a series of evolving fault splays. Each splay was activated and subsequently abandoned as it became locked; current interpretations show that the Mission Creek Fault was the dominant strand in the early Pleistocene before being abandoned in favor of the presently active Banning Fault. Recent slip rate investigations along the Mission Creek Fault have challenged this interpretation, however, and motivate new studies into strain distribution through San Gorgonio Pass and mechanisms of strain transfer to the Eastern California Shear Zone. It is therefore essential to establish an accurate Holocene slip rate on the Mission Creek Fault and revisit current interpretations of San Andreas Fault Zone kinematics.

In support of this goal, detailed fault and quaternary unit mapping was conducted in two field areas along the Mission Creek Fault, located in Mission Creek Preserve and Big Morongo Canyon. Separated by ~3 km, the two field areas allow for characterization of along-strike changes in Mission Creek Fault behavior and interaction with regional faults. 22 samples were collected from dextrally offset landforms within Big Morongo Canyon Field Area for Terrestrial Cosmogenic Nuclide (TCN) dating. TCN dating is based on the total concentration of *in situ* produced $^{10}$Be, which is proportional to exposure age of the surface. This provides the age constraint for accurate Holocene-Late Quaternary slip rate analysis. Constraining active slip on the Mission Creek Fault has significant implications for Southern California earthquake hazard assessment. It will also expand our knowledge of the evolving North America-Pacific plate boundary through time and help elucidate details of fault interaction, fluid migration, and seismic interpretation at this critical plate boundary.

# QUANTITATIVE AND INTERACTIVE QUALITY CONTROL ON TELESEISMIC P-WAVE RECEIVER FUNCTIONS

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Receiver functions are time series estimated from three-component seismograms representing the near receiver Earth structures. The receiver functions are frequently used in modeling the crustal and upper mantle structures beneath the seismic network. However, selection or quality control of receiver functions, for a long time, has not been effectively addressed. Current development of the quality control procedures on receiver functions are basically categorized into three directions: 1) fully automated procedures relying on preset global parameters for all stations, e.g., methods used by EARS (EarthScope Automated Receiver Survey) data; 2) fully manual selections accomplished by analysts under some interactive environments; 3) interactive environments with a few built-in automated procedures that users can choose to apply combining with manual trace editing. The latter two categories rely mainly on manual selections, though the 3rd method may involve some simple auto-editing procedures. In addition to the long time needed to spend on trace editing, the biggest problem of heavily relying on hand-selection is the large variation of analyst-dependent uncertainties that are difficult to quantify.

This study goes beyond those three categories above and falls into a new category aiming at developing a series of quantitative and interactive quality control procedures. These procedures can be accomplished either through fully automated environment or under interactive environment with customized editing parameters for individual stations. In this study, these procedures are implemented through a C++ program named *RFeditor* with the Graphical User Interface (GUI) option. We first apply auto-editing procedures based simply on characteristics of the receiver functions such as first arrival polarities and strengths, extremely large amplitude phases, P-coda strengths, etc. Those procedures all rely on user-defined parameters customized for each station gather. Then, we set thresholds for trace parameters generated in the deconvolution process and the signal-to-noise ratio (SNR) of the original waveform data that the receiver functions are derived from. We estimate the beam (stack of all of the traces) using Robust Stacking method, which is insensitive to outliers and is able to quickly sort out traces with consistent signals. This is followed by the stack-weight cutoff procedure, which marks all traces lower than given normalized stack-weight threshold.

The quality control method developed by this study depends heavily on auto-editing procedures with interactively customized parameters. Hence, it provides a quantified standard in receiver function quality control. This makes it possible or at least easier to compare or reproduce the receiver functions used in any further analyses.

# Geochemical characterization of coal-combustion byproducts and numerical simulations of their long-term effects as capping materials at coal mine reclamation sites

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Fixed scrubber sludge (FSS), a coal-combustion byproduct (CCB); is composed of flue gas desulphurization sludge, fly ash, and lime. FSS has potential usages as structural fill and capping materials in abandoned mine land (AML) reclamation because of its low permeability and acid-neutralization capacity. However, CCB usage has been limited due to concerns about toxic elements that have been leached out of the solids in laboratory experiments. Although leaching experiments are useful for determining worst case situations, little is known about the long-term issues of weathering and how it would change, if at all, this material over time in the natural environment.

The long-term issues of how applying engineered CCBs could affect groundwater quality are addressed using a combination of laboratory and physical-chemical modeling approaches. TOUGHREACT is a computer program that is capable of simulating water-rock-gas interactions during heterogeneous media; however, it requires detailed mineralogical composition to perform the simulation task. Therefore, the first main subject of this study is to examine the chemical phases, and to characterize the morphology of CCBs. Scanning electron microscopy analysis show that the FSS were comprised of aluminum/calcium rich silicate spheroids, iron-rich ferroshperes, and other minerals. Their quantitative chemical compositions were analyzed using electron microprobe. Sequential extraction was also conducted to analyze trace element concentration in different phases in the samples. Preliminary simulations from TOUGHREACT suggest that FSS has the ability to buffer acidic mine drainage by generating moderate alkalinity, and there are significant aqueous and mineral alterations occurring at various environments.