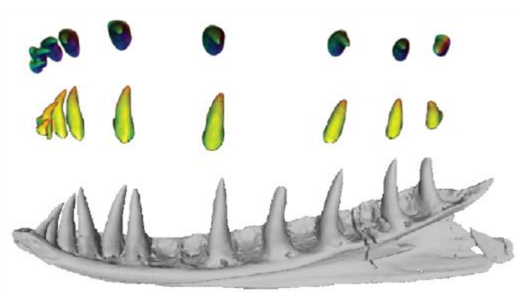
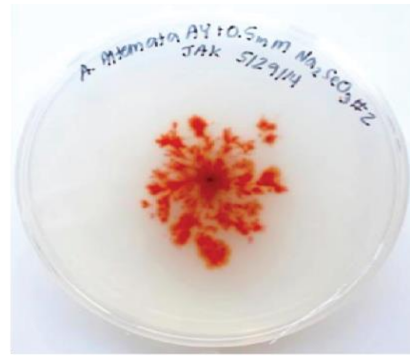
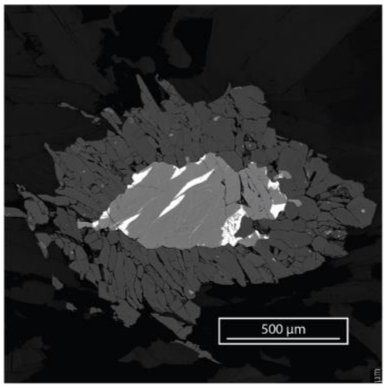
2020 EARTH & ENVIRONMENTAL SCIENCES STUDENT RESEARCH SYMPOSIUM

ABSTRACTS




2020 UMN Earth and Environmental Sciences
Student Research Symposium Committee

Department of Earth & Environmental Sciences
Woonghee Lee, Shanti Penprase, Natalie Raia, and Chris Schuler

Department of Soil, Water, and Climate
Jon Alexander, Persephone Ma

Program is presented in alphabetical order with departmental affiliation of student author noted. Abstracts selected for talks are denoted by an asterisk (*).

*Cold-Adapted Denitrifying Fungi for Nitrate Removal

NOUF ALDOSSARI, BRANDY TONER, SATOSHI ISHII

Department of Soil, Water, and Climate

The agricultural watershed in the upper Midwest is one of the major causes of high nitrate (NO3-) concentration in the Mississippi River, leading eutrophication in the Gulf of Mexico. Denitrifying bacteria have been the main focus of study to remove nitrate in environments, including constructed wetlands and woodchip bioreactors. Some fungi can also perform denitrification; however, fungi have received less attention. Fungi may play essential roles in NO3- removal, especially in woodchip bioreactors because fungi can efficiently degrade woodchips and use it as carbon and energy sources. Fungi can also grow well at relatively cold temperature conditions. Furthermore, fungal hyphae could also help them to stay in the reactors, in which bacteria may be washed out. In this study, we isolated denitrifying fungi and analyzed their ability to reduce NO3- for future nitrate bioremediation purposes. Fungal strains isolated from soil and woodchips were incubated at 5°C and 15°C in a liquid medium supplemented with 15N-labeled nitrate, and the productions of N2O and N2 gases were identified using gas chromatography-mass spectrometry (GC-MS). A total of 165 denitrifying fungal strains were obtained in this study. Among those, 37 strains reduced NO3- to N2O at 5°C, 121 strains reduced NO3- to N2O at 15°C, and seven strains reduced NO3- to N2 at 15°C. Based on the sequencing of the fungal internal transcribed spacer (ITS) regions, many of the denitrifying fungal strains belonged to Fusarium, Mortierella, and Cylindrocarpon genera. The nitrite reductase gene nirK was not detected in all strains by PCR, and denitrifying fungi may be useful for future nitrate bioremediation.

A New Approach to Indirect Quantification of Ammonia Acid Trap Capture Efficiency

JONATHAN ALEXANDER, JARED SPACKMAN, MELISSA WILSON, RODNEY VENTEREA, FABIAN FERNANDEZ

Department of Soil, Water, and Climate

Volatile ammonia (NH3) loss is an economically and environmentally significant loss pathway of fertilizer and organic N applied to agroecosystems. Accurate quantification of these losses can be accomplished with micrometeorological methods or indirectly with mass balance approaches or N15 tracer analysis. These methods, while accurate, are expensive and may not fit within the confines of common experimental designs used in agricultural research. Ammonia acid traps are a low-cost option to quantify relative treatment differences in volatile ammonia flux, however, the accuracy of these methods is dependent on trap design and the external environment. We developed a simple and cost-effective method to quantify ammonia acid trap capture efficiency to determine the effectiveness of four fundamentally different acid trap designs across variable wind environments. Our results help to inform design considerations for the utilization of ammonia acid traps in plot scale agricultural research.

Titanite Petrochronology Reveals Processes and Conditions of Eclogite Retrogression in an Exhumed (Ultra)high-Pressure Metamorphic Terrane

HANNAH BLATCHFORD

Department of Earth & Environmental Sciences

Continental crust can be subducted to mantle depths and undergo ultrahigh-pressure (UHP) metamorphism (depths > ~100 km) before returning to the surface during collisional mountain building events. In some cases, areas of exposed (U)HP rocks are found as large (>10,000 km2) coherent terranes. The record of deformation within these largest (U)HP terranes provides valuable information for understanding how significant volumes of continental crust respond to exhumation; a fundamental process in the lifecycle of collisional orogens.

Localized ductile shear zones (10s of meters wide) are a common occurrence in the Western Gneiss Region of Norway, a large exhumed (U)HP terrane. The shear zones are hosted in quartz- and feldspar-rich gneisses, and contain bodies of variably retrogressed eclogites. Both rock types commonly include titanite (CaTiSiO5), an accessory mineral chronometer ideally suited for tracking metamorphism and deformation processes through time. We use titanite from numerous retrogressed eclogites and gneisses across the Western Gneiss Region to investigate the geochemical and metamorphic processes associated with eclogite retrogression. Using laser ablation split stream inductively coupled plasma mass spectrometry (LASS-ICP-MS), we identify populations of titanite with distinct chemistries and U-Pb dates. The titanite populations also display different textures, and are associated with different stages of eclogite retrogression to amphibolite (+/- garnet). We supplement micro-scale observations with ground- and UAV-based mapping of meters-scale shear zones to link titanite (re)crystallization to deformation during exhumation of the large UHP terrane. Together, these datasets yield a detailed record of how deformation and metamorphism interact during decompression of a coherent (U)HP terrane.

Continental-Scale Coupled Groundwater-Surface Water Level Modelling

KERRY L CALLAGHAN, ANDREW D WICKERT, RICHARD BARNES

Department of Earth & Environmental Sciences

Groundwater accounts for almost one third of the world's fresh water. Lakes and wetlands account for an additional 0.25%, but are intimately linked with groundwater systems, and both modern and past lake levels record changes in regional groundwater tables. The evolution of water table depth through time records changes in the total terrestrial water storage in response to changing climate and topography. To study terrestrial water balance through the past and present, we develop and implement a coupled groundwater–surface-water model that can rapidly compute water-table fluctuations on a continental scale over time scales from years to thousands of years.

We model groundwater-table evolution following Reinfelder et al. (2013), using Darcy's Law with a finite-difference approach in a single layer of vertically-integrated hydraulic conductivity. Surface-water movement and storage are rapidly computed by constructing a map of flow directions and a hierarchy of all depressions in the landscape. Surface water is redistributed following a "fill-merge-spill" methodology: runoff flows into a local depression until it overfills, spilling over and merging with a neighbour. Surface water eventually infiltrates and becomes groundwater, reaches the ocean, or is retained in a depression to form a lake.

When using this method over long time periods (from the Last Glacial Maximum, 21,000 years ago, to the present day), one way to validate the results is by comparison to strandlines that indicate past lake levels. Since the size of a lake is directly influenced by the wetness of the climate inputs used, these results can be used to correct general circulation models outputs, and thus improve predictions of the past climate whose influence is still felt in present-day lakes, river systems, and water tables.

Geothermobarometry in quartzite mylonites that exhumed the Ruby Mountain metamorphic core complex (Nevada): the relation between trace-element concentrations and deformation fabrics in quartzite

ELENA CHAMBERS, CHRISTIAN TEYSSIER

Department of Earth & Environmental Sciences

The temperatures and pressures present during the mylonitization of the Ruby Mountain core complex have been previously analyzed through phase equilibria of metamorphic assemblages. The purpose of this study was to compare these results to titanium concentration in quartz using the new ESCI electron microprobe. In addition, electron backscatter diffraction (EBSD) imaging combined with cathodoluminescence properties of the quartzite provide a direct relation between trace-element concentration and dislocation creep microstructures. Petrographic microscopy and imaging were used to perform microstructure analysis of these quartzites to obtain a more thorough understanding of the deformation processes and conditions that occurred within the Ruby Mountain mylonitic shear zone.

Development of 3D-printed Halbach Cylinder for Teaching and Research in Geomagnetism

STEPHANIE FINCH, JOSH FEINBERG, MICHAEL VOLK

Department of Earth & Environmental Sciences

Strong magnetic fields are often used to characterize the magnetic mineral assemblage in rocks and sediments. Typically, these measurements are only possible in the lab, as the instruments needed to generate large fields are usually large, expensive, water-cooled electromagnets. Here we explore the use of a Halbach array, which is composed of a circular arrangement of carefully positioned magnets that additively create a stronger magnetic field in the center of the circle than that generated by any single magnet in the arrangement. The resulting field in the center of the Halbach array is homogeneous along one axis, while nulled along other axes. Such arrangements have many potential applications due to their portability; yet previous versions of the array have been expensive and/or required substantial resources to build. Here, we explore a more accessible design, constructed using 3D printing to create a rigid frame to position and hold commercially available rare earth magnets. Initially, a small hand-held ring was designed and successfully assembled to accommodate rock chip samples that could be collected in the field. A second, larger outer ring was then designed that can be rotated about the smaller ring to generate a range of adjustable fields. The ability to strongly magnetize a sample while outside in the field using a variety of user-controlled fields has many applications for paleomagnetic and environmental magnetic studies. Most smartphones contain 3-axis magnetometers that can be used to measure a sample's magnetization after being magnetized by the Halbach array. Thus, we envision that our device could potentially be used in conjunction with a mobile app, allowing field measurements to be taken with a smartphone.

Investigating complex metamorphic rock fabrics using magnetic anisotropy: a case study from the Entia Dome, central Australia

CLÉMENTINE HAMELIN,
ANDREA R. BIEDERMANN,
DONNA L. WHITNEY, CHRISTIAN TEYSSIER

Department of Earth & Environmental Sciences

Continental crust undergoes cycles of orogenesis, a process during which continental material deforms, chemically transforms and differentiates at high-temperatures and great depths, i.e. high pressures. A partial record of continental evolution is contained in rocks that have undergone metamorphism and deformation during orogenesis. In particular, domal structures present in exposed orogens worldwide represent the late stages of the orogenic cycle. As thickened crust collapses under its own weight, domes form by vertical ascent (flow) of hot, buoyant material from deep to shallow crustal levels within the orogen. Domes are composed primarily of gneisses, which are chemically poor recorders of their full metamorphic history, typically recording high-temperature and low-pressure conditions of emplacement in the shallow crust. One potential way to investigate the earlier, deeper deformation history obliterated in the felsic rocks is to study the volumetrically minor but petrologically significant refractory mafic rocks metamorphosed and deformed alongside the gneisses. Not many methods exist to systematically study the preferred orientation of mafic rock-forming minerals and their relationship to strain, and existing analytical methods are extremely time consuming. In this study, we show that the preferred orientation of mineral grains in mafic metamorphic rocks is related to the orientation of the principal magnetic susceptibility directions in a given bulk sample, providing a framework to interpret rock fabrics from careful magnetic and petrologic fabric analyses. Because magnetic fabric measurements are relatively fast (a few minutes to a few hours) compared to traditional grain orientation analysis, this new framework provides an efficient way to analyze and interpret mafic metamorphic rock fabrics, with the possibility to peer into the depths of once active orogens.

Abiotic-Biotic Fe-S-C Cycling in Riparian Wetland Systems

ELIZABETH HILL, SHREYA SRIVASTAVA,
AUBREY DUNSHEE, CRYSTAL NG,
KEN KEMNER, CARA SANTELLI

Department of Earth & Environmental Sciences

The hyporheic zone in riparian wetland systems is characterized by water-saturated sediments where oxic surface water may interact and mix with anoxic groundwater. This mixing results in steep geochemical gradients which promote changes in microbial community composition, activity, and function at depth in hyporheic sediments. The cycling of iron, sulfur, and carbon in this zone is of particular interest for understanding the global carbon cycle and the fate of metal contaminants in wetland areas. However, the role of sulfur in wetland biogeochemical cycling is inconclusive. The aim of this project is to better understand the function of microbes and their metabolic activities in coupled abiotic-biotic Fe-S-C cycles. The study site for this project was Tim's Branch, a riparian stream system at the Savannah River National Lab in South Carolina. Sediment cores were collected from stream sediments and flanking wetlands that represented variability in their hyporheic exchange (e.g., gaining system compared versus losing system). DNA was extracted from sediment core samples at varying depths using the FastDNA Spin Kit for Soil and quantified using a Qubit fluorometer. Following this, total abundances of bacteria and archaea at different depths were determined via qPCR assays of the 16s rRNA gene. For the distribution of sulfate-reducing and sulfur-oxidizing bacteria, we performed qPCR of the dsrB and soxB genes. While data analysis is still ongoing, we expect to find increased abundance of the dsrB gene at shallow depths where sulfate acts as an electron acceptor for carbon mineralization. We expect decreased abundance of dsrB and increased soxB abundance with increased sediment depth. Additionally, we expect gene abundances to vary seasonally with changes in rainfall and hydrologic gradients. In downwelling conditions, we expect higher abundance of the dsrB gene at lower depths. In upwelling conditions, we expect higher abundances of the soxB gene.

Determining the rate of microbially-mediated pyrrhotite dissolution using integrated geochemical, magnetic, and genomic analyses

KATHRYN HOBART, JOSH FEINBERG, DAN JONES

Department of Earth & Environmental Sciences

Pyrrhotite (Fe1-xS, $0 \leq x \leq 0.125$) is the second most abundant iron sulfide mineral in the Earth's crust, and is frequently associated with copper, nickel, and platinum-group element ores. Understanding pyrrhotite dissolution under realistic environmental conditions is critical to predicting the environmental impact and improving management of mine waste and water. However, little is known about the influence of microorganisms on the rate of pyrrhotite dissolution, particularly at near-neutral or mildly acidic pH.

We have conducted laboratory experiments using isolated sulfur-oxidizing microorganisms and enrichment cultures obtained from sulfide-bearing rocks from Minnesota's Duluth Complex, which hosts a large but undeveloped disseminated Cu-Ni-PGE deposit. The presence of these organisms results in a substantial acceleration of pyrrhotite dissolution as compared to abiotic conditions. Different isolates and enrichment communities result in different dissolution rates and affect the amount of elemental sulfur formed and the precipitation of secondary iron minerals. These differences in secondary minerals can be characterized using low- and high-temperature magnetic techniques with higher sensitivities than traditional geochemical or mineralogical techniques.

Small subunit 16S rRNA gene sequencing of the enrichment experiments, as well as whole genome sequencing of several isolates, allows us to link the differences in dissolution rates to strain or community specific elements. We found that enrichments with sulfur and iron-oxidizing members only slightly increased rates over sulfur oxidizing isolates, although less elemental sulfur was produced in incubations with the enrichments. Among the sulfur-oxidizing isolates, the fastest rates were realized with a strain of Sulfuriferula that has a somewhat minimal sulfur-oxidation pathway consisting of only a partial SOX system and sulfide quinone oxidoreductases.

Microstructural Analysis of volcanic rocks from Mont Gerbier de Jonc Volcanic Dome, France

SAMUEL HUNT, CHRISTIAN TEYSSIER

Department of Earth & Environmental Sciences

Magnetic susceptibility (AMS) has previously been employed to determine the magnetic properties and magnetic fabrics of the Mont Gerbier de Jonc (MGDJ) volcanic dome, located in the Massif Central, France, allowing an interpretation of the preferred orientation of minerals (von Siebenthal, 2010). However, this research has not been tested against the physical orientation of minerals. This study will investigate the physical orientation of minerals comprising MGDJ in order to understand the mechanical transitions in a cooling magma. Microstructures from orientated samples will be analyzed using optical microscopy, electrom backscatter diffraction (EBSD), and X-ray Computed Tomography (XRCT) to understand the relationship between fabric geometry and crystallographic preferred orientation. Understanding mechanical behaviors in magma will help with the prediction of pace and violence of eruptions.

Lawsonite oxygen isotope and trace element records of subduction fluids

PATRICIA KANG, DONNA L. WHITNEY, LAURE MARTIN, EDWARD GHENT, ALBERTO VITALE BROVARONE, KATHERINE F. FORNASH

Department of Earth & Environmental Sciences

The composition of lawsonite preserved in exhumed high pressure/low temperature (HP/LT) rocks is a sensitive indicator of chemical exchanges between various rock types and fluids during subduction metamorphism and exhumation. We determined the oxygen isotope and trace element contents of lawsonite in HP/LT rocks (e.g., blueschist, eclogite, omphacitite) from two mélanges (Franciscan/USA; Dominican Republic) and from three structurally coherent terranes (Sivrihisar/Turkey; Alpine Corsica/France; British Columbia/Canada).

The results of oxygen isotope analyses show no significant overlap in the δ18O value of lawsonite in mélange vs. coherent complexes: with one exception, coherent-complex lawsonite is isotopically heavier than mélange lawsonite. In structurally coherent terranes, lawsonite samples differ in δ18O from each other depending on their protolith types: lawsonite from metabasalt records lighter δ18O (11.52–14.83‰) than lawsonite from metapelite (22.23-24.50‰). Lawsonite from omphacitite (Alpine Corsica/France) is distinct from the other examples analyzed in that it has significantly lighter δ18O (3.72–4.32‰), consistent with extensive interaction with serpentinite-derived fluid. Mélange lawsonite from metabasalt has a range of δ18O (7.47–10.47‰) greater than that of average mid-ocean ridge basalt (5.7‰). This range of δ18O may indicate low-T hydrothermal alteration of the basaltic protolith and/or the interaction with a high δ18O fluid, such as that derived from high δ18O sediment. Lawsonite samples from both types of exhumed terranes display a large variability of TE and REE patterns across samples from different localities and bulk compositions of the protolith. Consequently, no systematic differences have been found in TE and REE contents and their patterns between mélange lawsonite and coherent-complex lawsonite. This likely suggests both types of terranes experienced significant fluid-rock interaction with various rocks types during subduction.

Modeling the Effects of Oblique Subduction on Mantle Wedge Seismic Anisotropy

LINDSEY M KENYON, IKUKO WADA

Department of Earth & Environmental Sciences

Oblique subduction results in 3-D mantle wedge flow, affecting the development of olivine crystallographic preferred orientation (CPO) and therefore the seismic anisotropy of the mantle wedge. Using generic kinematic-dynamic models of oblique subduction, we systematically examine the effects of subduction obliquity on mantle wedge flow, the pattern of CPO, and shear wave splitting parameters. The results indicate that the fast axis of the CPO does not align with the mantle flow except where material flows into the mantle wedge and the resulting shear wave splitting patterns are complex and vary with back azimuth.

Effect of organic carbon source and concentration on radial growth of filamentous fungi in the presence and absence of selenite

BRAYDEN KUESTER, MARY SABUDA, JACKIE MEJIA, CARA SANTELLI

Department of Earth & Environmental Sciences

Selenium (Se) is an "essential toxin"— it is required by most organisms for growth, but at high concentrations, Se can become toxic. Elevated environmental Se concentrations are caused by waste produced by a variety of anthropogenic activities such as mining, agricultural, and industrial manufacturing operations. Selenate (Se(VI)) and selenite (Se(IV)) are toxic, so it is preferential to find a way to reduce them to solid Se(0) or volatile Se(-II) forms which are far less bioavailable. In previous research, it has been proven that environmental microorganisms such as fungi are capable of transforming Se species through a range of processes including reduction. Therefore, Se-transforming fungi have potential to transform soluble Se oxyanions to insoluble and less biologically available forms in contaminated water and could be a useful method for remediation of Se contaminated environments. Previous experiments in the Santelli Lab utilized liquid media containing yeast extract as a carbon source. The problem with using yeast extract as a carbon source is that the chemical composition cannot be specifically verified, and the conditions of an experiment cannot be recreated consistently. The purpose of this study was to determine how the source and concentration of organic carbon affect radial growth of metal-tolerant fungi, both in the presence and absence of selenite. Specifically, this research examined how two organic carbon sources, acetate and glucose, provided at four different concentrations influenced the radial growth of six metal-tolerant species of fungi. This same experiment was repeated, but with the added presence of selenite as a contaminant of concern. We find that glucose allowed more growth than acetate in the presence of Se and the highest organic carbon concentrations allowed the most growth in the presence of Se. This research will ultimately help enhance Se bioremediation strategies and improve water and soil health of environments impacted by Se.

An analysis of Holocene mammalian functional diversity across the North American forest-prairie environmental gradient

NORA LOUGHLIN, DAVID FOX

Department of Earth & Environmental Sciences

In order to fully understand the history of North America's mammalian communities, it is necessary to analyze how diversity differs across continental environmental gradients. Previous studies on this topic have focused mainly on taxonomic diversity, or the number of species that are present within an ecosystem. However, gaining a more nuanced understanding of past biodiversity requires consideration of functional diversity in addition to taxonomic diversity. Functional diversity is a measure of how many ecological roles are filled within a community, as well as how species are interacting with their environment and each other. The data used in this study consist of nearly 1,400 specimens from 72 Holocene sites spanning the forest-prairie ecotone across North Dakota, South Dakota, Iowa, and Illinois. These sites were selected due to the fact that they have been used in previous studies of Holocene mammalian biodiversity. The dataset—obtained from the Neotoma Paleoecology Database and supplemented with ecological data for each extant species from previous compilations—includes the taxonomic identities, age estimates, latitude and longitude, body size, mass, preferred habitat, locomotor mode, and food resources for each specimen. Using GIS mapping technology, this research aims to test how mammalian functional diversity dynamics change over the course of the Holocene and across the forest-prairie ecotone in North America.

*Sewage Sludge Incinerator Ash as a Recycled Phosphorus Source

PERSEPHONE MA, CARL ROSEN

Department of Soil, Water, and Climate

The Twin Cities incinerate sewage sludge to produce energy while reducing volume and organic contaminants. Research has shown that the remaining ash, which is usually landfilled, can be a viable phosphorus (P) source for crops. However, there are questions regarding the behavior of P release, the amount of plant available P compared to total P, and metals concentrations. To determine the viability of this ash as a P fertilizer, we conducted a 3-year corn and soybean field study on a Waukegen silt loam soil comparing this ash to other P sources including conventional P fertilizer (triple super phosphate), dried pelletized biosolids, and struvite. Each P source was applied in the spring at 20, 40, 60, and 80 kg P/ha, with a zero-P control included. Soil samples were taken before application, at midseason, and at the end of the season and were analyzed for available P and EPA 503 metals. In-situ (PRS) probes that act as a proxy for ions in soil water were also analyzed. Additionally, plant samples were taken at the end of the season and were analyzed for P and EPA 503 metals. Corn yields in 2017 and 2018 were high overall, though they were not significantly affected by P source or rate. Data from the chemical analysis of 2017 and 2018 end-of-season soil in the top 15 cm showed a significant increase of Olsen- and Bray-P with increasing application rates for all P sources. Additionally, DTPA-zinc and DTPA-copper increased significantly with increasing rates with biosolids and ash applications resulting in the highest concentrations. Overall, there were no detectable increases in any metals of concern including total Hg, Se, As, Cd, and Pb. Late season plant-available PRS-P increased with increasing P rate. Cumulative PRS-Cu and PRS-Zn were highest in biosolids treatments in 2018. Available data from all three years (2017-2019) will be presented.

Using electrical conductivity measurements to understand groundwater salinity

JOHN R. MCDARIS, JOSHUA FEINBERG

Department of Earth & Environmental Sciences

Groundwater is a critical resource for the Twin Cities Metropolitan Area. We rely on it for most of our water and it is under threat from over-pumping and contamination by mixing with surface waters. One contaminant of growing concern is chloride, primarily due to widespread road salt application during the winter as well as effluent from water softeners across the region. As a primary constituent of salinity, chloride contributes strongly to the electrical conductivity (EC) of natural waters. This research aims to use real-time measurements of groundwater EC inside observation wells to understand regional groundwater salinity and track it's evolution with time. Preliminary results are presented along with plans for future work.

Urease and Carbonic Anhydrase field detection: A method to test microbially induced carbonate precipitation in situ

FERNANDO MEDINA FERRER,
KATHRYN HOBART, JAKE V. BAILEY

Department of Earth & Environmental Sciences

Active microbial metabolisms can be directly assayed in the environment by simple, economical, and rapid tests designed for field detection. Here, we designed rapid tests for carbonic anhydrase and urease activity, two enzymes that promote carbonate precipitation. We evaluated biofilms from calcareous fens, iron springs and a saline lake, showing active urease in most fen and lake samples. The presence of active microbial urease provides a novel mechanism of calcium carbonate formation in these environments.

*The latitudinal species richness gradient of North American mammals masks multiple ordinal level patterns

KIRSTEN M. MELTESEN, EVAN T. WHITING,
DAVID L. FOX

Department of Ecology, Evolution, and Behavior

North American mammals exhibit a strong latitudinal gradient in species richness. However, species richness varies substantially among the nominal orders of North American mammals; Rodentia and Chiroptera together comprise ca. 75% of North American mammal species. To determine the degree to which these two clades control the latitudinal diversity gradient of North American mammals, we analyzed the relationship between species richness and latitude for the ten orders of North American terrestrial mammals. We utilized principal component analysis to identify 12 climatic variables that best summarize the variance in North American climate and evaluated the extent to which those and 4 topographic variables explain the spatial distribution of each mammalian order using multiple linear regression. The latitudinal richness gradient for bats is exceptionally strong and accounts for much of the pattern for all mammals. However, the relationship between species richness and latitude is not monotonic or is weak to nonexistent for the remaining orders. For example, rodents have a mid-latitude peak in richness and eulipotyphlans have peaks in the Pacific northwest and northeastern North America. Thus, the latitudinal gradient in species richness for all North American mammals results from diverse biogeographic patterns at the ordinal level. Despite this observation, we find that the climatic and topographic variables that best explain species richness do not tend to differ between each mammalian order.

*Magnesium isotope behaviors during authigenic carbonate precipitation driven by anaerobic methane oxidation

ZEKUN MENG, DONG FENG, XINYUAN ZHENG, KANGJUN HUANG

Department of Earth & Environmental Sciences

Formation of authigenic carbonate during anaerobic oxidation of methane (AOM) has been invoked as a critical but previously neglected process in regulating the carbon cycle over Earth's history in cold-seep environment. Because Mg can be incorporated into crystal lattices of authigenic carbonates, this process, in principle, can play an important role in the global biogeochemical cycle of Mg. However, its contribution has not been quantified.

To estimate the influence of AOM-induced authigenic carbonate formation on the global Mg cycle, we investigate Mg isotope systematics in cold-seep sediments and pore fluids collected from Shenhu area in the South China Sea. δ26Mg values in pore fluids systematically increase with depths from -0.82‰ at 1 meter below the seafloor (mbsf) to -0.62‰ at 8 mbsf. In contrast, the co-existing AOM-induced authigenic carbonates have lower and wider range in δ26Mg values (-1.50‰ to -1.15‰) decrease from surface to bottom in general. The apparent Mg isotope fractionation between carbonates and pore fluids (αcar-sol) ranges from 0.99919 to 0.99974. The magnitude of this fractionation is significantly smaller than that of abiotic and biotic marine carbonates precipitation in non-AOM area (αcar-sol= 0.99517 to 0.99964) (Saenger and Wang, 2014), possibly reflecting high precipitation rates of carbonate formation induced by AOM. These results allow for new constraints on the Mg flux associated with AOM-induced authigenic carbonates and its significance in the Mg cycle in the global ocean.

*Hydrogeochemical characterization of glacierized volcanic watersheds in the subhumid inner tropics

LEAH NELSON, GENE-HUA CRYSTAL NG, JEFF LA FRENIERRE, LEILA SABERI, ANDREW WICKERT, MORGAN JOHNSTONE

Department of Earth & Environmental Sciences

Climate change will impact world water supply, resulting in water insecurities among vulnerable communities. Mountain glaciers in the tropics are particularly vulnerable, as the fastest rates of warming are predicted in high altitude, low latitude regions. Current observations indicate a decrease in streamflow in many tropical glacierized watersheds in the Andes, where 99% of tropical glaciers are located. Here, we investigate two Ecuadorian watersheds in the subhumid inner tropics, where seasonal changes in precipitation are less pronounced, leading to year-round ablation. Further, these watersheds are located on Volcán Chimborazo and Volcán Cayambe, where field observations of fractured volcanic bedrock raise the hypothesis that groundwater flow may be more substantial than in many previously studied crystalline-cored watersheds. Study of Gavilan Machay (Volcán Chimborazo) and Río La Dormida (Volcán Cayambe) will expand our understanding of hydrologic responses to glacier retreat to a greater range of climatic and geologic conditions. Río La Dormida has a smaller area, lower mean elevation, and lower percent glacier coverage than Gavilan Machay; the climatic setting also varies between the two watersheds. These discrete differences among otherwise similar watersheds enables us to isolate the impacts of climate and ice cover on glacial, groundwater, and surface-water contributions to streamflow. We compare seasonal and yearly synoptic sampling campaigns to parse out potential temporal changes. In an end-member mixing model designed for data-sparse watersheds, dissolved ions and stable water isotopes serve as tracers to parse out and quantify water sources, namely glacier melt and groundwater. We characterize the mineral geochemistry of bedrock and soil using XRD analysis to learn where these dissolved ions

originate. From this, we infer flow paths that influence the contributions of meltwater and groundwater to streamflow in the watersheds.

How Does Deeply Buried Continental Crust Return to the Earth's Surface?

CHRISTINE NEWVILLE, CHRISTIAN TEYSSIER, DONNA L. WHITNEY, HANNAH J. BLATCHFORD

Department of Earth & Environmental Sciences

Continental materials that are deeply buried at collisional plate boundaries return to the Earth's surface by tectonic and erosional processes. One method for investigating these processes is to analyze structures and minerals in formerly deep rocks. The return process (exhumation) is a complex process and the record of the exhumation pathway and process is typically complicated by prior regional deformational events and local variability of terranes and lithologies. In this study, we examine how records of deformational structures and mineral assemblages can be collectively used to understand larger regional structures, such as shear zones, in order to establish the regional history of exhumation. The peninsula of Roan, Norway, records multiple stages of deformation through processes such as shearing and folding in the rock, crenulation (delete fabric), and multiple generations of melt. The region is structurally characterized as a NE-SW trending dome bounded by two steeply dipping shear zones with lithologies of a hornblende +/- garnet felsic gneiss with intermittent mafic pods and layers. We investigate how the orientation of the shear zones relate to the deformational fabrics and features within the gneiss unit of the dome to understand how and when they developed during the exhumation of the terrane. We present a schematic cross-section from the core of the dome to the western margin to illustrate the partitioning of strain and the transition from a sub-horizontal high strain zone to a vertical high strain zone. This study illustrates the relationship between microstructural and petrological observations to a regional history of the exhumation of orogenic crust.

Biomechanical modeling of a Cretaceous ornithischian dinosaur

HAYLEY ORLOWSKI, PETER MAKOVICKY

Department of Earth & Environmental Sciences

The neornithischian dinosaur Haya griva from the Santonian of Mongolia is known from two nearly complete specimens, several complete skulls, and numerous isolated postcranial remains. It is notable for having an especially large mass of gastroliths (stomach stones) preserved within the abdominal region. A nearly complete specimen was CT scanned and the skeleton digitally prepared to produce a skeletal restoration. In order to produce a reconstruction of the centre of mass, and thereby model locomotory mode, we produced a three-dimensional model of the body of Haya using the open-source 3D modeling software Blender. As a way of testing the sensitivity of the modeling anatomy using different assumptions and extant analogs, we manipulated several different variables including lung volume, gastrolith mass position, and tail length to determine the magnitude of the corresponding effect on the location of the centre of mass.

Isolating climatic and glacial impacts on river morphology: a paired-catchment study in the upper Mississippi River watershed

SHANTI PENPRASE, ANDREW WICKERT, PHIL LARSON, FIONA CLUBB, ETHAN KURAK

Department of Earth & Environmental Sciences

Climate and tectonics impact sediment production and transport through the large river basins of the world, but deciphering their individual impacts on river morphology remains difficult, as these drivers are typically superimposed on one another. In the upper Mississippi River basin of the north-central USA, however, climate swings associated with glacial–interglacial cycles pair with tectonic quiescence, making it an ideal place to isolate climatic impacts on sediment dynamics. We study two adjacent Mississippi River tributaries, the Zumbro and Whitewater Rivers. Both have similar histories of base-level change due to the aggradation and incision of the mainstem upper Mississippi. The Zumbro River was fed by ice-sheet-sourced water and sediment, whereas the Whitewater catchment remained beyond the ice-sheet margin. Paraglacial hillslope-derived sediment production impacted both river systems. In this paired-catchment study, we seek to understand how these differing ice-sheet histories impacted long-profile evolution by studying the modern channel network and adjacent terraces. To do this, we combine one-meter LiDAR topography with the topographic analysis package, LSDTopoTools. We extract the modern long-profiles from each watershed and connect geomorphic change to the history of ice-sheet meltwater input and base-level adjustment. This natural experiment thereby allows us to disentangle the impacts of climate (water and sediment supply) and base-level change on river morphology and sediment delivery to large mainstem rivers.

The Effect of Climate Change on Methylmercury in Boreal Peatlands

CAROLINE PIERCE, STEPHEN D. SEBESTYEN, RANDALL K. KOLKA, NATALIE GRIFFITHS, EDWARD A. NATER, BRANDY M. TONER

Department of Soil, Water, and Climate

Peatlands hold large quantities of atmospherically deposited Hg and can be significant sources of methylmercury (MeHg). MeHg is a neurotoxin produced within peatlands and exported to aquatic systems where it bioaccumulates up the food chain resulting in human health effects. Because peatlands are saturated wetland systems they provide ideal conditions for methylation, so much so that the percentage of wetlands in a watershed is positively correlated with MeHg concentrations in fish.

This study investigated how increased temperature may impact MeHg in peat porewaters and export to surface waters. Global models predict a 2–4.5°C increase in temperature with more drastic increases at higher latitudes, where most peatlands are located. Peatlands are expected to become drier due to reduced precipitation. The combination of these factors may turn peatlands from mercury sinks into sources. Samples were collected from 10 enclosures at the Spruce and Peatland Responses Under Changing Environments (SPRUCE) site located in Minnesota. Each enclosure has above and below-ground heating resulting in temperature treatments ranging from +0°C to +9°C relative to ambient.

In porewaters, THg decreased with increasing temperature and MeHg increased with temperature. In outflow, both THg and MeHg decreased with increasing temperature. Temperature and discharge volume are negatively correlated because as the temperature increases, the watertable drops. The trend in decreasing mercury flux with temperature can be attributed to the decrease in discharge volume. Our findings suggest that while temperature plays a role in the production of methylmercury within porewaters, the export of methylmercury is controlled by discharge volume. Temperature will produce more MeHg but rewetting events will be required to flush MeHg into streams/lakes where it will impact aquatic wildlife.

Ice Flow Dynamics During Retreat Induced Separation of a Tributary Glacier

BEN POPKEN, MAX VAN WYCK DE VREIS, ANDY WICKERT, SHANTI PENPRASE

Department of Earth & Environmental Sciences

The Southern Patagonian icefield is the largest non-polar ice mass in the Southern Hemisphere and has been rapidly thinning over the past decades with Upsala glacier being the largest single contributor towards sea level rise. Much attention has been paid to the rate and magnitude of ice retreat rates, but fewer studies have examined how ice flow dynamics evolve during retreat. The rapid retreat of Upsala's front has resulted in a tributary glacier, Bertacchi, being partially detached from the main trunk of the glacier since a 2008-2011 episode of rapid retreat. Using a combination of LANDSAT and Sentinel2 satellite imagery, we measure changes in their surface dynamics. Our hypothesis was the separation of the two glaciers will have resulted in an increase in Bertacchi's flow velocity due to reduced buttressing at the front.

The analysis was conducted using a Matlab-based particle tracking algorithm named iceV which has been developed for our purposes. The algorithm makes use of a technique called orientation correlation. This makes the model able to correlate images with different shading and illumination, while detecting glacier surface displacements between image pairs. Poor quality data is removed and data is averaged over a time series. To gauge its spatial accuracy, iceV generates plots showing the number of data points used to build the average. Data from this and other studies were compiled to provide a velocity history of Upsala and Bertacchi.

Velocity profiles generated by our algorithm do much better further away from the glacier front, where the signal to noise ratio was often quite low and data was discarded. We observe a significant spike in ice velocity of both glaciers beginning right before separation of the glacier began. This spike in velocity could be due to Upsala's retreat exposing Bertacchi's front resulting in reduced interference in flow with Upsala and reduced buttressing in Bertacchi.

Extracting the redox state of subducted altered oceanic crust using the exhumed rock record

NATALIE RAIA, DONNA WHITNEY, CHRISTIAN TEYSSIER

Department of Earth & Environmental Sciences

Volcanic arcs are ubiquitous above subduction zones, regions where tectonic plates are underthrust into the Earth's mantle. Gaseous and magmatic outputs from these volcanoes provide a major control on the composition of Earth's atmosphere and are an important constituent of Earth-system material recycling. These erupted materials carry chemical fingerprints that indicate the influence of subducted tectonic plate components on the composition of their mantle source. Uniquely, arc magmas above subduction zones are more oxidized than magmatic oceanic crust being formed at mid-ocean ridges. The cause of this globally observed trend is widely contested. One hypothesis asserts that fluids released during the progressive metamorphism and dehydration of subducted oceanic plates are oxidizing, and consequently influence the net oxidation state of the overlying mantle that feeds the volcanoes.

We apply and compare new thermodynamic tools to test this hypothesis using rocks tectonically exhumed from a former subduction zone. High-pressure mineral assemblages preserved in this metamorphosed oceanic crust retain a rich record of deep fluid interaction, which we use to extract a redox profile of subducted oceanic crust with depth of subduction.

Identifying Phosphorus Hotspots in the Red River Valley of the North

HEIDI R. REITMEIER, LINDSAY A. PEASE

Department of Soil, Water, and Climate

This study explores a 40-year historical record of nutrient management data to identify how changing trends in cropping and fertilizer application has affected phosphorus loss risk in Northwest Minnesota. For this study, nutrient management records spanning from 1978 to 2018 were compiled across 1500 acres farmed by the University of Minnesota Northwest Research & Outreach Center (UMN NWROC). The UMN NWROC is located in the Red River Basin of the North—a critical watershed leading to Canada's Lake Winnipeg. Due to rising concerns about recurrent harmful algal blooms in Lake Winnipeg, there is a growing need to identify best management practices (BMPs) for phosphorus loss within the basin. This study combines long-term historical data with the Minnesota Phosphorus Index to provide insight into the benefits and limitations of in-field phosphorus management (i.e., the 4 R's) as a BMP for water quality improvement in the Red River Basin of the North.

Probing the Background Stresses in the Cascadia Forearc

JOE RIPPKE, IKUKO WADA

Department of Earth & Environmental Sciences

The Cascadia subduction zone is classified as a low-stress subduction zone because the magnitude of the compressive force due to plate convergence is similar to that of the gravitational force based on previous mechanical modelling results. This stress environment provides an opportunity to assess relative importance of plate coupling, gravitational force on the surface topography, and the buoyancy of the serpentinized mantle wedge. We compile and analyze focal mechanism solutions of earthquakes within the continental forearc along the length of the Cascadia subduction zone to determine the stress orientations in the forearc and their regional-scale variation and investigate their implications for subduction zone processes, such as earthquakes and fluid migration.

Integrating Cover Crops and Manure: Best Management Practices

MANUEL J. SABBAGH, MELISSA L. WILSON

Department of Soil, Water, and Climate

Cover crop (CC) adoption rates are low, particularly in the upper Midwest such as in Minnesota. Producers are becoming more interested in integrating CC in their farm management systems, especially when manure is utilized as a nutrient source. We aim to develop and demonstrate the best management practices to integrate CC and manure in cold climates. This three-year study began in spring 2019 and will be conducted at the University of Minnesota Research and Outreach Center in Waseca, MN. Various CC species and seeding methods were evaluated and liquid dairy and swine manure were injected through sweeps to minimize soil disturbance during early and late fall. We aim to determine the effects of the combination of CC and manure have on soil health, nutrient cycling, and agronomic responses in comparison to the two practices alone.

*Spatiotemporal variability of hydrochemistry in a tropical glacierized watershed in the Andes

LEILA SABERI, G.-H. CRYSTAL NG, LEAH NELSON, WEI ZHI, JEFF LA FRENIERRE, LI LI

Department of Earth & Environmental Sciences

With climate change, some of the highest rates of warming are occurring in tropical glacierized mountainous watersheds, 99% of which located in the Andes. Extensive glacier retreat throughout the Andes will not only impact the glacier meltwater contribution to the streamflow, but it may also alter the hydrochemistry of watersheds. This is because hydrological changes triggered by glacier retreat can affect chemical weathering, dilution, and transport – all of which control solute concentrations. Here, we examine how the spatiotemporal distribution of solutes within a watershed and the export of solutes out of a watershed will respond to glacier retreat due to both hydrological and geochemical processes. To do so, we implement the model RT-Flux-PIHM, which integrates multicomponent reactive transport with hydrologic and land-surface processes, for a 7.2 km2 tropical watershed on Volcán Chimborazo, Ecuador that is currently 34% glacierized. Preliminary results indicate that the spatiotemporal variability of the hydrochemistry in the watershed is controlled by both hydrological processes, particularly evapotranspiration and length of flow paths, and geochemical processes, mainly mineral dissolution. Further, sensitivity tests have been implemented to evaluate the role of meltwater in controlling geochemical conditions. The results suggest that without glaciers, flux of reactive solutes (mineral dissolution products) out of the watershed would be 30% lower while stream discharge would be 45% lower, corresponding to a greater solute concentration without glacier melt than with it. This finding indicates that glacier melt water produces an overall dilution effect by increasing the surface runoff contribution to the streamflow. A better understanding of the influence of meltwater on hydrochemical processes can provide insights into potential biogeochemical

impacts of future glacier retreat in downstream portions of the Amazon basin.

Using filamentous Ascomycetes to remove selenium from Minnesota industrial and municipal wastewaters

MARY SABUDA, CARLA ROSENFELD, TODD DEJOURNETT, KARL WUOLO-JOURNEY, KATIE SCHROEDER, CARA SANTELLI

Department of Earth & Environmental Sciences

Selenium (Se) is essential in moderate doses to most organisms for the production of selenoproteins, but elevated levels in the environment can cause detrimental biological repercussions. Selenium bioavailability is highly linked to its oxidation state in the environment, and the Se forms common in oxic surface environments are Se(VI) and Se(IV), which are highly water soluble and bioavailable. Current strategies for removing Se from wastewaters are expensive and inefficient, but some environmentally ubiquitous Ascomycetes remove Se from solution by aerobic reduction of dissolved Se(+IV/VI) to form solid Se(0) and volatile Se(-II). To this end, culture experiments with Se-reducing fungi, Alternaria alternata and Alternaria strain "F7", an isolate from Se-contaminated soil, were performed to quantify total Se removed from solution in two Se-contaminated Minnesota wastewaters. In parallel, a second set of cultures were assembled with nutrient-lean culture media ("AY") and 2000 µg/L or 25 µg/L Se(IV or VI) to reflect the wastewaters' Se content. Using a draw-and-fill method, samples were taken to monitor total Se in the aqueous phase at 0, 2, and 7 days. Solid-associated Se data was collected at the end of each experiment. As the industrial wastewater was lacking in N, P and C, a second and third set of experiments were designed with proprietary industry additives containing carbohydrate- or glycerin-based products and additional nutrients. The data presented here highlights the high potential for the mycoremediation of Se-contaminated wastewaters, and reveals that it is essential to understand the phase of selenium present in the contaminated water to achieve efficient bioremediation.

Magnetostratigraphy of the Eocene Green River Formation, Wyoming

EMMA L. SCHNEIDER, JOSHUA M. FEINBERG

Department of Earth & Environmental Sciences

The Green River Formation (GRF) is one of the most well-preserved continuous Eocene terrestrial records in the world, allowing researchers to track phenomena in high resolution on themes related to climate, vegetation, and geomorphology. The preservation of the early Eocene is of particular interest as it contains the Early Eocene Climatic Optimum (EECO), an analog for current greenhouse gas-driven global warming. Geochronologic dates in the section are sparse, limiting the resolution in time of ongoing research, especially studies of climate cycles. In this study, new paleomagnetic data is presented for 34 GRF ash-fall tuffs and 2 additional GRF samples collected in southwestern Wyoming. Geomagnetic polarity was determined using alternating field and thermal demagnetization protocols for each specimen and yielded results consistent with previous studies except for the Firehole Tuff, which showed normal instead of reversed polarity. The magnetic mineralogy of the samples was characterized by obtaining hysteresis loops, backfield curves, and magnetic susceptibility, which show minimal post-depositional alteration to the samples and indicate that the samples still retain reliable paleomagnetic information. The timing of the observed geomagnetic reversals in the GRF will be used to further refine the geochronology of the section, which will in turn provide a framework for ongoing research into Eocene cyclostratigraphy and ultimately enable correlation with the marine record.

A modern, ecological perspective on stomatal density

KATIE SCHROEDER, MEGAN WILCOTS,
ERIC SEABLOOM, ELIZABETH BORER

Department of Earth & Environmental Sciences

The stomata of plants play important physiological roles in carbon uptake and water use efficiency. Plants often regulate the rates of these processes by varying stomatal conductance and density in response to changing environmental conditions. Stomatal density in particular is often used as an indicator of historical carbon dioxide (CO2) levels or as a climate proxy in herbarium specimens and fossil leaves. CO2 and oxygen levels are not the only factors influencing stomatal density; light availability, pathogens, soil water, and soil phosphorus, are all factors that can also affect stomatal density. Similarly, differences in stomatal densities are often related to photosynthetic efficiency, as C4 plants tend to have decreased stomatal densities compared to C3 plants. Here, we present results from a field survey of stomatal density in C3 and C4 grasses across a fully factorial addition of nitrogen, phosphorus, and potassium to highlight non-CO2 linked variations in stomatal density. These results will provide key insight into factors affecting stomatal density in a natural environment.

Minerals Supporting Life in Minnesota's Iron Range

CHRISTOPHER J. SCHULER,
BRANDY M. TONER, CARA M. SANTELLI

Department of Earth & Environmental Sciences

The metabolic backbone of many isolated crustal environments is thought to be lithotrophy, and as such redox-sensitive elements in the surrounding rock may exert a great deal of control on subsurface microbial communities. To better understand the contributions of local mineralogy to the habitability of the deep biosphere, we characterized select portions of rock extracted from boreholes in the Soudan Underground Mine State Park. Located in Minnesota's Iron Range, the mine allows access to a deep saline aquifer within a 2.5 Ga banded iron formation in the southernmost portion of the Canadian Shield. Analyses of the water flowing from the aquifer through the legacy boreholes indicate an anoxic, highly reducing environment that has long been isolated from surface conditions. The cores from which rock was selected were obtained from depths ranging from 10 to 100 m into the borehole, almost 800 m below the surface. Petrographic thin sections prepared from areas of interest within the cores were analyzed via synchrotron-based X-ray fluorescence microprobe. The banded iron formations were found to contain a variety of iron minerals, largely a mix of hematite and iron-rich chlorites, with a great degree of spatial heterogeneity. µ-X-ray diffraction provided evidence of reduced iron sulfide deposits throughout. Additionally, investigations into the mineralogy abutting pores in the rock show areas with high manganese concentrations, roughly 150 µm in diameter. Because of the anaerobic nature and low energy availability of these crustal habitats, they are ideally situated to serve as analogues for extraterrestrial environments. Ultimately, a better understanding of the mineralogy of this site will provide insight into the metabolic pathways important to microbes living within the earth's crust and could inform our understanding of how subsurface life could exist on other planets.

Estimation of Well-Based Injection Capacity for Managed Aquifer Recharge Suitability Mapping

RAGHWENDRA N. SHANDILYA, ETIENNE BRESCIANI, ANTHONY C. RUNKEL, SEUNGHAK LEE, PETER K. KANG

Department of Earth & Environmental Sciences

Managed aquifer recharge (MAR) has proved an effective method for enhancing water resources in various geographic and socio-economic contexts. As a result, water management agencies around the world are showing an increasing interest for MAR technologies. However, practical guidance regarding how to identify suitable MAR sites remains limited. In order to estimate well-based injection capacity, we apply method based on the Theis solution of hydraulic head response to pumping. The applied method suggests that injection capacity is linearly related with the maximum allowable head change, and almost linearly related with transmissivity and pumping duration. Determining transmissivity is thus critical for injection capacity estimation. In contrast, injection capacity is little sensitive to storativity and well radius. Hence, the uncertainties on these parameters may not substantially affect the results. We apply the methodology to calculate the injection capacity of the Buffalo aquifer in northwestern Minnesota, USA. We present a spatial map of injection capacity and the influence of aquifer heterogeneity and groundwater level fluctuations on the results will be discussed. This study demonstrates the value of the applied approach and addresses practical question about well-based injection capacity.

Irrigation management impacts on corn yield and nitrate leaching

GURPARTEET SINGH, VASUDHA SHARMA

Department of Soil, Water, and Climate

Irrigated agriculture combined with fertilizer application, normally involves nutrient leaching. The environmental impacts of irrigated agriculture on ground and surface water resources are of major concern in Minnesota. Better irrigation scheduling has the potential in addressing these complex agricultural environmental challenges we face. Irrigation scheduling enables the irrigator to apply the right amount of water at the right time, which increases irrigation efficiency and reduces nitrate-N leaching. However, proper irrigation scheduling is a difficult task. Over-irrigation wastes water, causes nutrients to leach, contaminates ground water, increases energy and labor costs, and reduces soil aeration. On the other hand, under irrigation creates plant water stress and reduces yield.

Four irrigation scheduling methods (1) in-field soil moisture monitoring using soil moisture sensors, (2) Irrigation Management assistant tool (IMA), (3) the University of Minnesota checkbook method, and (4) crop growth model (EPIC) are evaluated and compared in terms of total volume of water used, nitrate leaching and corn yield for two corn growing seasons (2019-2020) at two different sites. The goal of this research is to identify and develop irrigation management strategies and techniques that will increase corn water use efficiency, while minimizing nitrate leaching and maximizing crop utilization of soil nitrogen without impacting the yield.

*Measuring Pb Diffusion in a Deformed Pegmatite Vein from the Western Gneiss Region, Norway

GREY SMALL, CHRISTIAN TEYSSIER

Department of Earth & Environmental Sciences

Titanite is an important U/Pb geochronometer for determining the melt crystallization ages of igneous and metamorphic rocks. Titanite is more reactive than other U/Pb geochronometers such as zircon, and ages from titanite are often interpreted as the time at which it reached its closure temperature at 600-650°C. Reheating of titanite as a result of subsequent metamorphism after the original crystallization causes the radiogenic Pb to diffuse out of the titanite crystals; partially or wholly resetting the geochronometer and making it difficult to determine the original melt crystallization age from the titanite alone. This study examines an intrusive pegmatite dike collected from the Roan Peninsula in the northern part of the Western Gneiss Region (WGR) of Norway that experienced simple sinistral shear localized in the center of the dike, and contains abundant titanite crystals throughout the strain gradient. This study uses an electron microprobe to determine Pb zoning in deformed titanites and Electron Backscatter Diffraction (EBSD) to observe microstructures and determine the stresses experienced by different portions of the dike in order to determine a relationship between strain and Pb diffusion which would allow for more accurate dating of deformed titanite crystals.

Morphological disparity across the Geomyoidea clade: how modularity, integration, and trait covariation impact functional evolvability

FRANCESCA SOCKI, DAVID FOX

Department of Earth & Environmental Sciences

The rodent group known as the Geomyoidea, which consists of the two families Heteromyidae and Geomyidae, are commonly investigated in the field of evolutionary biology. Both families occupy extreme environments that can be seen in their anatomy, with many of the Geomyidae “gophers” living completely underground, while some of the more extereme Heteromyidae such as “desert kangaroo rats” living in vast arid deserts. Even given relatedness, Geomyidae and Heteromyidae exhibit extreme disparity which could be potentially tied to environmental selection pressures across an evolutionary time scale. Morphological variation could potentially be due to these families having very different lifestyles in regards to their locomotion, choice of diet, and habitat quality. Given the variation and the multitude of potential factors involved, a comparative functional anatomy approach can be taken to understand how strongly each group is selected to a specific lifestyle, and simultaneously observable patterns may be seen across closely related groups. Modularity is the concept that different components upon an anatomical feature can be further grouped into areas related to specific functions, breaking down a larger feature into structures of covariation. In other words, multiple traits on a single animal can be closely associated and therefore will evolve together, which can be grouped into a module, and there are typically multiple modules on an organism. Association of traits is called integration, with the trend of higher integration within a module, and lower (weaker) integration between modules (Klingenberg 2013). Our study so far notices potential module areas that may be associated with the more extremely adapted members of each family, such as the rostrum of the Geomyids to aid in fossoriality, and the auditory bullas in Heteromyids to help acclimate to a more fast landscape.

Determining Human Impacts on Lake Harriet

KAELYN SPERLE

Department of Earth & Environmental Sciences

Lake Harriet is an urban lake in Hennepin county that has substantial housing and roads along the shore and three parks bordering the lake to the north. As the area surrounding the lake wasn't heavily developed until the late 1890s, Lake Harriet offers an opportunity to study how human development has affected the lake sediments and subsequently the health of the lake. It is expected that there will be traces of human activity from recreation and pollutants, such as larger sand deposits from a sandy beach that was created for swimmers. However, later in the 1990s to present day, it is expected that the sediments will show a decrease in pollutants as management of the lake became more effective as human impacts on lake health were better understood. This would be in line with trends from nearby Lake McCarrons in Roseville, MN, that has similar human developments surrounding it, and has cores that show it was poorly managed in the middle of the 20th century. Cores taken from Lake Harriet in 2004 and cores that will be taken 2/23/2020 will be analyzed using smear slide analysis to determine how lake sediments varied with time. The cores will be also be analyzed using loss-on-ignition (LOI) to determine carbon content, with expectations that this would increase with urban development. Historical research of the surrounding area will be correlated with Pb-210 dating of the cores from 2004 to link events and actual dates. Preliminary research on the older cores from Lake Harriet show that charcoal and organic matter appear often in the cores from 2004, but human impact will be determined when correlated with the cores from 2020 and the dates from the Pb-210 dating. Determining how Lake Harriet's sediments have been altered will affect not only how the lake is viewed in the past, but how the lake is managed in the future to preserve it for generations to come.

Comparison between measured finite strain in quartzite-pebble metaconglomerate and incremental strain obtained from quartz crystallographic fabrics (Bygdin conglomerate, Norway)

LEXI STRICKER, CHRISTIAN TEYSSIER

Department of Earth & Environmental Sciences

The Bygdin Conglomerate is part of the Upper Jotun Nappe in the Norwegian Caledonides. Strain analysis of the pebbles by Hossack (1968) found that the finite strain was both extensional and constrictional in various areas of the Sandvikshytten Fold. Initial crystallographic preferred orientation (CPO) analysis on 8 samples, spanning the spectrum from flattening to constrictional finite strain, was conducted by using a manual U-stage, which showed that the quartz c-axis of all samples have a cross-girdle fabric suggesting plane strain deformation. These manually obtained results are compared to the more thorough and accurate electron backscatter diffraction method to assess whether quartz CPO correlates or not with the finite strain established from pebble-shape measurements.

Low-temperature thermochronology reveals tectonic and erosional exhumation of the Pioneer metamorphic core complex, Idaho

JENNIFER M. TAYLOR, CHRISTIAN TEYSSIER, DONNA L. WHITNEY

Department of Earth & Environmental Sciences

Rock within metamorphic core complexes reaches Earth's surface predominantly through tectonic exhumation facilitated by normal faulting, including extension along a low-angle detachment fault. When tectonic exhumation ceases, further exhumation is accomplished through erosion, including the development of topography and landscape evolution. Understanding the transition from tectonic to erosional exhumation is essential not only for determining the timing and magnitude of tectonic exhumation but also for considering long-term erosion rates and landscape evolution. High-temperature thermochronologic studies of the Pioneer metamorphic core complex (PMCC; south-central Idaho) have traced tectonic exhumation from ~500 °C to 200 °C between 50-33 Ma (Silverberg, 1990; Vogl et al., 2012; McFadden et al., 2015) while new and existing low-temperature apatite helium data point to erosional exhumation likely related to landscape evolution at ~10 Ma (Vogl et al., 2014). This study presents new zircon helium (ZHe) data to address the ~10 Ma gap between these existing datasets, with ZHe ages ranging from 20-31 Ma. The thermo-kinematic modeling program Pecube is used to investigate the influence of both tectonic exhumation and erosional landscape evolution on the thermochronologic record. Initial modeling results suggest ZHe ages in the PMCC are unaffected by regional landscape evolution and instead reflect the final stages of tectonic exhumation.

Investigating the potential for bioremediation of cobalt and manganese using biogenic manganese oxides in carbonate buffer solution

RACHEL TRIPP, TINGYING XU, CARA SANTELLI

Department of Earth & Environmental Sciences

Specific strains of ascomycete fungi can oxidize Mn(II) to form Mn(IV). Because Mn(IV) minerals are insoluble in normal pH, they can be more easily removed from solution due to biogenic Mn oxides' high reactivity and ability to act as natural sponges for heavy metal contaminants. This experiment highlights the potential applications for bioremediation by studying if the Mn removal remained efficient in the presence of carbonate buffer as opposed to HEPES buffer. F1, a strain of fungi that is isolated from the Soudan Iron Mine, was grown in a brine solution with Co(II) as the metal of interest for co-precipitation. Over time, the change in Mn(II) concentration was observed. Through this, it was determined that samples exceeding a critical concentration of carbonate buffer showed removal Mn(II) and Co(II) from solution. This ongoing work will help develop fungal bioremediation strategies applicable to treating contaminated wastewater created by mining operations.

*Geochemistry of Yellowstone Lake Hydrothermal Vent Deposits

AMANDA TUDOR, WILLIAM E. SEYFRIED JR

Department of Earth & Environmental Sciences

Yellowstone Lake hydrothermal vent systems have been studied recently in connection with the HD-YLAKE program, a multidisciplinary project investigating the feedback between chemical and physical processes characterizing the sublacustrine hydrothermal system. Here we focus on the chemical and mineralogical composition of deposits/alteration and coexisting vent fluid chemistry associated with Stevenson Island Deep Hole Vents. Located at a depth of 121 meters in the northern part of Yellowstone Lake, the Stevenson Island Deep Hole vent system is a vapor driven system where vent fluid temperatures measure up to 174 °C. The sublacustrine fumarole is highly enriched in dissolved H 2 S and CO 2. Accordingly, the acidic fluids enhance mass transfer reactions (H + metasomatism), effectively transforming the sedimentary substrate to an assemblage predominantly characterized by kaolinite, boehmite or smectite, and pyrite. Differentiation between clay minerals can be achieved by XRD and hydrogen isotope analysis. H/D data show that the clay minerals are in equilibrium with the measured vent fluid at approximately 130ºC in good agreement with the vent fluid temperature average. Moreover, similarities in spatial variation of hydrothermally altered clay minerals within sampled areas suggest a dynamic system, with hot vapors convectively circulating in the subsurface throughout the entire area, even in the absence of active venting. Thus, hydrothermal vent deposits provide insight into the spatial and temporal evolution of this system. Within Stevenson Island Deep Hole vents, this can be attributed to chemical and physical processes (hydrothermal explosions and/or degassing effects) at the site of venting. Analysis of these deposits indicate the overwhelming importance of alteration of precursor lake sediment and the replacement by minerals stable at chemical and physical conditions intrinsic to the composition of the corresponding vent fluids.

*Extent of late Holocene volcanic activity in southern Patagonia

MAXIMILLIAN VAN WYK DE VRIES, EMI ITO, MARK SHAPLEY, GUIDO BRIGNONE

Department of Earth & Environmental Sciences

Glaciated volcanoes respond in several ways to changes in ice volume. For instance, the rate of magma influx, number of volcanic debris avalanches and quantity of eruptions may all be affected by thinning ice. The magnitude of these effect is variable, depending on the properties of both the volcano and local ice mass. Due to their remoteness and difficulty of access, ice covered volcanoes are also some of the least well studied. This is particularly relevant in areas such as southern Patagonia, where active volcanoes are adjacent to the southern hemisphere's largest non-polar ice cap. In this project we aim to determine the background frequency and magnitude of eruptions in southern Patagonia. Previous work has identified a small number of Holocene eruptions, however the lack of an extensive and high preservation dataset limits our understanding of the volcanic sources. We collect a total of nearly 50 lake cores from a large proglacial lake, Lago Argentino, within 100 km of the three active volcanoes of the Southern Patagonian Icefield. We use over 100m of well laminated lake bottom sediment to identify tephras from local volcanic eruptions. Early analyses suggest that an order of magnitude more late Holocene tephra horizons can be identified than found in previous studies, including both key regional volcanic horizons and fine cm to mm scale tephras.

Our results suggest that the understudied volcanoes within the Southern Patagonian icefield may have a higher eruptive frequency than previously considered. This has geohazard implications for a region with a rapidly growing tourist population, and more active magma plumbing systems increase the likelihood of ice thinning and depressurization triggered eruptions. With much of the Southern Patagonian icefield thinning at rates of over several metres a year, more detailed work is required to understand likely future volcanic influence on this region in the coming decades to centuries.

First We Should Consider Manoomin (Wild Rice): Co-Producing Interdisciplinary Ecological Knowledge and Co-Protecting Indigenous Resource Sovereignty

MADDY NYBLADE, ALEX WAHEED, CRYSTAL NG, CARA SANTELLI, ERIC CHAPMAN, JOE GRAVEEN, KARI HEDIN, JEREMY BLOOMQUIST, CHAD WEISS, PERRY BUNTING, DARREN VOGT, MIKE DOCKRY, DAN LARKIN, MAE DAVENPORT, LAURA MATSON, DIANA DALBOTTEN, MCKAYLEE DUQAIN, HANNAH JO KING, JOSH TORGESON, PATRICK O'HARA, JAMIE KAY, TRINATY CALDWELL, BRENA MULLEN, RILEY SCHMITTER, BRAYDEN KUESTER, LILAH WHITE

Department of Earth & Environmental Sciences

Manoomin (Ojibwe/Anishinaabe), or northern wild rice (Zizania palustris), is an annual aquatic grass that grows across the Great Lakes region. It has medicinal, spiritual and dietary significance to the sovereign Tribes of the region, but its abundance has been declining despite its legal protection under treaties. Standard practices in State and Federal environmental management involve non-Native scientists examining Indigenous lands to draw conclusions that drive resource extraction without input from Indigenous people. This method represents continued physical, economic, and intellectual colonization. In an attempt to subvert this paradigm, our project brings together representatives from a number of Tribes across this region -- including natural resource stewards, cultural leaders, elders, and rice chiefs -- as well as Native and non-Native students and researchers to protect manoomin. Over the past two years of collaboration and field work, our close partnership has brought forth scientific and relational insights that would not have emerged with standard western science approaches. Ongoing work between researchers and partners has yielded a multi-dimensional approach which seeks to capture the various forces influencing manoomin. In this conceptual approach, watershed changes, sediments, nutrient concentrations, hydrologic parameters, and competitive vegetation are assessed to examine the impact on the growth of manoomin while maintaining a genuine collaboration with project partners and treating manoomin with the utmost respect. While the threats to manoomin vary from site to site, the continued interactions of humans on these aquatic systems is clear above all. Our relationships with each other and this ecosystem are not only an integral part of our methods, but are also the emerging solution to holistic scientific inquiry and socio-environmental community health.

Small fungi, big (selenium) problem: tracking the removal of elevated selenate concentrations by Alternaria alternate

MEGAN R. WEDAL, MARY C. SABUDA, JACQUELINE MEJIA, CARA M. SANTELLI

Department of Earth & Environmental Sciences

Selenium (Se) is considered an "essential toxin": small quantities are needed for proper function in most organisms, but large quantities can be fatal. Some species of filamentous fungi are capable of transforming aqueous selenium in the form of selenate, Se(VI), or selenite, Se(IV) into solid elemental [Se(0)] or volatile [Se(-II)] forms. Bioavailable forms of selenium include selenate and selenite, which, if accumulated, can be fatal. At present, most work in the Santelli lab has focused on Se(IV) transformations by fungi,, and little is known about how these fungi perform in extremely high selenate concentrations. To determine the amount of selenate removed from solution and rate of reduction, one metal-tolerant Ascomycete fungus, Alternaria alternata, was cultured in a defined, liquid medium. After 14 days of growth, these cultures were spiked with 10 mM selenate and the reduction of selenate to solid Se(0) or potentially volatilized Se(-II) will be tracked through time. The amount of selenium left in solution will be analyzed with an ion chromatograph, and the amount of selenium transformed into the solid phase will be determined with a solid-phase digestion followed by quantification with inductively coupled plasma - optical emission spectroscopy. By subtracting the original selenate concentration added from the aqueous and solid phase measurements, the remaining mass will be determined to infer the percent of Se volatilized by Alternaria. As the experiments are still in progress, the results will be presented in April. After this work is completed, we hope to gain a better understanding of the genetic mechanisms of fungal selenate reduction through additional '-omics type approaches coupled to the geochemistry results in this study. In turn, the use of these and other Ascomycete fungi may be used in the design of an effective bioremediation strategy for the treatment of Se-contaminated wastewater.

*Linking diet and tooth morphology in modern and fossil lizards and snakes

EVAN T. WHITING, DAVID L. FOX

Department of Earth & Environmental Sciences

Diet is one of the most important components of the ecology of any animal. Understanding diet allows us to better understand a whole animal, which is especially useful for reconstructing the ecology of extinct animals from fossil evidence. For vertebrate animals with teeth, tooth morphology is often directly associated with diet, thus providing an ecological proxy that can be extended into the fossil record. Quantitative analyses of tooth morphology and complexity are now commonplace for modern and fossil mammals, but these techniques have still not been widely applied to non-mammalian vertebrates, such as fish, dinosaurs, and squamates (lizards and snakes). Recent studies have demonstrated the efficacy of some quantitative tooth morphology and complexity methods for modern and extinct fossil reptiles, but there are still a multitude of additional methods and vertebrate groups that deserve exploration. In this study, we used high-resolution computed tomography (CT) scanning and 3D dental topography techniques to establish a quantitative link between diet and tooth morphology in modern and fossil squamates. We sampled >70 modern lizard and snake species from around the world, and gathered dietary information for all of them from the literature. We also sampled several fossil lizard specimens from the Paleogene of Wyoming and North Dakota, in order to test the applicability of our methods on extinct squamates. We CT-scanned museum specimens at the University of Minnesota and University of Florida, and downloaded additional CT data from the online repositories MorphoSource and DigiMorph. We digitally extracted 3D tooth surfaces and subjected them to a post-processing routine in preparation for analyses. Our preliminary results suggest that these methods can differentiate among broad dietary categories in modern lizards and snakes, and also be used to help reconstruct the likely diets of extinct fossil squamates.

Thermomechanical analysis of natural quartzite deformed under various stress and temperature conditions

RONGXUAN ZHU

Department of Earth & Environmental Sciences

The crystallographic orientations of quartz were studied by using Electron Backscatter Diffraction (EBSD), a scanning electron microscope technique. The samples of quartzite were collected from the Ruby Gap Duplex in Central Australia. The crystallographic orientations of quartz deformed in the dislocation creep regimes 1, 2 and 3 were analyzed. Regime 1 represents relatively low-strain quartz that was deformed at high stress and low temperature. Regime 2 represents quartzite in which original grains are stretched and partially recrystallized under lower stress and higher temperature compared to Regime 1. Regime 3 represents highly deformed and recrystallized quartzite with strong crystallographic preferred orientation developed under low stress and highest temperature. The crystallographic orientations of quartzite are related to lattice rotation, grain boundary migration, and diffusion processes. Tectonic histories and deformation processes of quartz were reconstructed through estimations of the temperature and pressure conditions at which quartzite deformed. EBSD mapping was performed on selected areas of deformed quartz in order to measure recrystallized grain sizes and evaluate the differential stress under which deformation took place.