The 55th Annual Graduate Student Colloquium

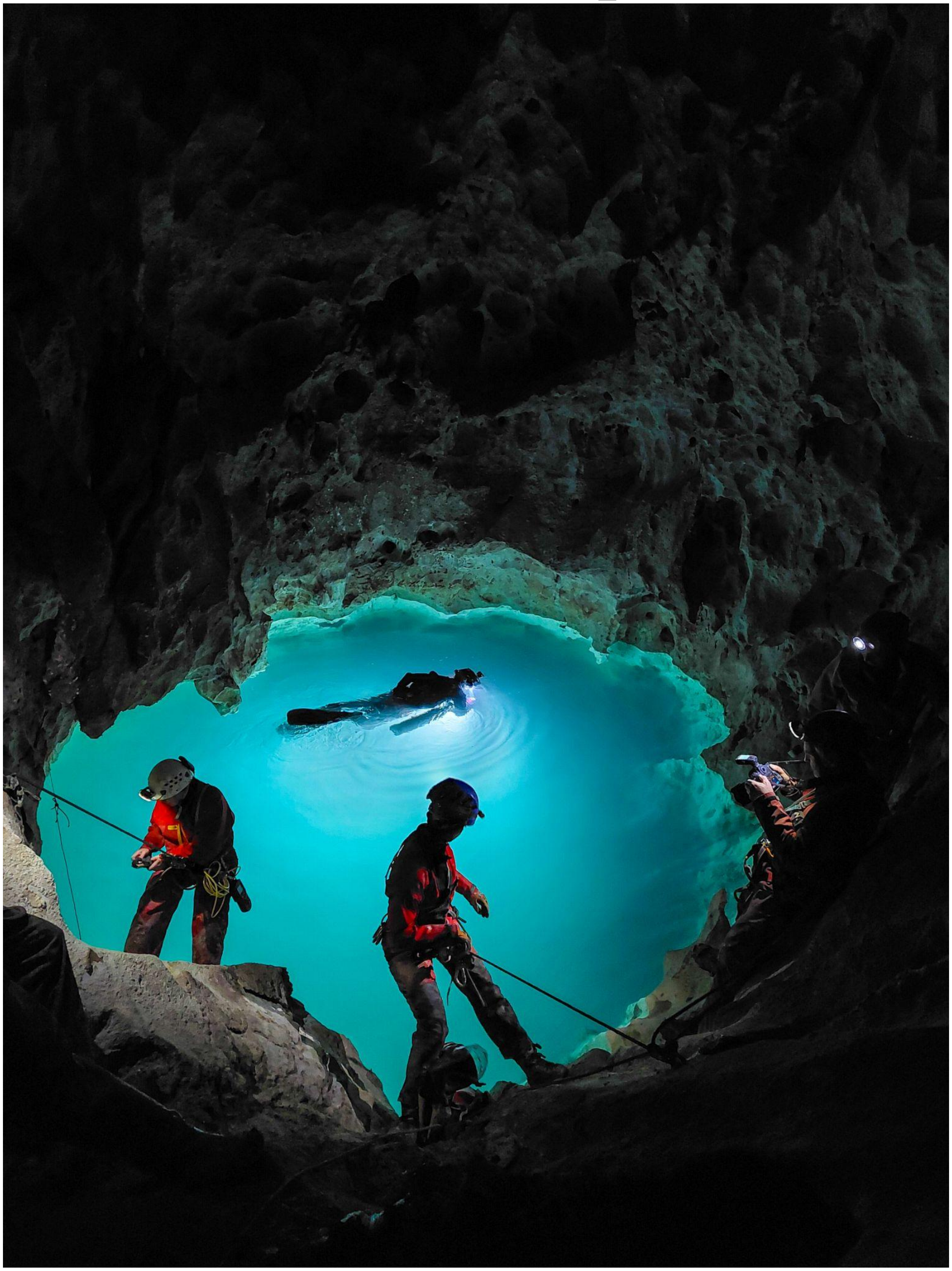

Photo: Dani Buccheister (Field Work Photo Contest Winner)

Hosted by the Department of Geosciences
April 20th – 21st, 2023

55th Annual Graduate Student Colloquium

Sponsored by the Shell Graduate Student Colloquium Award and the Cannon Family Graduate Symposium Award. Hosted by the Department of Geosciences.
April 20-21, 2023

The Graduate Student Colloquium is a forum where students present their research or research proposal to faculty, friends, and peers. The Colloquium is hosted by the Department of Geosciences and is open to graduate students involved in geosciences research. The Colloquium format stimulates research discussion, allows students to practice for national meetings, and helps students improve their presentation skills. The Colloquium assists both the Department and Penn State in maintaining and strengthening their reputations for giving high quality talks and poster presentations at national and international meetings.

The Graduate Colloquium Committee wishes to thank the students for sharing their work and the post-docs and faculty for providing constructive feedback. The Committee also wishes to thank the Shell People Services division of Shell Oil Company for their generous financial support, Dave Cannon for generous donations that go towards prize money and the Department of Geosciences for hosting this Colloquium.

Graduate Student Colloquium Committee
Chairs: Leonie Strobl, Shavonne Morin
Members: Nolan Roth, Rory Changleng, Em White, Claire Hines, Ella Do

Event Schedule

Thursday 20th April

Opening Remarks – 9:00 to 9:15 am

Oral Session 1 – 9:15 to 10:30 am

Break – 10:30-10:45 am

Oral Session 2 – 10:45 am to 12:00 pm

Lunch Break – 12:00 pm to 1:00 pm

Poster Session 3 – 1:00 to 2:45 pm

Break – 2:45 to 3:00 pm

Oral Session 4 – 3:00 to 4:00 pm

Friday 21st April

Opening Remarks – 9:00 – 9:15 am

Oral Session 5 – 9:15 to 10:15 am

Break – 10:15 to 10:30 am

Oral Session 6 – 10:30 am to 11:15 pm

Lunch Break – 11:15 pm to 1:00 pm

Poster Session 7 – 1:00 pm to 2:45 pm

Break – 2:45 pm to 3:00 pm

Oral Session 8 – 3:00 pm to 4:15 pm

The Peter Deines Lectureship

The first place award for an oral presentation by a post-comprehensive Ph.D. student is designated the Peter Deines Lectureship for the following academic year.

This award was started in 2004 to represent the tremendous amount of respect and admiration the graduate students in the Department of Geosciences had for Dr. Peter Deines, who that year was stepping down from the position of Graduate Program Chairman. Recipients of the honor are invited to give a departmental colloquium talk during the proceeding academic year.

The department and the world lost a great man and wonderful person when Peter passed away on February 2, 2009. It is with great pride that the Graduate Student Colloquium continues the tradition born in 2004.

Past Recipients:

2022-23: Shelby Bowden
2021-22: Julia Carr
2020-21: Graduate Student Colloquium Canceled due to COVID-19 pandemic
2019-20: Allison Fox
2018-19: Beth Hoagland
2017-18: Matthew Herman
2016-17: Rosie Oakes
2015-16: John Leeman
2014-15: Ashlee Dere
2013-14: Jonathon Schueth
2012-13 :Elizabeth Herndon
2011-12: Bryan Kaproth
2010-11: Tim Fischer
2009-10: Aaron Diefendorf and Bryn Kimball
2008-09: Daniel Hummer
2007-08: Gavin Hayes
2006-07: Christina Lopano
2005-06: Shawn Goldman and Courtney Turich
2004-05: Margaret Benoit

The Peter Deines Lectureship

Peter Deines (4/02/36 - 2/02/09) earned a Geologen Vordiplom at the Rheinische Friedrich Wilhelms Universität, Bonn, Germany in 1959, an M.S. (1964) and a Ph.D. (1967) in Geochemistry and Mineralogy from Penn State University. Since 1967, and after 2004, as an Emeritus Professor, he was a member of the Geological Science Faculty of the Pennsylvania State University. He earned an international reputation for his geochemical research, teaching, and science administration. Recognition came in teaching awards, election to the University Senate, in which he served for 24 years, and election especially to Treasurer of the International Geochemical Society. In that office, he was so effective that he was awarded a unique Honorary Life Membership for his financial management of the society. He was a principal organizer of that Society's primary international meetings, the famous Goldschmidt Conferences.

With his gift for organization, he also served the Department of Geosciences on most of its committees. He served as its Graduate Program Chairman, while also administering committees for the College of Earth and Mineral Sciences, primarily for scholarships. Most important was his commitment to the University Academic Senate, in which he served in 28 committee posts, including its Chair for 1990-91; and to the University, on 34 committees and commissions, including University Ombudsman since 2006. He also was elected President of the Faculty-Staff Club. Dr. Deines' research centered on precise explanations of natural variations in stable isotope abundances as means of understanding geologic processes. Results were presented in lectures throughout the world and in over 60 published papers. His illustrated book, "Solved Problems in Geochemistry", was polished by his teaching of eight graduate courses and is available on the web especially for graduate students.

A 40-year member of the Nittany Valley Symphony, Peter will be missed for his finesse with violin and viola.

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Opening Remarks

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Ph.D. student, 3rd year, Pre-Comps
Past ecological interactions between humans and baobabs in Velondriake, Southwest Madagascar

9:30 am – 9:45 am
Dongyoun Chung
Ph.D. student, 1st year, Pre-Comps
Crystal structure dependent dissolution mechanisms of Fe oxide/ hydroxide

9:45 am – 10:00 am
Raphael Affinito
Ph.D. student, 3rd year, Pre-Comps
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10:00 am – 10:15 am
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Data-Driven Dynamics on Thwaites Glacier, West Antarctica

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Nolan Roth
Ph.D. student, 3rd year, Pre-Comps
Simulating Seismo-Electric Signals for Water Exploration of Mars' Subsurface

Past ecological interactions between humans and baobabs in Velondriake, Southwest Madagascar

Karen V. Pham[1], Dylan S. Davis[2,3], George Manahira[4], Kristina Douglass[2,3,4], Sarah J. Ivory[1,5]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*
[2]*Columbia Climate School, Columbia University, New York, NY, USA*
[3]*Division of Biology and Paleoenvironment, Lamont-Doherty Earth Observatory, Palisades, NY, USA*
[4]*The Morombe Archaeological Project, Morombe, Madagascar*
[5]*Earth and Environmental Systems Institute, Pennsylvania State University, State College, PA, USA*

In Madagascar, 3 of 6 endemic, large-fruited baobab tree species (genus *Adansonia*) are currently threatened, and the remaining species are experiencing population declines. Future climate shifts are expected to greatly reduce baobab species' geographic range distributions unless these species can successfully disperse their seeds over larger distances. It is imperative for baobab conservation that we better our understanding of biotic influences on future baobab distributions. Though we know that baobabs rely on animals for seed dispersal, the primary living disperser of Malagasy baobabs is unknown. Baobab trees near modern villages in Madagascar and documented cases of human-baobab interactions in Mali suggest that humans may influence baobab distributions. Thus, we hypothesize that humans may act as dispersers of baobabs in Madagascar.

Here, we use spatial analyses on modern baobab occurrence data and locations of archaeological sites to determine whether ecological interactions have occurred between humans and baobabs through time in the Velondriake Marine Protected Area, Southwest Madagascar. We observe that areas where more archaeological materials have been recovered positively correlate with high density of baobabs. We also gain further insights on past human-baobab interactions by dividing archaeological sites indicative of different subsistence strategies utilized by those who occupied these sites. Our results show strong associations between past human presence and baobabs, though it is difficult to determine whether humans planted baobabs or simply congregated near them. If future work incorporating a temporal aspect of the system reveals that past humans indeed dispersed baobabs, this would suggest that modern humans in SW Madagascar may play a key role in the future conservation of baobabs.

Crystal structure dependent dissolution mechanisms of Fe oxide/ hydroxide

Dongyoun Chung[1], Peter Heaney[1], Jeffrey E. Post[2], Peter J. Eng[3,4], and Joanne E. Stubbs[3]

[1]Department of Geosciences, Pennsylvania State University, State College, PA, USA
[2]Department of Mineral Sciences, Smithsonian Institution, Washington, D.C., USA
[3]Center for Advanced Radiation Sources, The University of Chicago, Chicago, IL, USA
[4]James Franck Institute, The University of Chicago, Chicago, IL, USA

Changes in the crystal structures of hematite (Fe_2O_3) and goethite (FeOOH) were analyzed using in situ, time-resolved X-ray diffraction of powders in 3 *M* HCl solutions. Rietveld refinements indicated that the crystallite size of hematite decreased as expected during dissolution, but surprisingly, the refined crystallite dimensions for goethite increased. On this basis, we propose different dissolution mechanisms for hematite and goethite. Whereas hematite dissolved by sequential removal of surface layers, the open tunnels of goethite allowed H^+ ions to diffuse into the structure and substitute for Fe^{3+}, generating "hydrogoethite". The exchange of H^+ for Fe^{3+} was accompanied by an expansion of the unit-cell volume of goethite during dissolution, indicating an overall destabilization of the structure that ultimately led to disintegration. The evolution of Fe occupancy in the octahedral sites of hematite and goethite supports this dissolution model. As goethite dissolution proceeded, Fe occupancy systematically decreased from 0.7966(4) to 0.732(5), whereas the refined Fe occupancy in hematite increased from 0.899(4) to 0.98(1). We attribute the increase in Fe occupancy as hematite dissolved either to sequential removal of defective surface layers and/or to diffusion of Fe^{3+} from the surfaces into the particle cores. In contrast, the decrease in the Fe occupancy as goethite dissolved reflects the leaching of $Fe^{3+}$and the interior diffusion of dissolved H^+, as facilitated by the open tunnel structure.

The Stability Transition from Stable to Unstable Frictional Slip with Finite Pore Pressure

Raphael Affinito[1], Clay Wood[1], Samson Marty[1], Derek Elsworth[1,3], Chris Marone[1,2]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*
[2] *Dipartimento di Scienze della Terra, La Sapienza Università di Roma, Rome, Italy*
[3] *Dept. of Energy and Mineral Engineering, EMS Energy Institute, and G3 Center, Pennsylvania State University, State College, PA, USA*

Pore fluids are ubiquitous throughout the lithosphere and are commonly cited as the cause of slow-slip and complex modes of tectonic faulting. We investigate the role of fluids for slow-slip and the frictional stability transition and find that the mode of fault slip is mainly unaffected by pore pressures. We shear samples at effective normal stress (σ'_n) of 20 MPa and pore pressures Pp from 1 to 4 MPa. The lab fault zones are 3 mm thick and composed of quartz powder with median grain size of 10 µm. Fault permeability evolves from 10^{-17} to 10^{-19} m^2 over shear strains up to 26. Under these conditions, dilatancy strengthening is minimal. Slow slip may arise from dilatancy strengthening at higher fluid pressures but for the conditions of our experiments slip rate-dependent changes in the critical rate of frictional weakening are sufficient to explain slow-slip and the stability transition to dynamic rupture.

Data-Driven Dynamics on Thwaites Glacier, West Antarctica

Emily Schwans[1], Byron R. Parizek[1,2], Richard B. Alley[1], Sridhar Anandakrishnan [1], Mathieu Morlighem[3]

[1]Department of Geosciences, Pennsylvania State University, State College, PA, USA
[1]Department of Mathematics, Pennsylvania State University, Dubois, PA, USA
[1]Department of Earth Sciences, Dartmouth College, Hanover, NH, USA

Thwaites Glacier lies in an area of the West Antarctic Ice Sheet that is particularly sensitive to recent ocean warming. Increased sub-shelf melt has caused much of Thwaites' floating ice-shelf to disintegrate, leading to faster flow, thinning, and grounding-line retreat. Predictive models of Thwaites Glacier's catchment show how the future rate of this glacier's contribution to sea-level is dependent on poorly-constrained basal conditions, including the rate of sub-shelf melt and the underlying bed rheology. Seismic surveys show systematic along-flow variability in bed character beneath Thwaites—subglacial topographic ridges upstream of the modern grounding zone consist of hard and soft material on the upstream and downstream sides of these features, respectively. The impact that this lee/stoss pattern in bed rheology could have on future retreat rates is assessed using the Ice-sheet and Sea-Level System Model (ISSM). As Thwaites' grounding line retreats over subglacial ridges in response to ice-shelf melt, the glacier oscillates between retreat over more-nearly plastic prograde slopes to retreat over linear-viscous material on retrograde portions of the bed. This creates modeled behavior that falls outside of what is seen in endmember cases using homogenous rheology, adding further uncertainty to projections of sea-level contribution from this area of the ice-sheet. Additional data collection and assimilation should be used to guide models in order to more-confidently simulate short-term and long-term behavior in key regions of Antarctica that are susceptible to rapid retreat under future warming.

Simulating Seismo-Electric Signals for Water Exploration of Mars' Subsurface

Nolan Roth[1], Tieyuan Zhu[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*

The presence of near-surface liquid water on Mars is critical to furthering our understanding of current and past habitability. Theory on Martian groundwater ranges from simple deep aquifers to a complex subsurface system of interacting brine pools, hydrothermal fluids, and fracture conduits at depths of tens of kilometers. Traditional seismic or electromagnetic sounding techniques for water exploration via rovers or astronaut deployment cannot currently uniquely provide confirmation of liquid water. Instead, the coupled seismo-electric exploration technique can be used to offer an unambiguous detection of liquid water in the subsurface. The seismo-electric phenomenon requires micro-scale flow of pore water induced by seismic waves, thus the detection of such signals confirms the presence of liquid water. In this work, a full-waveform horizontal layer simulation was used to test the efficacy of passive and active seismo-electric sensing on Mars. In this first research stage, aquifer depth and source location were varied in a suite of simulations. Future work will vary water chemistry and aquifer thickness. Early results show seismo-electric signals unique to pure liquid water have magnitudes several orders smaller than would be detectable by currently deployed instruments on Mars.

Oral Session 2

Thursday 20th April
10:45 am – 11:45 am

10:45 am - 11:00 am
Charlotte Connop
Ph.D. student, 4th year, Post-Comps
Heat sources for high temperature-low pressure metamorphism: constraints from a petrochronological investigation of Trois Seigneurs Massif, French Pyrenees

11:00 am - 11:15 am
Junzhu Shen
Ph.D. student, 5th year, Post-Comps
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Xi
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Ph.D. student, 5th year, Post-Comps
Deep learning based microearthquake location prediction at Newberry EGS using physics-informed dataset

11:30 am - 11:45 am
Clay Wood
Ph.D. student, 6th year, Post-Comps
Multiphysics modeling of rough fracture deformation to constrain the connection between fracture stiffness, permeability, and acoustic transmission
(Virtual)

Heat sources for high temperature-low pressure metamorphism: constraints from a petrochronological investigation of Trois Seigneurs Massif, French Pyrenees

Charlotte H. Connop[1], Andrew J. Smye[1], A.J, Josh M. Garber[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*

High-temperature–low-pressure (HT-LP) metamorphic terranes preserve a record of partial melting in the shallow crust (<20 km depth). The thermal budget of such metamorphism cannot be explained by conductive relaxation of thickened crust, instead requiring the advective addition of heat to overcome the cooling effect of the Earth's surface. Here, we present results from a systematic monazite and zircon petrochronological investigation of a classic, regional HT-LP terrane: the Variscan-aged Trois Seigneurs Massif, French Pyrenees.

The massif comprises a progressive metamorphic sequence from chlorite-bearing phyllites to sillimanite-bearing migmatites, culminating in an S-type granitoid body that occupies over one-third of the massif's area. Monazite from five metapelitic samples spanning all structural levels constrain the duration of peak metamorphism to 310-295 Ma, which overlaps zircon U-Pb dates obtained from the S-type granitoid (305.1 ± 1.9 Ma). These dates at the Trois Seigneurs massif overlap with published dates for HT-LP metamorphism and granitoid emplacement across the Variscan Pyrenees. Phase equilibrium modelling refines established pressure-temperature (PT) conditions of melting and granite formation to 4-6 kbar and >685 °C. Combining these PT estimates with those derived from proximal Variscan Pyrenean massifs defines a composite geotherm with elevated dT/dz through the shallow crust (>50 °C/km, < 12 km) and near-isothermal conditions through the mid-crust (12-25 km).

A simple thermal model is used to show that this "dog-legged" geotherm can be attained in <10 Myr by advection of magmatic heat from the lower to the shallow crust. For such a mechanism to operate on orogenic length scales, however, requires a critical combination of: i) a fertile lithologies in the lower crust, ii) attenuated mantle lithosphere during the waning stages of orogenesis, and iii) focusing of melt through the crustal column. We speculate that melt-driven HT-LP metamorphism should be present in other orogenic belts where these conditions are met.

Machine learning on DAS data has potential to help urban flooding monitoring

Junzhu Shen[1], Tieyuan Zhu[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*

Climate change and decreased urban catchments have led to problems that large volumes of stormwater from extreme rainy events exceed the drainage capacity. Therefore, flooding monitoring and warning are essential to protect human life and property. To achieve this goal in urban areas, fine spatial scale data coverage is required. Distributed acoustic sensing (DAS) could provide high spatiotemporal resolution seismic data in cities. Moreover, DAS-equipped telecommunication fiber in the conduit has potential to record noise generated by the stormwater runoff flowing into/in the nearby drainage pipes. Effective and accurate detection of such signals could benefit the real-time monitoring of flooding. However, it is challenging to identify particular signals from strong anthropogenic noise in the massive DAS dataset.

In this study, we use an unsupervised machine learning approach to detect rain-induced signals in urban areas based on their seismic signatures. We use continuous recordings from the DAS array deployed beneath the Penn State campus between June and September of 2021. A deep embedded clustering (DEC) model is trained to automatically learn feature representations from continuous DAS recordings and identify rain-induced noise by clustering them into different classes. We show that our predictions could help understand the relationship between rainfall intensity and accumulating surface runoff, which is essential to urban drainage system design. The combination of DAS dense acquisition and machine learning detectors provides significant advantages for real-time flooding monitoring in urban areas. Looking forward, this approach can be generalized in detecting various seismic signals and give inspiration to other urban environmental monitoring.

Deep learning based microearthquake location prediction at Newberry EGS using physics-informed dataset

Zi Xian Leong[1], Tieyuan Zhu[1,2], Chris Marone[1]

[1]*Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
[2]*EMS Energy Institute, The Pennsylvania State University, University Park, PA, USA*
[3]*Dipartimento di Scienze della Terra, La Sapienza Università di Roma*

Enhanced geothermal systems (EGS) is a promising technology to generate clean power by extracting heat energy from injection and extraction of water in geothermal reservoirs. The process of stimulation involves hydroshearing which reactivates pre-existing cracks and triggers microearthquakes (MEQs) in the subsurface. Locating these earthquakes provide reliable constraints on the progress of stimulation and guiding optimum production of the reservoir. However, the inversion problem of MEQ location presents a significant challenge due to its highly nonlinear nature. Additionally, accurate physics-based earthquake location solvers demand substantial computational resources, rendering them potentially unsuitable for real-time monitoring during stimulation. Besides, current deep learning methods for estimating earthquake locations require large datasets for training, which is problematic since the available dataset for MEQ events is often limited. We propose a novel convolutional neural network (CNN) based method that utilizes physics-informed dataset to estimate MEQ locations directly from first arriving waveforms. By using a 3D velocity model of Newberry site that is derived from ambient noise interferometry, we generate synthetic MEQs and 3D acoustic waveforms for CNN training. The high accuracy on testing and validation dataset suggests good neural network convergence, and we expect the trained CNN model to perform well on the Newberry field data.

Multiphysics modeling of rough fracture deformation to constrain the connection between fracture stiffness, permeability, and acoustic transmission

Clay Wood[1], Chun-Yu Ke[2], Andy Rathbun[3], Jacques Rivière[2], Derek Elsworth[1,4], Chris Marone[1,5], Paris's Shokouhi[2]

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[2]Deptartment of Engineering Science and Mechanics, Pennsylvania State University, State College, PA, USA
[3]Chevron ETC
[4]Department of Energy and Mineral Engineering, EMS Energy Institute, and G3 Center, Pennsylvania State University, State College, PA, USA
[5]Dipartimento di Scienze della Terra, La Sapienza Università di Roma, Rome, Italy

The focus of this study is to elucidate the relation between elastodynamic and hydraulic properties of fractured rock subjected to local stress perturbations in relation to fracture aperture distribution. The goal of our integrated numerical and experimental investigations is to understand the mechanisms responsible for changes in fault zone permeability and elasticity in response to dynamic stressing in the subsurface (anthropogenic or seismic in origin). High-resolution (micron-scale) optical profilometry measurements combined with pressure sensitive films have been used to characterize fracture properties such as 'true' contact area, aperture distribution and morphology, as well as asperity deformation under applied loads in our experiments. These measurements allow a direct correlation between fracture properties and our lab measurements of fracture elastic nonlinearity and permeability. Using micron-resolution profilometry of centimeter-scale samples, we calculate the elastic deformation of fracture asperities to varying applied stresses (static and dynamic) using Hertzian contact mechanics. Then, permeability is calculated for each applied stress (deformed asperities) using the parallel plate approximation, in which the Reynolds equation is solved using the finite difference method. Wave propagation properties such as transmission coefficient and phase delay are derived from the effective contact stiffness of the digital fracture interface. We aim to resolve the link between nonlinear elastic properties and hydraulic properties of fracture rock with direct comparisons between experiment and numerical studies.

Poster Session 3

Thursday 20th April
1:00 pm – 2:45 pm

Visit 240 Deike for GEOSC 497 *Data Visualization for Scientists & Engineers* poster session.

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Adam Stone
Ph.D. student, 2nd year, Pre-Comps
Phosphorus Release Through Low-Temperature Hydrothermal Alteration on Waterworld Exoplanets

Aristle Monteiro
Ph.D. student, 1st year, Pre-Comps
Constraining Cooling Rates and Emplacement Histories of Lava Flows Using Crystal Size Distributions: Implications for Emplacement of Continental Flood Basalt (CFB) lavas

Caleb Norville
Ph.D. student, 1st year, Pre-Comps
Afroalpine Vegetational Change in the Rwenzori Mountains: a New 13.3ka Pollen Record from Lake Africa

Jackson Saftner
Ph.D. student, 1st year, Pre-Comps
Constraining 3D Geometry of Induced Fractures Networks using Time-Lapse Seismic Profiles

Kate Meyers
Master's student, 2nd year
Wastewater Remediation via Phosphorus-Carbonate Interactions in Coastal Effluent Injection Zones

Enock Bunyon
Master's student, 1st year
Using sensitivity analysis to identify drivers of environmental impacts in coupled human-natural systems.

Phosphorus Release Through Low-Temperature Hydrothermal Alteration on Waterworld Exoplanets

Adam Stone[1], Bradford Foley[1], Kimberly Lau[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*

On Earth, the ocean receives most of its phosphorus (P)—an essential ingredient to all known life—from subaerial dissolution of felsic rock, which delivers P via rivers. However, the reaction parameters of this process likely differ on waterworld (ocean-covered) exoplanets because the dissolution occurs entirely in subaqueous environments with P hosted in mafic rock. The hydrothermal alteration of seafloor basalt, which in the modern ocean is a sink of P, may instead be a source of P under anoxic conditions. We use waterworlds as case studies to address the question: *What are the parameters that control the release and subsequent stabilization in solution of P through seafloor weathering to sustain the development of life?* We use geochemical thermodynamic modeling to quantify the amount of P released into porewater as low-temperature seawater advects through oceanic crust. Preliminary results show that host rock lithology significantly affects the saturation state of apatite, which is a first-order control on how much P remains in solution. Our results advance constraints on waterworld ocean geochemistry and their potential habitability.

Constraining Cooling Rates and Emplacement Histories of Lava Flows Using Crystal Size Distributions: Implications for Emplacement of Continental Flood Basalt (CFB) lavas

Aristle Monteiro[1], Tushar Mittal[1], Raymond Duraiswami[2], Hardik Sanklecha[2]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*
[2]*Department of Geology, Savitribai Phule Pune University, Ganeshkhind, Pune, India*

Continental flood basalt (CFB) volcanism is the largest scale volcanism that occurs on Earth, with millions of cubic kilometers of lava being emplaced in a relatively short time span (~1 Ma). Individual eruptions can be hundreds of kilometers long and be active for decades. Such massive eruptions can have a significant impact on the paleoclimate. Yet, little is known about how these flows are emplaced. To understand their exact impact, it is important to understand how these provinces evolve over space and in time. In the present study, we aim to understand and compare the cooling and crystallization of basaltic lavas from CFBs with basalts erupted and emplaced in different settings using crystal size distributions (CSDs). Compared with other existing plagioclase CSD datasets, we find that the cooling rate of most CFB flows observed is much higher than expected for a purely insulated flow. Overall, we find that the emplacement and cooling of CFBs is a complex, multi-faceted process with a dominant role of (multi-stage) lava flow lobe inflation and local-scale topography in determining flow morphology and LIP flow emplacement.

Afroalpine Vegetational Change in the Rwenzori Mountains: a New 13.3ka Pollen Record from Lake Africa

Caleb Norville[1] , Sarah Ivory[2]

[1]Department of Geosciences, Pennsylvania State University, State College, PA, USA

Afroalpine ecosystems are ecologically unique areas found throughout the highlands of Africa in places above the tree line with consistently low temperatures. Higher temperatures and shifts in rainfall related to climate change may correlate with increased local incidence of wildfire, landslides, and flooding, imposing serious geohazards on local communities. As these geographically isolated Afroalpine ecosystems are expected to shrink due to climatic warming, effective conservation measures will require an understanding of how these plant communities have responded to past climatic changes as well as feedback associated with disturbance during previous warm intervals, such as Holocene Humid Period (8-6ka). In order to reconstruct these ancient landscapes, pollen analysis was conducted on a 13.3kyr sediment core from Lake Africa (3895 m elevation) in the Rwenzori Mountains of southwestern Uganda to reconstruct past local vegetation change and wildfire incidence. Preliminary palynological analysis indicates that vegetation composition around Lake Africa has remained relatively stable for at least the past 2 ka, with assemblages consistent with the modern vegetation. However, pollen samples from the early Holocene indicate a higher abundance of plant taxa associated with lower Afromontane forest zones, suggesting that the elevational ranges of these mountain ecosystems have shifted over the past 13 ka.

Constraining 3D Geometry of Induced Fractures Networks using Time-Lapse Seismic Profiles

Jackson Saftner[1], Xuejian Liu[1], Jonathan Ajo-Franklin[2], and Tieyuan Zhu[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*
[2]*Department of Earth, Environmental, and Planetary Sciences, Rice University, Houston, TX, USA*

Hydraulic fracturing is an important technique used to improve the permeability of the subsurface and facilitate fluid transport (e.g. for oil and gas recovery, remediation injection, carbon sequestration, and geothermal). To ensure the efficacy of hydraulic fracturing activities, emplaced fracture networks must be accurately characterized. This project aims to map the geometry and evolution of induced fractures using continuous active source seismic monitoring data (CASSM) collected during a shallow hydrofracturing experiment conducted at the FE Warren AF Base. We implement the correlative double-difference time-lapse full waveform inversion (CDD-TLFWI) workflow of Liu et al. (2023) with multi-level continuous active source seismic monitoring data (ML-CASSM) to produce two time-lapse seismic profiles that image changes in Vp associated with fracture emplacement and fluid injection. The results of differential Vp models provide key constraints of the emplaced fracture network and the radius of impact for an injected remediation amendment.

Wastewater Remediation via Phosphorus-Carbonate Interactions in Coastal Effluent Injection Zones

Kate Meyers[1], Lee Kump[1], Sam Webb[2], Jocelyn Richardson[2], Ted Present[3], Megan Martin[1], Miquela Ingalls[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*
[2]*SLAC National Accelerator Laboratory, Menlo Park, CA, USA*
[3]*California Institute of Technology, Pasadena, CA, USA*

The nearshore, oligotrophic waters of the Florida Keys National Marine Sanctuary (FKNMS) are sensitive to fluctuations of phosphate, a limiting nutrient in the Florida Bay. Shallow, 27-meter injection wells are the primary method for disposing treated wastewater effluent in the FKNMS. This remediation method relies on the rapid adsorption of phosphate onto the carbonate mineral surfaces of the Key Largo Limestone (KLL) before the effluent emerges into nearshore waters. However, laboratory studies have demonstrated there are potential drawbacks to this mode of remediation, including limits to phosphate adsorption in the bedrock or desorption from seawater incursions.

We assessed the uptake capacity and permanence of wastewater-derived phosphate onto KLL (1) in the field at the Area 3 Wastewater Facility in Marathon, Florida, (2) with geochemical modeling, and (3) in a laboratory flow-through experiment. In Marathon, we tracked the migration and chemical evolution of the effluent plume following injection by analyzing concentrations of total and soluble reactive phosphate and sucralose, a conservative pharmaceutical tracer found in wastewater, over two years. Geochemical data (i.e. pH, salinity, [DIC], [PO4], alkalinity, etc.) collected from nested monitoring wells were used in PHREEQC (USGS) to model the thermodynamic feasibility of mineralization of phosphorus-containing carbonate minerals forming in the wastewater pathway. Finally, we tested the behavior, reaction kinetics, and mineralogy of phosphate uptake via flow-through experiments on KLL cores using wastewater standards and phosphate-spiked seawater.

Phosphate phases in experimental cores and cores recovered from Marathon were investigated via X-ray Absorption Near Edge structure spectroscopy, X-ray Fluorescence, and Raman spectroscopy to determine the mode of phosphorus incorporation into carbonate minerals. These spectroscopic studies will be essential for understanding carbonate's role in coastal wastewater remediation in addition to determining the phases that preserve phosphate-carbonate interactions in the rock record.

Using sensitivity analysis to identify drivers of environmental impacts in coupled human-natural systems.

Enock Bunyon[1], Antonia Hajimichael[1]

[1]Department of Geosciences, Pennsylvania State University

Across the Great Lakes region (GLR), nutrient exports from agricultural lands pose a threat to water quality and ecological health through eutrophication, hypoxia, and harmful algal blooms. Accurately modeling and predicting hydrologic fluxes in GLR watersheds is therefore essential for stakeholders and policymakers to effectively manage water resources and nutrient loads. Hydrologic models have made great advances in how they represent watershed processes. They are becoming increasingly more complex because of rapid technological advancements and our growing understanding of the complexity of watersheds affected by human activity. As a result, to understand what is controlling hydrologic model performance, advanced tools like global sensitivity analysis (SA) have become necessary. This study applies SA methods to diagnose and calibrate a state-of-the-art hydrologic model: the Soil and Water Assessment Tool (SWAT) model developed by the United State Department of Agriculture. The model is applied on the Portage River watershed, a medium-sized watershed of the GLR that drains into Lake Erie. The Portage River watershed has been heavily modified by human activities such as filling or draining, clearing of upland forests, agricultural development, and urbanization. The intensification of the hydrologic cycle (e.g., more frequent high rainfall events) and how that interacts with the heavily modified land cover can have effects on the Portage River water balance and the GLR hydrology at large. The objectives of this study are to 1) perform a model diagnostic analysis using Sobol variance decomposition, a SA technique, to identify the key parameters driving error in the SWAT model, and 2) use this information to calibrate the SWAT model and improve its performance on key hydrologic fluxes. The outcomes of this work will enable us to model future nutrient loading in this watershed as a result of evolving human activities.

Oral Session 4

Thursday 20th April
3:00 pm – 4:00 pm

3:00 pm – 3:15 pm
Youki Sato
Ph.D. student, 3rd year, Pre-Comps
Revealing Interstellar Synthesis Pathways of Pyruvate via Position-Specific Isotope Analysis (PSIA) on the GC-Orbitrap MS

3:15 pm – 3:30 pm
Miranda Sturtz
Ph.D. student, 1st year, Pre-Comps
End Fates of Prebiotic Molecules on Early Earth: From Cycling Reactors to pre-RNA Molecules

3:30 pm – 3:45 pm
Juliana Drozd
Ph.D. student, 1st year, Pre-Comps
Position-Specific Isotopic Analysis of $\delta^{13}C$ in Modern and Geostable Triterpenoid Lipids

3:45 pm – 4:00 pm
Emma Hartke
Ph.D. student, 1st year, Pre-Comps
Reconstructing Adriatic paleoclimate across the Late Quaternary: A paired clumped carbonate isotope (Δ_{47}) and GDGT (TEX_{86}) proxy investigation

Revealing Interstellar Synthesis Pathways of Pyruvate via Position-Specific Isotope Analysis (PSIA) on the GC-Orbitrap MS

Youki J. Sato[1], Katherine H. Freeman[1]

[1]*Department of Geosciences, Pennsylvania State University, University Park, PA, USA*

The distribution of carbon isotopes (i.e., $^{13}C/^{12}C$) within a given molecule reflects the carbon sources and the biological, chemical, and/or physical processes involved in its synthesis. New methods have opened access to position-specific isotope analyses (PSIA), although doing so often requires method development steps that are unique for different classes of target compounds, as can be illustrated in this study of pyruvic acid. Intramolecular isotope patterns are likely to differ significantly between pyruvate synthesized biologically and presumably abiotic pyruvate carried by carbonaceous and chondritic meteorites.

Organics synthesized in space are thought to draw from two different carbon pools corresponding to the following equilibrium reaction: $12CO + 13C^{+} \rightleftharpoons 13CO + 12C^{+}$ (Charnley *et al*., 2004). The forward reaction is greatly favored at the low ambient temperatures of the interstellar medium (ISM), leading to a large ^{13}C enrichment in the CO pool and a lightly depleted C^{+} pool. The isotopic signature is further fractionated during the formation of a solar nebula due to CO self-shielding, which leads to effectively reversing the trend (with the solar CO pool depleted and an enriched C^{+} pool; Broadley *et al*., 2022). Carbon atoms in a molecule may draw from different carbon pools, and past techniques that measure the molecular average $\delta^{13}C$ of organics extracted from interstellar samples hides this potential intramolecular heterogeneity in carbon isotopes.

Measuring the position-specific $\delta^{13}C$ of organics extracted from meteorite samples has the potential to reveal the abiotic synthesis pathways involved in its synthesis and the carbon pools that were drawn upon. Therefore, my upcoming work will use the GC Orbitrap-MS to measure the intramolecular $\delta^{13}C$ of pyruvic acid extracted from meteorites to try to identify the abiotic synthesis pathways and the likely carbon pools that were involved.

End Fates of Prebiotic Molecules on Early Earth: From Cycling Reactors to pre-RNA Molecules

Miranda Sturtz[1]

[1]Department of Geosciences, Pennsylvania State University, University Park, PA, USA

While products formed in reducing early Earth hydrothermal systems have been well studied, their long-term fates and degradation products are lesser known. There may be the potential for prebiotic reactors that cycle through products and supply degraded compounds to new reactions. Research is required into these determination of these fates and characterization of prebiotic molecular degradation routes in early Earth hydrothermal systems. This work examines common prebiotic molecules including sugars, nitriles/HCN polymers, heterocyclic rings, and amino acids as well as their implications for long term products that could be the basis or other prebiotic organic molecules, or to strike down previously imagined pathways if degradation times are too short to allow for concentration of products. In addition, catalytic reduction reactions are of interest due to the competition they would have to face with the main hydrolysis reactions. When combined with the HCN trimer (aminomalononitrile), reduction at ocean water cycling through hydrothermal systems in mafic and ultramafic systems may lead to a backbone basis for a pre-RNA molecule. Based upon analogous chemistry, aminomalononitrile should catalytically reduce to serinol, a three-carbon molecule (2-amino-1,3-propanediol), as an alternative to ribose in an early genetic molecule. In turn, this serinol may phosphorylate and polymerize into serinol-imine nucleic acid (SINA) for a pre-RNA structure. A serinol-based genetic molecule could also be an attractive intermediate step between the previously proposed peptide nucleic acid (PNA) and ribonucleic acid (RNA) during the evolution into today's modern life.

Position-Specific Isotopic Analysis of $\delta^{13}C$ in Modern and Geostable Triterpenoid Lipids

Juliana Drozd[1], Christopher House[1], Katherine Freeman[1]

[1]*Department of Geosciences, Pennsylvania State University, University Park, PA, USA*

The structures of molecular fossils, or biomarkers, and isotopic signals left by life uniquely give insight into the biogeochemical and metabolic processes that formed them. This information can be encoded by isotope patterns within molecules, and new analytical methods, collectively termed position-specific isotope analysis (PSIA), allow us to track these patterns for the first time. PSIA has not been developed for application to the geological triterpenoid lipid biomarker record yet. Triterpenoid lipid biomarkers, like the steranes and hopanes that act as chemotaxonomic markers in the rock record, are already utilized in studies seeking to characterize ancient organisms and ecosystems. New PSIA techniques involving an Orbitrap-based mass spectrometer allow for PSIA to be done at geologically relevant concentrations but have not been applied to molecules as complex as triterpenoids. I propose to expand PSIA methods for geostable triterpenoid lipids, focusing on developing an analytical and interpretation scheme for analysing the isotopic patterns within triterpenoid biomarkers and their precursor lipids. The development of a framework and methodology for applying PSIA to the triterpenoid biomarker record will allow for new information on the specific biochemical pathways used by an organism to synthesize biomarker precursor lipids to be gained from the sparse record we have of microbial life. This information will provide new insights into ancient metabolisms, possibly allowing us to study the evolution of metabolism from the rock record itself.

Reconstructing Adriatic paleoclimate across the Late Quaternary: A paired clumped carbonate isotope (Δ_{47}) and GDGT (TEX_{86}) proxy investigation

Emma Hartke[1], Katherine Freeman[1]

[1]Department of Geosciences, Pennsylvania State University, University Park, PA, USA

Quaternary (2.58 Ma–present) geochemical records from Europe and Africa often demonstrate contradictory trends in temperature and hydrology when compared to records from the Mediterranean. Moreover, geochemical data obtained from the eastern and western Mediterranean reveal distinct paleoclimate histories. Thus, multiple climate records from regions with a single Köppen classification are necessary for distinguishing climate patterns across spatial scales and essential for isolating climate parameters to forecast future climate trends.

This new study aims to reconstruct climate for the Adriatic region, a limited and climatically "homogenous" space that straddles the boundary between the eastern and western Mediterranean. This work will apply two well-known temperature proxies (Δ_{47} from clumped carbonate isotopes and TEX_{86} from glycerol dialkyl glycerol tetraethers, or GDGTs) to multiple archives along the Dalmatia Coast, the eastern border of the Adriatic. Paleotemperature data will supplement existing hydrological data in attempt to create a comprehensive picture of climate change in this region across the Late Quaternary (44 kyrs BP–present).

By the end of this project, we hope to assess three hypotheses related to the coincidence of Adriatic climate oscillations with those across the Mediterranean, Europe, and Africa: (1) temperatures from proxy reconstructions (Δ_{47} and TEX_{86}) should decrease synchronously with temperature records from surrounding regions during periods of global glaciation and ice-rafting events (Last Glacial Maximum, 22 kyrs BP; Heinrich Events, 38, 31, 24, and 16.8 kyrs BP; and Younger Dryas, 11 kyrs BP), (2) temperatures should increase asynchronously during periods of high regional sedimentation (S1 sapropel deposition, 10–6 kyrs BP), and (3) warmer climates will co-occur with arid conditions, while cooler climates will co-occur with humid conditions, based on current combined temperature–hydrology reconstructions for the entire Mediterranean. Addressing these points will help us improve our understanding of Adriatic temperature and hydrology in a rapidly warming climate.

Friday 21st April

Oral Session 5

Friday 21st April
9:00 am – 10:15 am

9:00 am – 9:15 am
Opening Remarks

9:15 am – 9:30 am
Kaitlyn Horisk
PhD student, 4th year, Post-Comps
Hydroclimate variability across the late Holocene in Dhofar, Oman, and its implications for vegetation change in arid ecosystems

9:30 am – 9:45 am
Adam Benfield
PhD student, 4th year, Post-Comps
The Assembly of Indonesian Rainforests during the last two Glacial Terminations

9:45 am – 10:00 am
Sam Shaheen
PhD student, 4th year, Post-Comps
Biogeochemical aquifer changes driven by methane migration from abandoned oil and gas wells

10:00 am – 10:15 am
Tsai-Wei Chen
PhD student, 5th year, Post-Comps
Frictional Properties and Healing Behavior of Tectonic Mélanges:
the Role of Pressure Solution in Subduction Fault Zones

Hydroclimate variability across the late Holocene in Dhofar, Oman, and its implications for vegetation change in arid ecosystems

Kaitlyn Horisk[1], Sarah J. Ivory[1,2], Kate Freeman[1], Allison Baczynski[1,3], Joy McCorriston[4]

[1]Penn State University Department of Geosciences
[2]Penn State University Earth and Environmental Systems Institute
[3]Penn State Laboratory for Isotopes and Metals in the Environment
[4]Ohio State University Department of Anthropology

Dryland ecosystems are especially sensitive to changes in climate, where small changes in precipitation can cause degradation of the vegetation. Over 1/3 of the Earth's population relies on these ecosystems for food and water resources; however, modern observations are insufficiently brief to constrain how hydrological mechanisms influence plant communities. Here, I use rock hyrax middens as a paleoecological archive in the arid, biodiverse region of Dhofar, Oman. This study uses stable isotopes of nitrogen and leaf wax biomarkers to constrain local hydrological changes over the late Holocene. Stable $\delta^{15}N$ values measured on fecal pellets demonstrate changes in soil moisture through time. *N*-alkanes (a component of leaf waxes) were extracted from the hyraceum (crystallized urinary product) of the middens, from which compound specific δD analysis can be conducted. δD_{wax} values reflect values in meteoric water and are a useful proxy for changes in paleoprecipitation. These complementary signals, in tandem with a previously established pollen record, can be used to develop a more complete picture of hydrologic change and vegetation response. The samples for this project include 22 fossil midden samples, which have ages that span the last 4,000 years, and a network of modern samples from Dhofar. The modern samples in these locations will constrain geographic variability in δD_{wax} between the coast and inland. δD_{wax} analyses will also be conducted on modern herbarium specimens of plants collected in Dhofar to assess taxonomic variability and model a biological fractionation factor for this region. $\delta^{15}N$ results suggest a transition to hyperaridity across this time frame. Preliminary δD_{wax} will be discussed in the context of meteoric water sources and hydrological processes, as well as taxonomic turnover in the pollen record.

The Assembly of Indonesian Rainforests during the last two Glacial Terminations

Adam J. Benfield[1] and Sarah J. Ivory[1]

[1]*Department of Geosciences, Pennsylvania State University, State College, PA, USA*

The rainforests of Sulawesi are hyper diverse yet under multiple anthropogenic threats from land clearance, rising temperatures, and increasing seasonality of precipitation. Located within the Indo-Pacific Warm Pool, Sulawesi is the largest island within Wallacea, where everwet rainforests contain a mixture of plant lineages with high regional endemism. Terrestrial paleoecological records, which can help document historical forest composition and long-term ecological interactions, are limited. On Sulawesi, records of the last glacial termination (~20-12 ka) are rare and discontinuous, and the penultimate glacial termination (~140-130 ka) is not documented at all. However, the Towuti Drilling Project recently obtained a nearly continuous, million-year drill core record from Lake Towuti, a tectonically-formed in eastern Sulawesi. Multi-millennial scale pollen and microcharcoal analysis shows major changes in vegetation composition and fire regimes were largely paced by the rhythm of glacial-interglacial transitions over 600,000 years. However, the timing and character of vegetation turnover on centennial timescales in response to rapid climate changes during deglacial warming remains obscure. Here, we present preliminary results of centennial-scale pollen and microcharcoal analysis of the last two glacial terminations from the Lake Towuti. Preliminary results show rainforest composition differed substantially during the last two glacial terminations and interglacial periods. The most substantial differences between the two terminations were in the abundance of montane gymnosperms (i.e. Agathis, Phyllocladus) and Dipterocarpaceae pollen taxa indicating differing boundary conditions of the glacial terminations produced substantial differences in stand dominance. Fire regimes also changed dramatically during the deglaciation, including a change of the major fuel source changes on the landscape. Finally, we examine the role of precipitation seasonality and maximum temperatures on forest composition across deglaciations using species distribution models of exemplar taxa. Taken together, preliminary findings show complex ecological interactions resulted in unique rainforest composition in response to glacial-interglacial climate change during different transitions.

Biogeochemical aquifer changes driven by methane migration from abandoned oil and gas wells

Sam Shaheen[1], Tao Wen[2], Max Lloyd[1], Chris House[1], Eric Roden[3], Susan Brantley[1]

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Historical oil and gas extraction has left a high density of poorly maintained, orphaned, or abandoned wells in many hydrocarbon-bearing basins across the world. Aging and abandoned wells are a well-established source of methane (CH_4) emissions to the atmosphere, particularly in regions such as the Appalachian Basin where extraction dates back two centuries, but less is understood about their impacts to water resources. In this study, we investigated the impacts of abandoned oil and gas wells on aquifer biogeochemistry using field, lab, and modeling-based observations.

Our field sampling campaign identified groundwaters in Pennsylvania where dissolved gas compositions suggest CH_4 migration from oil and gas activities. In these waters, we measured elevated concentrations of redox-active species potentially indicative of anaerobic oxidation of CH_4 (AOM), a microbially-mediated reaction often coupled with iron and sulfate reduction. To understand the controls on CH_4 cycling, we compared results from two types of hydrologic settings: artesian groundwater flow directly from abandoned wellbores vs. groundwater seepages where CH_4 leaked from oil and gas wells migrates through shallow aquifers. 16S rRNA gene sequencing supports the presence of microbial communities involved in AOM and methanogenesis at both types of sites. Additionally, microcosm experiments indicate active AOM in groundwater incubations amended with goethite and/or sulfate. Based on these measurements, we constructed reactive transport models to investigate the significance of electron acceptor availability along CH_4 migration pathways. Our results indicate that transport along more direct pathways (e.g., abandoned wellbores) vs. diffuse transport within an aquifer influences the impacts of CH_4 leakage on groundwater chemistry due to varying availability of electron acceptors for AOM. Microbially-mediated redox reactions that consume CH_4 can mobilize hazardous aqueous species (e.g., arsenic), emphasizing the potential water quality risks associated with structurally deficient oil and gas wells.

Frictional Properties and Healing Behavior of Tectonic Mélanges: the Role of Pressure Solution in Subduction Fault Zones

Tsai-Wei Chen[1], Raphael Affinito[1], Chris Marone[1,2], Donald Fisher[1], Yoshitaka Hashimoto[3]

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[3]*Department of Applied Science, Faculty of Science, Kochi University, Kochi, Japan*

The frictional velocity dependence and healing behavior of subduction fault zones play key roles in the nucleation of stick-slip instabilities at convergent margins. The diagenetic to low-grade metamorphic processes such as pressure solution are proposed to be responsible for the change in frictional properties along plate interfaces. The processes of pressure solution also likely contribute to the acceleration of healing according to previous studies. Here, we first report on velocity-step experiments using rocks collected from ancient subduction fault zones, the Lower Mugi and Makimine mélanges of the Cretaceous Shimanto belt. The two units preserve paleotemperature records corresponding to the updip and downdip limits of the seismogenic zone. Our experimental data indicate that the Lower Mugi mélange sample exhibits velocity-weakening behavior under low normal stress and the Makimine mélange sample exhibits velocity-strengthening behavior under high normal stress. This is consistent with the slip behavior observed at the corresponding depths of active margins. The abundant framework silicates in the Makimine mélange sample resulting from the diffusive mass transfer process suggest that pressure solution has the potential to alter the frictional properties of plate boundary fault materials. We also perform a series of slide-hold-slide experiments under different hydrothermal conditions using the Lower Mugi mélange sample to evaluate the role of pressure solution in fault healing and its dependency on temperature. Our results show an acceleration of healing at elevated temperatures. This likely results from pressure solution, supported by the microstructural evidence found in postexperimental gouges. The low activation energy of pressure solution we calculate for the phyllosilicate-rich mélange material suggests the prevalence of pressure solution in subduction fault zones. The accelerative healing due to the temperature dependence of pressure solution can be another cause of the change in seismic behavior along plate interfaces.

Session 6: Oral Session

Friday 21st April
10:30 am – 11:15 am

10:30 am – 10:45 am
Paul Volante
Masters student, 2nd year
Intramolecular $^{13}C/^{12}C$ analysis of phytane from the mid-Cretaceous DSDP Site 398 via GC-Orbitrap-MS

10:45 am – 11:00 am
David Early
Masters student, 2nd year
Detecting rates of vegetation change in Africa from the Pleistocene-Holocene transition to the present

11:00 am – 11:15 am
Alejandro Giraldo Ceron
Masters student, 2nd year
Insect feeding traces in Eucalyptus fossils indicate unknown evolutionary history in Australia's iconic gum trees

Intramolecular $^{13}C/^{12}C$ analysis of phytane from the mid-Cretaceous DSDP Site 398 via GC-Orbitrap-MS

Paul Volante[1], Caitlyn Witkowski[2], Youki Sato[1], Hao Xie[1], Heike Betz[1], Allison Baczynski[1], Kate Freeman[1], Max Lloyd[1]

[1]Department of Geosciences, Pennsylvania State University, University Park, PA, USA
[2]University of Bristol, Bristol, United Kingdom

The high mass resolving power of Orbitrap mass spectrometry separates isotopologue ion fragments of organic biomarkers and enables isotope ratio analyses at precisions needed for natural abundance applications. We have developed a means for extending a gaussian-shaped, conventional GC peak (on the order of seconds) to 5 to 10 minutes in duration with a steady amplitude. Our "peak trapper" affords longer analyses and enhances analytical accuracy and precision. A trapped sample compound remains in the gas phase so it can diffuse to yield a flat amplitude profile; this diffusion step also reduces potential errors introduced by fractionation during chromatography.
We report $^{13}C/^{12}C$ values of phytane extracted from marine sediments mid-Cretaceous in age from the Cenomanian-Turonian oceanic anoxic event (OAE 2) from the DSDP Site 398 sample collection. Our approach is to compare the $^{13}C/^{12}C$ values for the 57, 71, and 85 m/z mass fragments of phytane to interrogate differences in position specific carbon isotope values that arise from the different lipid synthesis pathways used by prokaryotes (MEP), archaea (MVA), and eukaryotes (combination of the two). Thus far, relative standard error in per mil (RSE ‰) for a 10, 25, 50, and 100 ng/µL phytane standard range from 2.91 to 1.52 and 2.35 to 1.29 for the 57 and 71 m/z fragments respectively.
This automated GC-Orbitrap-MS technique is intended to enhance our understanding of intramolecular $\delta^{13}C$ values of lipid biomarkers such as phytane. During periods of severe changes in ocean chemistry, such as OAE-2, the relative contributions of phytane from bacteria, archaea, and eukaryotes could be altered. It may be possible to study these changes in biological origin of phytane through this technique. If this is the case, the analysis of position specific carbon isotope values of phytane could reduce uncertainty in pCO_2 reconstructions from $\delta^{13}C_{phytane}$ values and may supplement other climate proxies that rely on isoprenoid lipids.

Detecting rates of vegetation change in Africa from the Pleistocene-Holocene transition to the present

David Early[1], Sarah Ivory[1], Ondřej Mottl[2], Suzette G.A. Flantua[2], John Williams[3], Nicholas McKay[4], Anne-Marie Lezine[5]

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[2]*Department of Biological Sciences and Bjerknes Centre for Climate Research, University of Bergen, Berken, Norway*
[3]*Department of Geography, University of Wisconsin-Madison*, Madison, WI, USA
[4]*School of Earth and Sustainability, Northern Arizona University, Flagstaff, AZ, USA*
[5]*Centre national de la recherche scientifique, Paris, France*

Detecting the timing and rate of past vegetation changes and linking these to climate change and/or human impacts is essential to understand the degree of turnover observed in modern ecosystems. Recent studies assessing global rate-of-change in Holocene plant assemblages suggest that rapid ecosystem turnover can occur on human timescales and are evident in data-dense regions. However, insufficient spatial coverage left the tropics underrepresented in past analyses. Tropical ecosystems are considered biodiversity hotspots, with the African tropics containing highly endemic, charismatic, and endangered organisms. Understanding how these ecosystems have changed in the past is imperative for preserving their future. Here, we present an unprecedented continental and regional rate-of-change analysis for Africa during the last 20 kyr using a new compilation of pollen datasets as a part of the recent relaunch of the African Pollen Database (constituent database of the Neotoma Paleoecology Database). Datasets were standardized, processed, and assembled using a novel R-package - *FOSSILPOL* - that allows users to filter and select data, construct age models, and harmonize taxon names within a reproducible workflow. Regional and local rate-of-change calculations, along with their peak points, were calculated from multivariate paleoecological data using the *R-Ratepol* R-package. Preliminary results indicate elevated rates of turnover between 20 and 12 ka, potentially corresponding with the abrupt climate change facilitated by Northern Hemisphere deglaciation at the end of the Pleistocene. The rate of turnover remains consistent until elevating again around 4 ka to the present. Future studies may use these results to help attribute a causal relationship between elevated rates of turnover and changes in climate or human land use.

Insect feeding traces in Eucalyptus fossils indicate unknown evolutionary history in Australia's iconic gum trees

Alejandro L.Giraldo[1], Peter Wilf[1], Michael P. Donovan[2], Maria A. Gandolfo[3]

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The Laguna del Hunco (LH; 52.2 Ma) locality, in Argentinean Patagonia, has yielded diverse floras with multiple plant lineages that today survive in rainforests of the West Pacific, highlighting former Gondwanan connections between South America, Antarctica, and Australia. However, whether the ancient insect herbivore assemblages tracked survivor plant taxa through time —a major question in biogeography— has only been tested in Agathis (Araucariaceae) fossils from the early Cenozoic of Patagonia (including LH), where similar suites of insect damage in fossil and extant specimens suggested plant-host tracking. Here, we describe the abundant and diverse insect herbivore damage found in ca. 250 Eucalyptus leaves from LH — the oldest macrofossil evidence of the genus — and compare it with modern Eucalyptus herbarium specimens to test for the persistence of insect herbivore assemblages. Thirty-six rainforest-associated living Eucalyptus species were selected for comparison, given that LH is interpreted as a vegetational mosaic wherein Eucalyptus dominated volcanically disturbed areas alongside rainforests. After reviewing more than 10000 physical and digitized herbarium specimens, we found 29 damage types, 14 corresponding to external feeding, five to galling, and ten to mining; each damage trace has been recognized in extant Eucalyptus specimens. The nearly identical suites of insect herbivore damage found in fossil and modern Eucalyptus suggest that insect herbivore assemblages have tracked Eucalyptus through time and space, although some of the similarity could result from convergence in damage type morphology, particularly for external feeding. However, the modern insect culprits for the damage remain largely unknown, indicating unknown evolutionary history in Australia's iconic Eucalyptus.

Session 7: Poster Session

Friday 21st April
1:00 pm – 2:15 pm

Gabriel Rocha dos Santos
PhD Student, 2nd Year, Pre-Comps
Study of Sea Ice Dynamics Using Cryoseismic Events and Distributed Acoustic Sensing in Utqiaġvik, Alaska

Edward J. Spagnuolo
PhD Student, 1st Year, Pre-Comps
Giant seeds of an extant Australasian legume lineage discovered in Eocene Borneo

Claire Hines
Masters Student, 1st Year
Fate and Transport of Suspended Sediment in Arctic Deltas

Ella Do
Masters Student, 1st Year
Boron loss and isotopic fractionation as a result of sediment dehydration during subduction from seafloor to sub-arc in SW Japan

Fran Meyer
PhD Student, 1st Year, Pre-Comps
Characterizing uranium speciation in marine phosphorites to advance the paleo-redox proxy

Rory Changleng
PhD Student, 1st Year, Pre-Comps
A trans-lithospheric view of Archaean continent building from detrital diamonds and Eoarchaean terranes, Slave Craton, NW Canada

Em White
PhD Student, 1st Year, Pre-Comps
Continental crust evolution during the Archean using isotope geochemistry of zircons from granites/granitoids from the Slave Craton, Northwest Territories (Canada)

Yusuke Kabota
Ph.D. student, 1st year, Pre-Comps
Investigating the formation of Hadean crust with constraints on Hf Isotopes: A 1-D numerical simulation approach

Ran He
Ph.D. student, 2nd year, Pre-Comps
Assessment of deep burial to modern meteoric diagenesis of siderite: Core-outcrop comparison from the Paleocene Fort Union Formation in Wind River Basin, Wyoming

Study of Sea Ice Dynamics Using Cryoseismic Events and Distributed Acoustic Sensing in Utqiaġvik, Alaska

Gabriel Rocha Dos Santos[1], Rafal Czarny[1], Nolan Roth[1], Tieyuan Zhu[1], Ahmad Tourei[3,4], Eileen R. Martin[4], Xiaohang Ji[2], Min Liew[2], Anne Jensen[5], Dmitry Nicolsky[6], Ming Xiao[2]

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[5]*Department of Anthropology, University of Alaska Fairbanks, AK, USA*
[6]*Geophysical Institute, University of Alaska Fairbanks, AK, USA*

Arctic sea ice is constantly moving. The sea ice grows and expands in winter, and melts and contracts in summer. Each winter, the remaining unmelted ice grows thicker as new ice forms. In the last decades, less multi-year ice and more ice melt during the summer have been seen due to climate change, therefore altering the sea ice equilibrium. The so-called icequakes, tremors caused by the ice movement, allow us to study the sea ice dynamics. Strong cryoseismic events are indicative of ice motion and deformation and may offer insights into several parameters related to the ice formation on Arctic coasts. This information can be invaluable in regions where sea ice is a vital feature for the balance of the ecosystem, such as in Utqiaġvik, Alaska. The region is equipped with only one permanent seismometer station A21K that can detect icequake events. However, the results from A21K have great uncertainty because it lacks spatial information, i.e., moveout or phase travel times. Here we show that distributed acoustic sensing (DAS) can be used as a reliable and cost-effective tool to detect icequake events in harsh environments. In a month of DAS recording from a 2-km fiber optic cable installed in the Arctic tundra, we identify over four hundred strong local events using Template Match approach and compare them with the seismograms from the local seismometer A21K. These icequake events happened during the winter, and they are validated with indications of ice movement along the coast from a local radar. The events vary in duration from hundreds of milliseconds up to 30 seconds, but they are consistent in frequency between 1–10 Hz. We anticipate that further analysis of high frequency icequake events using DAS will uncover a reliable tool for assessing the ice dynamics in the changing Arctic environment.

Giant seeds of an extant Australasian legume lineage discovered in Eocene Borneo

Edward J. Spagnuolo[1], Peter Wilf[1], John-Paul Zonneveld[2], Aswan[3], Yan Rizal[3], Yahdi Zaim[3], Jonathan I. Bloch[4], Russell L. Ciochon[5]

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Borneo is among the most biodiverse islands on Earth, home to over 15,000 plant species. The rarity of plant macrofossils has limited knowledge of the evolution of the Malay Archipelago (Malesia) rainforests, which are severely threatened by human-driven deforestation and climate change. Here, we report a preliminary sample with the first fossil seeds and leaves from the Cenozoic of Indonesia collected in approximately a century. In 2014, 45 plant fossils were collected from the Tanjung Formation in the Wahana Baratama coal mine, South Kalimantan, Indonesia. The collection sites are late Eocene, based on foraminiferal index fossils. This small collection represents Bornean forests well before the late Oligocene onset of collision of the Australian plate (Sahul) into Southeast Asia (Sunda) and associated biotic interchange. Two isolated, large seed casts (length 72 mm) were discovered in the mine. The seeds are flattened on one side (mound-shaped), bilobed, and heart-shaped with a long hilum (approx. 60 mm) overlain on the suture. Although these seeds do not fully match any modern species, they most closely resemble *Castanospermum*, the blackbean tree, found almost entirely in coastal rainforests of northern Australia and nearby islands, and usually water dispersed. The only difference is that the fossils are about double the size of extant *Castanospermum,* probably representing a closely related but extinct taxon. The new seed species is the only known fossil relative of *Castanospermum* and suggests an Asian origin, a much later Sunda-Sahul migration, and eventual Asian extinction for the lineage. The leaves (42 fossils from lower in the section) represent 10 morphotypes, including some Fabaceae leaflets and many unidentifiable unlobed and untoothed leaves; one specimen preserves in situ cuticle. These seeds and leaves provide a window into Malesian rainforests in their nascency and provide rare macrofossil evidence of a living Australasian lineage originating in SE Asia.

Fate and Transport of Suspended Sediment in Arctic Deltas

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Fluxes of sediment, nutrients, and heat to the ocean control coastal geomorphology and biogeochemistry. Where rivers terminate in deltas, flux distribution and magnitudes along the coast are modified through several processes occurring within the delta. Understanding the dynamics of river fluxes in the Arctic is crucial to properly modeling the regional response to warming, especially given that river fluxes are expected to increase as the Arctic warms. The magnitude, timing, and extent of sediment fluxes to the Arctic coast are unknown, and the effects of deltas on these fluxes have not been considered. Thus, I will develop a novel model of suspended sediment transport in six deltas to estimate sediment storage in the delta and delivery to the coasts. A reduced-complexity model is being designed to transport sediment through a delta based on a computed channel network and rules for deposition and erosion. Channel networks, flow directions, and morphologic metrics were derived from channel masks of each delta using RivGraph. Discharge and suspended sediment are routed through the channel network using width-based partitioning and transport rules from previously tested routing schemes. Sediment retention and release in the channel and delta plain will be parameterized. The fluxes within the delta and from each delta outlet to the ocean will be quantified to estimate the regional flux distribution at the land-ocean interface. The model will be applied to six Arctic deltas with different boundary conditions to account for their differences in morphology, seasonality, and hydrology. We hypothesize that sediment fluxes will be more unevenly distributed at the coastline with increasing delta complexity and size. The regional sediment flux distribution can be used in future studies of coastal biogeochemistry and regional models to capture the impacts of flux distribution on marine primary productivity and Arctic warming.

Boron loss and isotopic fractionation as a result of sediment dehydration during subduction from seafloor to sub-arc in SW Japan

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The active SW Japan subduction zone is a site of extensive geologic, seismic, hydrologic, and volcanic research to date. Material input comprises both sediments and altered oceanic crust (AOC) as evidenced by cores obtained from seafloor drilling sites, ultimately resurfacing as arc lavas. However, mass balance of fluids in and out of the system between the time of subduction and arc magmatism remain poorly constrained. Boron can be a useful hydraulic tracer given its solubility and high concentrations in subducted sediments relative to the overlying mantle wedge. Under lower PT conditions, diagenetic processes drive fluid loss. At higher PT, the predominant driver transitions to metamorphic dehydration, or breakdown of hydrous mineral phases. Using B concentration and $\delta^{11}B$ values as a proxy to quantify fluid loss, we hope to detail the geochemical evolution from when sediments first enter to the system, undergo metamorphism at depth, and resurface.

Preliminary [B] and $\delta^{11}B$ data have been collected from (meta)sediments along a SE-NW transect across Shikoku Island from the Nankai trough, through the Shimanto belt, to the Sanbagawa metamorphic belt. The data show decreasing [B] and $\delta^{11}B$ with increasing temperature, covering a range of ~25-500°C. This suggests progressive fluid loss with increasing metamorphic grade due to slab dehydration, with ^{11}B being preferentially incorporated into the fluid. To assess provenance, $^{87}Sr/^{86}Sr$ data have also been obtained for samples from the Shikoku transect including clays, shales, schists, and basalts. Five of the seven schist samples have an $^{87}Sr/^{86}Sr$ value range of 0.709-0.715, which largely fall within the range for Nankai Trough clays (0.710-0.715) and Shimanto shales (0.710-0.717). This overlap suggests shared input sources, thus a viable analog of a continuous sedimentary suite. This assessment of initial homogeneity establishes a strong base for interpretation of boron cycling in global subduction zones.
Exploring the origins and evolution of oxygen in organic matter via stable isotopes

Characterizing uranium speciation in marine phosphorites to advance the paleo-redox proxy

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The amount of oxygen in the ocean has exerted a major control on the development of complex life throughout Earth's history, making it important to understand the timing and frequency of oxygenation changes. Records of uranium (U) concentrations and isotopes are invaluable for reconstructing long-term and transient changes in the redox state of oceans. The redox-controlled solubility and isotope fractionation of U make it an applicable proxy for revealing these changes. However, interpreting U concentrations and U isotopes from marine sedimentary rocks as a paleo-redox proxy assumes that burial and isotope fractionation are associated with the reduction of U(VI) to U(IV). Without knowing the actual oxidation states or phase associations of U in marine sedimentary rocks, interpretations of the U isotope proxy remain uncertain. We address this by characterizing U speciation within marine sedimentary samples that are expected to be anoxic.

We used X-ray Absorption Fine Structure spectroscopy at the L3 edge to study U speciation in marine phosphorites from the Monterey Formation (Miocene) and the Phosphoria Rock Complex (Permian). The X-ray Absorption Near Edge Spectroscopy results from six powdered samples provide important context for whole-rock shale U concentration and U isotope analyses reported in paleo-redox studies. Linear combination fitting results indicate a mixture of U(IV), U(VI), and surprisingly, U(V) for both formations. Extended X-ray Absorption Fine Structure data from thin sections provide spatially resolved U speciation and were used to determine characteristics of the solid phases that incorporate different U oxidation states. Taken together, these new insights draw a more complicated picture where multiple U redox pathways occur simultaneously in these settings. The U oxidation states present in marine sedimentary rocks, including the apparent persistence of U(V), could impact the interpretation of the U isotope signature.

A trans-lithospheric view of Archaean continent building from detrital diamonds and Eoarchaean terranes, Slave Craton, NW Canada

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Earth's continents are characteristic and unique among all known planets. Constraining early continental crust composition and the driving mechanisms of crustal production is crucial to further our understanding of the early Earth system. Subsequent emergence of these continents above the oceans facilitated greater sub-aerial silicate weathering, with far-reaching implications for atmospheric formation and nutrient delivery to the oceans, driving complex life evolution. The development of lithospheric mantle roots that underpin blocks of continental crust called cratons is hypothesised to drive continental stabilisation and emergence. However, the timing and mechanisms that drove continental crust production and subsequent lithospheric root formation remain enigmatic. Constraining these requires investigating material formed in settings that transect across the early continental lithosphere from the crust to the lithospheric mantle.

The Slave Craton, Northwest Canada, represents a world-class location to sample different settings of an Archaean continent. Recently discovered detrital diamonds in ~2.83 Ga sediments provide a unique window into the base of an Archaean continent. The state of nitrogen aggregation within these diamonds can be applied as a geochronometer to evaluate the diamond mantle residence time as a proxy for lithospheric mantle root formation age. Here we report the recent discovery of 25 new nanodiamonds, expanding upon our current sample database and offering the potential to understand Archaean lithospheric mantle through direct sampling.

Exceedingly rare Palaeo-Eoarchaean (3.2-4.0 Ga) terranes represent direct samples of early continental crust. The Slave Craton contains recently identified up to 3.8 Ga terranes, the Eokuk Uplift and Kangguyak Gneiss Complex, representing exciting new locations to test hypothesise concerning early continental crust. Here we report on collected samples of these two terranes with preliminary U-Pb geochronology. This study represents the first attempt to combine crustal analysis with the evaluation of the lithospheric mantle root for an Archaean continent.

Continental crust evolution during the Archean using isotope geochemistry of zircons from granites/granitoids from the Slave Craton, Northwest Territories (Canada)

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The Slave Craton in the Northwest Territories in Canada hosts some of the Earth's earliest known preserved continental crust, the evolution of ancient crust into this extant continental crust is shown through its geochemistry. The geochemical development of the Earth's early crust is a key factor to understanding how our planet, with its characteristic global tectonic regimes, evolved through time and to further understand how the Earth differs from other terrestrial planetary bodies. Preserved granites/granitoids with ages in the Neoarchean (2.8-2.5 Ga) found across this region are representative of continental crust formed towards the end of the Archean. These granitic rocks contain the durable and insoluble mineral zircon which stores the geochemical rock record and can be used for geochronology and fingerprinting the source material of their host rock. We use laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) on the zircons to measure the uranium-lead-hafnium (U-Pb-Hf) isotopic concentrations reflective of the host rock. The age of the sample is determined from their zircon U-Pb measurements. Zircon Hf measurements correspond to the composition of the parent material of their host rock, differentiating whether the bulk of their composition was from a newly generated addition to the crust from the mantle during the mid to late Archean, or if it consists primarily of existing material from the lower crust which had been reworked to form this newer crust. The spatial distribution of the parent materials of these samples can be mapped using existing zircon oxygen isotope data and the whole-rock geochemistry of these samples with the new zircon U-Pb-Hf analyses. This distribution shows the extent of parent material across the Slave Craton prior to any crustal constructing event which resulted in the formation of this Neoarchean continental crust.

Investigating the formation of Hadean crust with constraints on Hf Isotopes: A 1-D numerical simulation approach

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The formation mechanism of the Hadean felsic crust is not well understood due to a lack of geologic samples. Nevertheless, this process may have influenced the transition from stagnant lid tectonics to plate tectonics and ultimately the surface environment. Hf isotopes are particularly useful to understand this process, as they store original magma characteristics, and the Hadean zircon dataset demonstrate a continuous negative trend before 3.7 Ga, indicating continual remelting of a Hadean protocrustal source. This could be attributed to crustal formation in a plateau melting model where melting occurred beneath a thick crustal pile. However, this hypothesis has not yet been tested with geophysical modelling. We perform a 1-D numerical simulation of Hadean crust and mantle, incorporating additional constraints on Hf isotopes to test the formation mechanism of Hadean felsic crust. Specifically, we developed a model that simulates the thermal evolution of Hadean mafic crust with extrusion and intrusion of new crust. We determine when hydrated mafic crust would melt to form felsic magma and the Hf isotope composition of this magma. We used a Monte Carlo method to sample from distributions of the key model parameters, initial crust thickness, advection rate, and extrusive rate, to investigate which parameters best satisfy the observed Hf isotopic composition and geological constraints. We defined a successful model as one that exhibits a continuous, decreasing trend of εHf ($^{176}Hf/^{177}Hf$ ratio relative to the chondritic reservoir) over a period of 300 million years without any interruptions for at least 100 million years, and with an average melting depth of less than 35 km, designed to replicate the observed geochemical dataset of Hadean zircons. Our findings indicate that most successful models had surface volcanic eruption rates of 0.1 mm/year or less, inconsistent with a previously proposed heat pipe model of the Hadean

Assessment of deep burial to modern meteoric diagenesis of siderite: Core-outcrop comparison from the Paleocene Fort Union Formation in Wind River Basin, Wyoming

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Calcium carbonate minerals (calcite, aragonite) are susceptible to water-rock exchange with deep burial fluid or meteoric water, which obscures the primary fabrics and geochemical signals. Siderite ($FeCO_3$) forms ubiquitously in reducing Earth surface environments, particularly during globally warm climatic intervals such as the K-Pg and PETM. Because of siderite's slower dissolution kinetics and lower solubility than calcium carbonate, we hypothesize siderite is more resistant to diagenetic alteration. If so, siderite stable isotopes have a promising potential for better paleoclimatic reconstruction, especially for deeper time. The Cretaceous Lance Formation and Paleocene Fort Union strata in the Wind River Basin (WY) recorded the regression of the Western Interior Seaway and a transition to terrestrial sedimentary environments during the Laramide orogeny. Concretionary and disseminated siderite cement occur in lacustrine and fluvial deposits. In this research, we apply a suite of petrographic and geochemical proxies on outcrop and coeval core (burial depth 800-2000m) samples to investigate the burial and late-stage meteoric diagenesis. EPMA analyses provide quantitative evidence of different alteration environments because burial fluids typically have higher cation concentrations than meteoric water. Chemical homogeneity and smaller $\delta^{18}O_{siderite}$ range (-4.7‰ to -7.2‰ VPDB) indicate that outcrop siderite nodules preserve a primary signal. The $\delta^{18}O_{calcite}$ values of recrystallized calcite cement (-18.8‰ to -13.1‰ VPDB) suggest the calcite reprecipitated from ^{18}O-depleted meteoric water. The significant range in $\delta^{13}C_{siderite}$ (-13.5‰ to +13.1‰ VPDB) indicates that siderite in the K-Pg Wind River basin formed as an early diagenetic product with different DIC sources and carbon cycling processes, including organic matter respiration and methanogenesis. Further assessment of siderite burial and meteoric diagenesis will be supported by clumped isotope analysis.

Session 8Z: Oral Session

Friday 21st April
3:00 pm – 4:15 pm

3:00 pm - 3:15 pm
Eric Hasegawa
PhD Student, 2nd Year, Pre-Comps
Exploring the origins and evolution of oxygen in organic matter via stable isotopes

3:15 pm - 3:30 pm
Leonie Strobl
PhD Student. 2nd Year, Pre-Comps
Dehydration systematics of eclogite-facies oceanic crust: constraints from the Eclogite Zone, Tauern Window (Eastern Alps)

3:30 pm - 3:45 pm
Erik Schoonover
PhD Student, 2nd Year, Pre-Comps
Micrometer-scale records of granitoid differentiation preserved in zircon from the Tuolumne Intrusive Complex, CA (USA)

3:45 pm - 4:00 pm
Sierra Melton
PhD Student, 3rd Year, Pre-Comps
Exploring Stresses and Glacial Thinning at a Marine Ice Cliff
(Virtual)

4:00 pm - 4:15 pm
Thomas Givens
PhD Student, 4th Year, Pre-Comps
Detailed Numerical Modeling of Glacial Isostacy in Iceland Using Stress-Dependent Mantle Rheology, Implications for Timescale-Dependent Flow, and Future Volcanic Hazard
(Virtual)

Exploring the origins and evolution of oxygen in organic matter via stable isotopes

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Carbonaceous chondrites carry organics from the early solar system. This organic matter may be a key source of the "building blocks" necessary for life to emerge on Earth. Oxygen atoms are necessary for many prebiotic and biochemical reactions, however oxygen has multiple origins in space (water, CO, CO_2), and different organic oxygen sites are differently susceptible to exchange and overprinting in the time since these compounds formed. We aim to answer the question of where oxygen in chondritic organic matter comes from, and how it changes when organic matter evolves from insoluble to soluble phases. To do so, we are using theory, exchange and pyrolysis experiments, and new analytical techniques to understand how oxygen isotopic compositions are modified during the formation and alteration of organic matter. Initial work focuses on phenol for the following reasons: *i)* phenol is a major product of hydrothermal alteration of both terrestrial and extraterrestrial organic matter; *ii)* its oxygen atoms are resistant to exchange; yet *iii)* the molecular origin of this oxygen (which sites it samples) is unclear. This work is being conducted in several parts. First, we are determining the kinetics of oxygen isotope exchange between phenol and water to better understand its resistance to overprinting as a function of temperature, time, and pH. Second, we are using Density Functional Theory to predict the oxygen isotopic fractionation between these phases at equilibrium. Third, we will perform stepped pyrolysis experiments to release phenol from coal and analyze how its isotopic composition evolves with reaction progress. We expect: *i)* kinetics of exchange to be negligible on laboratory time scales; *ii)* equilibrium between water and phenol will have a fractionation factor of approximately 1.0359 at 25 ºC; and *iii)* pyrolysate phenol oxygen will have an isotopic composition that can be traced back to ether linkages in kerogen.

Dehydration systematics of eclogite-facies oceanic crust: constraints from the Eclogite Zone, Tauern Window (Eastern Alps)

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Prograde metamorphic reactions in subduction zones regulate the fluid flux past arc magma genesis feeding into the mantel. Current global fluid flux estimates are derived from thermodynamic modelling that assumes efficient removal of fluids from the subducting slab [1]. However, the ubiquitous presence of veins, vugs and segregates associated with peak high pressure – low temperature (HP-LT) mineral phases suggest incomplete fluid removal from the downgoing slab. To better understand the chemical and physical controls on fluid migration through subducting oceanic crust, this study presents a field-based investigation of an eclogite-facies vein system from the Tauern Window, Austria. Phase equilibria modelling of growth-zoned garnets from mafic eclogites constrains a prograde P-T path between conditions of garnet core growth at 21 ± 0.5 kbar, and 550 ± 2.5°C to rim equilibration at 26 ± 2 kbar, and 640 ± 25 °C. The P-T evolution is consistent with garnet growth during burial along the wedge-slab interface, characterized by low values of dT/dP. Contemporaneously to prograde garnet growth, the mafic eclogites experienced dehydration via the breakdown of several volumetrically significant hydrous phases: lawsonite, Na-amphibole (glaucophane), epidote. The decomposition of lawsonite and glaucophane released up to 6 wt. % H_2O and created transient porosity of ~ 5–17 volume %. Our modeling shows that the blueschist-to-eclogite transition—in these eclogites—is a net volume-reducing reaction and is likely to have resulted in a transient reduction in pore fluid pressure. We propose a petrological-mechanical model for the formation of the Type I dilatant structures in which rock deformation is outpaced by this reduction in pore fluid pressure, leading to a decrease in silica solubility and the precipitation of high-pressure mineral phases. Garnet diffusion timescales and convergence rates are used to constrain plausible timescales of the process.

[1] van Keken, P. E. et al (2011). Journal of Geophysical Research: Solid Earth 116:1401

Micrometer-scale records of granitoid differentiation preserved in zircon from the Tuolumne Intrusive Complex, CA (USA)

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The Tuolumne Intrusive Suite (TIS) in the Sierra Nevada Batholith is one of the best-exposed and most-studied examples of incrementally constructed, arc-magmatic plutons. However, the emplacement mechanisms, cooling history, and total volume of the TIS remain hotly contested. The geochemistry, chronology, and temperatures of the granitoids from the exterior to the interior of the pluton have been leveraged in different ways to support highly variable theories of magma intrusion and evolution. In this work, we studied zircons from five representative rock types with rim-to-core laser-ablation split stream inductively coupled mass spectrometry depth-profiling (LASS-DP). We use this technique to determine the chemical evolution of zircon crystallization to understand the magmatic evolution of the TIS.

Existing data demonstrate that the TIS evolves from a more mafic exterior to a more felsic interior, albeit with similar mineralogy. Our results show zircon geochemistry tracks this evolution in intra- and inter-rock trends. Analysis of trace elements using established discrimination trends and crystallization indicators show broad-scale differentiation in trace element compositions. Intra-sample variations show Yb/Dy increasing from zircon cores to rims with rapid change at the rims, with accompanying Ti-concentrations decreasing from core to rim. These trends suggest zircon is tracking geochemical changes during magmatic cooling. Based on the observed TIS mineralogy and corresponding trace element partition coefficients, this is likely indicative of a shift from amphibole to titanite co-crystallization during zircon growth. Our results further allow us to uniquely identify the Ti-concentrations of zircon at the onset of titanite saturation, which is consistent among samples. Paired with Zr-in-titanite, we can explicitly solve for the temperature and α-TiO_2 of each magmatic pulse as titanite crystallization commenced. Therefore, our zircon-based approach can uniquely identify magmatic compositions from the rock record, allowing us to make comparisons to zircon from other rock types, including extrusive compositions.

Exploring Stresses and Glacial Thinning at a Marine Ice Cliff

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Ice stored in the Greenland and Antarctic Ice Sheets largely flows to the ocean through fast-flowing outlet glaciers and ice streams. Most Antarctic ice flowing across the grounding line forms ice shelves, which provide buttressing that slows ice flow. Ice shelves are susceptible to melting and collapse, which has been observed to speed flow of non-floating ice and to expose grounded ice cliffs that can retreat rapidly by iceberg calving, raising sea level. Most ice-sheet models informing the IPCC do not simulate coupled ice-shelf loss and calving-cliff retreat, in part because of difficulty in modeling the governing processes at suitable spatiotemporal resolutions. Some models approximate these processes by numerically removing all ice crossing the grounding line, but this omits additional, potentially important stresses present at an ice cliff. Many of the outlet glaciers in Greenland, including Helheim Glacier, have already lost their persistent floating ice shelves and now terminate in grounded ice cliffs, where lack of support from an ice shelf causes a stress imbalance that reaches a maximum at the water line and increases with cliff height. Stresses within the ice compensate for the ice-front imbalance, so these internal stresses must also increase with cliff height. Ice deforms more rapidly under higher stress, with strain rate dependent on deviatoric stresses in all directions. To explore the impact of the additional stresses at an ice cliff on viscous thinning and retreat, we compare the full 3D stresses, thinning, and retreat rates at the grounding line for a Helheim-like ice cliff versus a small, freely spreading shelf using the NASA-JPL Ice-sheet and Sea-level System Model (ISSM). Greater deviatoric stresses at an ice cliff should enhance rates of thinning to flotation and retreat, compared to the ice shelf scenario. These results will ultimately help represent ice-cliff retreat more accurately in continuum ice sheet models to improve sea-level rise projections.

Detailed Numerical Modeling of Glacial Isostacy in Iceland Using Stress-Dependent Mantle Rheology, Implications for Timescale-Dependent Flow, and Future Volcanic Hazard

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My project seeks to quantify the effect of modern-day Glacial Isostatic adjustment (GIA) on the melt supply of Icelandic volcanic systems while testing the relevance of new considerations regarding nonlinear mantle flow against Iceland's glacial and eruptive history. With knowledge of glacial mass balance history, regional crustal structure, the regional surface deformation field, and constraints on melt parameterization, we simulate the rheological and melting response of the Earth to glacial load changes in Iceland using the Finite Element Modeling (FEM) method. Although nearly all current published Icelandic GIA models have used linear viscoelastic rheology to invert for mantle viscosity, strong evidence from laboratory studies and process understanding indicates that the flow law for the upper mantle is nonlinear. We suspect that the low mantle viscosity estimates in Iceland from previous researchers are due to attempting to invert for linear viscosity with geodetic data observing a nonlinearly deforming Earth. Changing stress in the flexing crust during periods of GIA in Greenland has been shown to have the necessary magnitude to drive melt into storage within the lithosphere. We will use our models to repeat this examination in Iceland while looking into the feasibility of a nonlinear mantle and its effect on the evolution of mantle and crustal stresses relevant to magma generation and transport. Here we use simplified "sandbox" level modeling to generate estimates for post-LGM melt generation and ascent mechanisms. We will develop linear and nonlinear mantle rheology models using recent (1994-2023) GPS and (2015-2018) InSAR data and test them against the record of post-glacial early Holocene eruptive history.