The 53rd Annual Graduate Student Colloquium

Photo: Julia Carr (Field Work Photo Contest Winner)

Hosted by the Department of Geosciences

April 8th – 9th 2021

53rd Annual Graduate Student Colloquium

Sponsored by Shell and hosted by the Department of Geosciences
April 8-9, 2021

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 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 Members:
Kirsten Stephens (chair), Troy Ferland (chair), Kirsty McKenzie, Judit González-Santana, Hee Choi, Nolan Roth

Event Schedule

Thursday 8th April

Opening Remarks – 8:50 to 9:00 am

Oral Session 1 – 9:00 to 10:30 am

Coffee Break – 10:30-10:45 am

Poster Session – 10:45 am to12:00 pm

Lunch Break – 12:00 to 12:45 pm

Oral Session 3 – 12:45 to 2:00 pm

Coffee Break – 2:00 to 2:15 pm

Oral Session 4 – 2:15 to 3:30 pm

Coffee Break – 3:30 to 3:45 pm

Oral Session 5 – 3:45 – 5:00 pm

Friday 9th April

Opening Remarks – 9:00 – 9:15 am

Oral Session 1 – 9:15 to 10:30 am

Coffee Break – 10:30 to 10:45 am

Oral Session 2 – 10:45 am to 12:00 pm

Lunch Break – 12:00 to 1:00 pm

Oral Session 3 – 1:00 to 2:15 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:

2020-21: Graduate Student Colloquium Cancelled 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 Rheinsche Friedrich Wilhelms Universitaet, 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 and 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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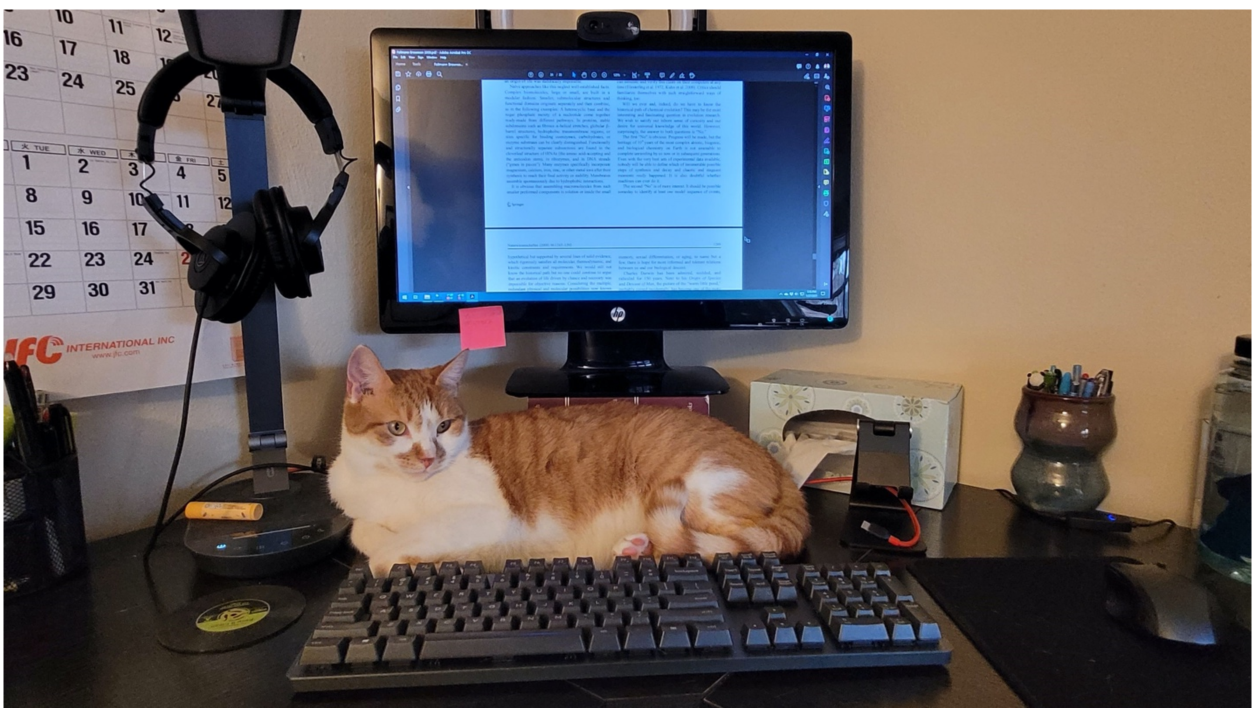

Photo: Youki Sato ('Work From Home' Photo Contest Winner)

Thursday 8th April

Session 1: Oral Session

Thursday 8th April
8:50 am – 10:30 am

8:50 am – 9:00 am
Opening Remarks

9:00 am – 9:15 am
Troy Ferland
Ph.D. student, 4th year, Post-Comps
Pleistocene fire activity in East Africa paced by sea surface temperature gradient responses to northern hemisphere ice volume

9:15 am – 9:30 am
Kirsty McKenzie
Ph.D. student, 5th year, Post-Comps
The Role of Upper-Plate Strength in Controlling Apparent Coupling Patterns along Subduction Zones

9:30 am – 9:45 am
Joanmarie Del Vecchio
Ph.D. student, 4th year, Post-Comps
How old is Bear Meadows?

9:45 am – 10:00 am
Ben Barnes
Ph.D. student, 4th year, Post-Comps
The geologic history of seawater heavy REE enrichment and carbonate chemistry

10:00 am – 10:15 am
Machel Higgins
Ph.D. student, 5th year, Post-Comps
Fore-Arc Sliver Shear Mechanism in Nicaragua Revealed by Upper-Plate Earthquakes

10:15 am – 10:30 am
Kirsten Stephens
Ph.D. student, 5th year, Post-Comps
Connecting the dots from surface to magma plumbing system: A case study of ground deformation at Masaya caldera over the last 10 years

Pleistocene fire activity in East Africa paced by sea surface temperature gradient responses to northern hemisphere ice volume

T.M. Ferland[1], S.C. Brassell[2], I.G. Stanistreet[3,4], H. Stollhofen[5], J. Njau[2,3], K. Schick[3], N. Toth[3], and K.H. Freeman[1]

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[2]*Indiana University, Bloomington, IN, USA*
[3]*The Stone Age Institute, Bloomington, IN, USA*
[4]*University of Liverpool, Liverpool, UK*
[5]*Friedrich-Alexander-Universität, Erlangen, Germany*

Pleistocene sediments deposited in the Paleolake Olduvai (Olduvai Gorge, Tanzania) record orbitally paced changes in vegetation and hydroclimate, inferred from leaf wax carbon isotopes, hydrogen isotopes, and bulk organic data. Fire feedbacks between vegetation and climate are well-studied in modern savannah ecosystems, but there is less known about how they operate on longer timescales. Using polycyclic aromatic hydrocarbons (PAHs), a suite of molecules produced during biomass fires, we reconstructed paleo-fire activity in the Olduvai paleolake catchment from 1.9-1.8 Ma and compared it with previous biomarker records of vegetation and hydroclimate. PAH-inferred paleo-fire from Olduvai Gorge Coring Project (OGCP) Core 2A appears to be paced by orbital obliquity (in contrast to the precessional pacing of vegetation change), which points to the influence of the "short rains" (i.e., Oct-Dec precipitation) on paleo-fire activity at Olduvai Gorge from 1.9-1.8 Ma. We suggest a linkage between Northern Hemisphere glaciation and short rain intensity at Olduvai Gorge, facilitated by the closing of the Indonesian Throughflow and a subsequent reinforcement of the east-west sea surface temperature gradient in the Indian Ocean, resulting in increased fire frequency during glacial periods. The interplay between hydroclimate, fire, and vegetation on orbital timescales may have impacted the distribution and availability of food resources for hominins at Olduvai, potentially exposing exploitable resources such as rodent burrows or plant underground storage organs.

The Role of Upper-Plate Strength in Controlling Apparent Coupling Patterns along Subduction Zones

Kirsty A. McKenzie[1], Kevin P. Furlong[1], Matthew Herman[2]

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[2]California State University, Bakersfield, CA, USA

Subduction zone earthquake behavior is dependent on the patterns of inter-plate coupling during the interval between major events. Typically, GPS data, that record upper-plate surface displacements at subduction zones are used to characterize this subduction coupling. Using the observed Cascadia horizontal GPS velocity field, we determine a coupling model for Cascadia and explore how variations in upper-plate strength influence the patterns of observed surface velocities, and the resulting interpretation of coupling and earthquake potential.

Our preferred coupling model (determined by a homogeneous elastic inversion), constrained by the location of episodic tremor and slip in Cascadia has a large (2-6 mm/yr) misfit between the observed and modeled surface velocities in central and northern Cascadia (from 123° W to 121° W). We propose that this misfit is not indicative of an unsatisfactory model, but rather, is produced by differences in the strength of the upper-plate that is coupled to the subducting plate. In central Cascadia coupling extends from beneath the accretionary margin sediments to below the western edge of the strong Siletzia terrane. In contrast, in southern Cascadia coupling only extends beneath the relatively weak accretionary margin sediments and Franciscan coast ranges, west of the stronger Klamath terrane.

We use finite element modeling to assess how changes in the extent of plate coupling with respect to variations in upper-plate strength can affect the surface velocity patterns. We test two end-member models: (1) coupling extends beneath weak (trenchward) and strong material (akin to central Cascadia), and (2) coupling only extends beneath weak (trenchward) material, west of a stronger material (akin to southern Cascadia). By incorporating upper-plate strength in our plate coupling models we are able to determine that there is a higher slip deficit accumulation in central Cascadia compared to southern Cascadia. The details of coupling (such as patterns of slip deficit accumulation) can be used to characterize the hazard(s) posed by future subduction megathrust events across the margin.

How old is Bear Meadows?

J. Del Vecchio[1], R. A. DiBiase[1,2], S. J. Ivory[1,2], L. B. Corbett[3], P. R. Bierman[3], M. W. Caffee[4] M. Leddy[5], G. Mount[6]

[1]*Penn State Department of Geoscience*
[2]*Penn State Earth and Environmental Systems Institute*
[1]*Penn State Department of Geoscience*
[2]*Penn State Earth and Environmental Systems Institute*
[3]*University of Vermont*
[4]*Purdue University*
[5]*Penn State Geography*
[6]*Environmental Planning and Community Resilience Division, Broward County, Florida*

Ancient permafrost landscapes south of the Laurentide ice sheet underwent large-scale climatic and land cover changes during last deglaciation, but comparatively little is known about erosion process, rate, and timing. To determine the timescales of hillslope responses to climate warming, we sampled sediment from across Bear Meadows, Pennsylvania, ~100 km south of the maximum extent of the Laurentide Ice Sheet. We measured bulk geochemistry and cosmogenic 10Be and 26Al concentrations in the sand fraction of an 18 m hillslope regolith core. We show that central Appalachia has experienced multiple Pleistocene periglacial episodes, which resulted in a sustained increase in long-term erosion rates compared to the relatively warmer Neogene. The long residence time of periglacial sediments and features implies that permafrost processes efficiently erode hillslopes in landscapes where stable temperate climates would otherwise promote slower landscape processes. We then targeted the fine-grained sediments in the peat bog to understand transient responses to postglacial warming at a higher temporal resolution. We use ground-penetrating radar, radiocarbon dating, and geochemistry to connect sedimentation to global climate and local vegetation change. By using bulk geochemistry in sediments track the relative contribution of dust versus locally derived sediment and pairing it to our local pollen record, we show how the warm-and-dry conditions of the Bolling-Allerod promoted deeper soil disturbances. In contrast, the warm, wet conditions of the early Holocene resulted in vegetation turnover in response to erosion which promoted flushing of fine-grained sediments (predominantly dust) stored on hillslopes. Thus, during late glacial warming, different temperature and moisture conditions drove different styles of hillslope processes. This work helps us understand the implications permafrost processes had in shaping both modern Appalachia and high-latitude landscapes.

The geologic history of seawater heavy REE enrichment and carbonate chemistry

Ben Davis Barnes and Lee R. Kump

Department of Geosciences, The Pennsylvania State University, Deike Building, University Park, PA 16802

The determination of ancient ocean carbonate chemistry from the geologic record is one of the most reliable methods to track the long-term evolution of Earth's climate and carbon cycle. By constraining any two variables, e.g., pH and pCO_2, one can fully characterize the carbonate system through ocean acidification and global warming events. Despite this utility, there are relatively few marine geochemical proxies for the carbonate system, and the proxy record is sparse through many key intervals. In order to expand our geochemical toolbox to generate novel paleoclimate and paleoceanographic reconstructions, we explore the rare earth elements (REE) preserved in calcite sediments as a novel carbonate ion (CO_3^{2-}) proxy.

A persistent feature of the REE composition of ancient carbonates is the relative enrichment of the elements with increasing atomic number (i.e. heavy REE), a pattern which is maintained in modern seawater by complexation reactions with CO_3^{2-}. However, no work to date has compiled data to test if the relative enrichment of REE in carbonates evolves through time. We present a novel compilation of >9,876 published REE measurements in carbonate sediments spanning 3.5 billion years of Earth history. Our results demonstrate that the REE composition has varied significantly and coherently from the Archean to the recent. Furthermore, Phanerozoic trends in heavy REE relative enrichment show a first-order covariation with [Ca^{2+}] reconstructions. This pattern suggests that that evolution of surface seawater [CO_3^{2-}] on 10^8-year time scales is primarily driven by seafloor hydrothermal inputs and a tendency for homeostasis of carbonate saturation state to maintain the carbonate sedimentation balance of continental weathering fluxes. The capacity of seawater to buffer against short-term climate-system disruptions has therefore varied significantly and episodically, forced by changes to [Ca^{2+}] driven from the seafloor up.

Fore-Arc Sliver Shear Mechanism in Nicaragua Revealed by Upper-Plate Earthquakes

Higgins[1], La Femina[1], Saballos, Fischer, Ouertani

[1] *Department of Geosciences, The Pennsylvania State University*

Oblique convergence and strong mechanical coupling along subduction zones result in strain partitioning and the development of translating forearc terranes. Translation of the fore-arc relative to the over-riding plate is typically accommodated by strike-slip fault systems; for example, the Great Sumatran Fault, Indonesia. The Central American Fore-Arc (CAFA) is a northwestward translating (8 mm/yr to 13 mm/yr) fore-arc sliver, the result of oblique Cocos - Caribbean convergence, and Cocos Ridge collision. However, the CAFA in Nicaragua does not have the expected trench-parallel, strike-slip fault system to accommodate its relative motion with the Caribbean Plate. It has been proposed that CAFA-Caribbean dextral shear is accommodated by clockwise rotating tectonic blocks (Bookshelf Faulting), where faulting is characterized by NE-SW striking left-lateral and NW-SE striking right-lateral strike-slip faulting. Using Global Positioning System data, and a Bayesian inversion approach, we determined the kinematics and geometries of three moderate-magnitude upper-plate earthquakes in Nicaragua. We investigated the April 10th, 2014 Mw 6.1, September 15th, 2016 Mw 5.7, and September 28th, 2016 Mw 5.5 earthquakes. We find that April 10th, 2014 earthquake occurred on a NW-SE (140°) striking fault with right-lateral coseismic slip. This is the first well-documented historical earthquake with this geometry and kinematics. The September 15th and September 28th, 2016 earthquakes were located on NE-SW (~50° & 202°, respectively), striking faults with left-lateral and dip-slip coseismic slip. Coulomb failure stress analysis, suggests that the 2016 earthquakes were promoted by the 2014 earthquake and that the September 28t^{h}, 2016 earthquake was promoted by the September 15th, 2016 earthquake. The determination of the geometry and kinematics of these upper-plate earthquakes provides support for CAFA-Caribbean dextral shear via Bookshelf Faulting and important implications for near- to mid-real-time seismic hazard estimates.

Connecting the dots from surface to magma plumbing system: A case study of ground deformation at Masaya caldera over the last 10 years

Kirsten Stephens[1], Christelle Wauthier[1,2]

[1]*Department of Geoscience, The Pennsylvania State University*
[2]*Institute for Computational and Data Science, The Pennsylvania State University*

Volcanic unrest in calderas can be exhibited through a variety of different mechanisms, such changes in seismicity, ground deformation, thermal radiance, and/or gas emissions. However, not all caldera unrest results in explosive caldera-forming volcanic activity. Alternative activity may include a period of quiescence, or effusive activity in the form of lava flows or appearance of lava lakes. In December 2015, the Nicaraguan basaltic caldera, Masaya, exhibited signs of unrest with the formation of a lava lake in the Santiago summit pit crater. Geodetic studies spanning the 2015-2016 period using Interferometric Synthetic Aperture Radar (InSAR) [Stephens & Wauthier, 2018, *GRL* and precision leveling data [Murray *et al.*, 2017, *IAVCEI 2017*; Rymer *et al.*, 2017, *IAVCEI 2017*] identified a previously undetected magma reservoir (Masaya Central Reservoir, MCR) located 3 km north of the active Santiago pit crater. Furthermore, gas geochemistry in-conjunction with geodetic data indicated changes occurring within the MCR in the weeks leading up to the appearance of the lava lake [Aiuppa *et al.*, 2018, *GCubed.*; Stephens *et al.*, 2020, *RS.*].

This study takes advantage of the increase in available SAR datasets (*e.g.,* Sentinel-1, RADARSAT-2 and COSMO-SkyMed) to examine the long-term evolution of ground deformation within the caldera and the sub-surface conditions of the MCR during different periods of volcanic activity. InSAR time-series analysis provides high temporal resolution of the spatial extent and magnitude of ground deformation during the 2011-2019 period at Masaya. Time-series results were used to estimate incremental volume change of the MCR, and preliminary results suggest that the MCR began inflating ~2.5 years prior to the onset of lava lake activity in late 2015. The results from this work emphasize the importance of long-term deformation monitoring of caldera regions to improve our understanding of the relationship between the magma plumbing system and observed volcanic activity. In-conjunction with multi-disciplinary efforts, this approach will provide a more detailed framework on volcanic behaviour for forecasting in caldera settings.

Session 2: E-Lightning/Poster Session

Thursday 8th April
E-Lightning Talks 10:45 am – 11:00 am
Breakout (Poster) Rooms 11:00 am – 12:00 pm

10:45 am – 10:47 am
Tsai-Wei Chen
Ph.D. student, 3rd year, Pre-Comps
The relation between temperature and element mobility in subduction fault zones

10:47 am – 10:49am
Karen Pham
Ph.D. student, 1st year, Pre-Comps
Differential Seed Size Evolution of Palm Plants (Arecaceae) in Madagascar and Mainland Africa

10:49 am – 10:51 am
Judit González-Santana
Ph.D. student, 4th year, Pre-Comps
Identification of long-term flank motion at Pacaya Volcano, Guatemala, through InSAR time-series analysis

10:51 am – 10:53 am
Hanna Leapaldt
Master's student, 1st year
Impacts of in situ microbial metabolisms on the isotopic composition of lake carbonates

10:53 am – 10:55 am
Michael Forgeng
Master's student, 2nd year
Investigating the dominant controls on nitrate transport and denitrification at two scales: from a single farm field to a HUC-10 watershed

10:55 am – 10:57 am
Raphael Affinito
Ph.D. student, 1st year, Pre-Comps
Laboratory seismic faulting and early observations of slow-slip earthquakes

10:57 am – 10:59 am
Samuel Hone
Master's student, 2nd year
Seismic observations of thunderquakes detected by the Penn State FORESEE array

The relation between temperature and element mobility in subduction fault zones

Tsai-Wei Chen[1], Donald M. Fisher[1], Andrew J. Smye[1], Yoshitaka Hashimoto[2]

[1]*Department of Geosciences, Penn State University*
[2]*Department of Applied Science, Kochi University*

Mineral redistribution along subduction interfaces is likely to result in diverse plate boundary slip behaviors. Observations in subduction mélanges provided evidences of local element diffusion from anastomosing scaly fabrics in mudstones into cracks of sandstones and precipitation as minerals veins. This kinetic process is likely to seal cracks at varying rates under different temperatures, which has the potential to modulate the strength of rocks and fracture porosity and thus the slip behaviors along the depths of plate interfaces. To test whether the relation between temperature and the degrees of mass redistribution can be observed in subduction rocks, we conducted series of geochemical survey using samples collected from nine mélanges of exhumed accretionary prisms, the Kodiak accretionary complex and the Shimanto belt, that have undergone a range of temperatures that correspond to the full range of the seismogenic zone according to previous studies. Here, we first present element maps for each mélange sample obtained by electron probe micro-analyzer (EPMA). The maps demonstrate the enrichment of immobile elements, such as Ti, in the scaly folia due to the mass transport of mobile elements, such as Si, into cracks and precipitation as veins. The degrees of depletion of Si and enrichment of Ti increase in the mélanges that have experienced higher temperatures, supporting our hypothesis that the degree of mineral redistribution increases as a function of temperature. We then used laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS) to analyze along transects across scaly fabrics and veins to obtain the concentrations of trace elements. Combing the LA-ICP-MS data and EPMA maps, we were able to calculate the mass loss in scaly fabrics to represent the strains accommodated by each mélange and quantify the variations in element mobility related to temperatures.

Differential Seed Size Evolution of Palm Plants (Arecaceae) in Madagascar and Mainland Africa

Karen Pham[1], Sarah Ivory[1], Lee Hsiang Liow[2]

[1]*The Pennsylvania State University*
[2]*Natural History Museum in Oslo and University of Oslo*

Seed size and dispersal in flowering plants are closely linked to a seedling's ability to successfully germinate and colonize new habitable areas. Over time, loss of animal dispersers or climate changes result in selection pressures that may influence seed size evolution. On the island of Madagascar, human colonization and climate changes caused a megafaunal extinction ~2000 years ago that disproportionately affected larger animal species. Several of these species, such as giant lemurs, were critical dispersers for large-seeded plants, and the effects of these extinctions on seed sizes of Madagascar's diverse flora are yet unknown. In contrast, large-seeded plants in mainland Africa continue to benefit from large-bodied seed dispersers such as the African elephant. Comparing seed sizes in these two regions may better our understanding of whether plants on Madagascar are adapting or going extinct in response to modern-day defaunation and climate change.

In our study, we will compare distributions of seed sizes in Madagascar and in mainland Africa for plants in the palm family (Arecaceae) to understand how Madagascar's recent megafaunal extinction and unique climate affect seed size evolution on the island. Preliminary results suggest that mean seed sizes for some members of the large-seeded Borasseae tribe are smaller on Madagascar than on mainland Africa. Though it is currently unknown whether this seed size difference has been primarily shaped by biotic (i.e., selection pressures from seed dispersers) or abiotic (i.e., climate) factors, the narrow range of seed sizes of Madagascar palm fruits relative to those of mainland Africa suggest potential specialization of Malagasy plants to smaller seed dispersers such as extant lemurs and birds. Future work will focus on extending this analysis to other genera in the Arecaceae family and investigating the underlying reasons why seed size differences in these two regions occur.

Identification of long-term flank motion at Pacaya Volcano, Guatemala, through InSAR time-series analysis

Judit Gonzalez-Santana[1] and Christelle Wauthier[1,2]

[1]*Department of Geosciences, The Pennsylvania State University, US*
[2]*Institute for Computational and Data Sciences, The Pennsylvania State University, US*

Volcanic flank collapse is one of the most dangerous hazards affecting communities and infrastructure near volcanoes. In Guatemala, 9,000 people live less than 5 km away from the summit of Pacaya, an active basaltic stratovolcano which shows evidence of past flank collapse and where field studies have highlighted factors which could promote failure of the southwest flank. To assess the hazards posed by this volcano, a better understanding of the deformation behavior and the factors promoting flank instability, as well as the triggers necessary for collapse, is required.

Interferometric Synthetic Aperture Radar (InSAR) is a useful tool for remote monitoring of surface deformation. In conventional differential InSAR, the difference in phase between two radar images is used to determine centimeter-scale ground deformation. Previous InSAR studies have thus identified episodes of flank motion at Pacaya, associated with eruptions in May 2010, as well as possibly in January-March 2014. However, differential InSAR provides no insights into longer-term displacements at this highly dynamic and vegetated volcano. In order to constrain the evolution of surface deformation at Pacaya Volcano over time, we perform InSAR time-series analysis using RADARSAT-2 and COSMO-SkyMed datasets acquired between 2010 and 2015, spanning a major eruptive episode in 2014.

For the first time, we reveal long-term flank motion of the southwest flank of Pacaya between 2011-2014, with an increased rate of motion coinciding with the 2014 eruptive period. Subsequent inversions suggest that slip on a southwest dipping detachment fault is likely accommodating the observed flank motion, and that slip was punctuated by dike intrusion during the 2014 eruption. This work highlights that long-term flank motion might be more prevalent than currently recognized and that an awareness of existing structural weaknesses such as detachment faults and of possible magma-faulting interactions is vital when assessing the likelihood and style of volcanic flank collapse.

Impacts of in situ microbial metabolisms on the isotopic composition of lake carbonates

Hanna Leapaldt and Miquela Ingalls

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Microbes living in ocean and surface water sediments are known to alter pore water chemistry. Specifically, through consuming and producing alkalinity and dissolved inorganic carbon (DIC) when metabolizing, microbes can increase or decrease the carbonate saturation state in porewaters. A change in carbonate saturation state can result in precipitation/dissolution of carbonate *in situ*. Diagenesis via remineralization is an active branch of research for marine sediments but is less studied for lacustrine systems. Closed basin lacustrine carbonate sediments record a history of regional hydroclimate and hydrological balance in their isotopic signatures, but dissolution-precipitation due to microbial metabolisms may cause an early diagenetic overprinting of that signal. To characterize such early diagenesis, we will study the carbon and oxygen isotopes of the shoreline sediments, the carbon isotopes of the pore water and organic matter, the dissolved ion chemistry of the pore water, and the microbial communities of the sediments in a closed basin lake with known microbial influences over carbonate mineralization — Green Lake in Fayetteville, NY. Preliminary results from the pore water of a Green Lake shoreline sediment core show a sharp decline in carbon isotope values within the first 5 cm below the sediment-water interface, potentially indicating active aerobic remineralization of organic matter in the sediment subsurface.

Investigating the dominant controls on nitrate transport and denitrification at two scales: from a single farm field to a HUC-10 watershed

Michael J. Forgeng, Andrew R. Shaughnessy, Jonathan M. Duncan, Susan L. Brantley

The Pennsylvania State University, Deike Building, University Park, PA 16802

The loss of nitrate from agricultural fields is a global hazard that degrades critical ecosystems and negatively impacts the health and way of life of regional populations. An overabundance of nitrate in a natural system, whether that be an estuary or stream, stimulates a process called eutrophication that causes algal blooms to thrive. These algal blooms can reduce the dissolved oxygen of an ecosystem to the point that aquatic life cannot thrive. The load of nitrate lost from farming communities is difficult to reduce because it is a non-point source of pollution. The goals of this study are to investigate how nitrate is lost from an individual farm to the larger watershed, identify what areas of the watershed contribute the highest loads of nitrate, identify the specific sources of nitrate at different points throughout the watershed (manure, inorganic fertilizer, atmosphere, etc.), and identify areas of the watershed where denitrification is occurring. Synoptic sampling campaigns conducted from 2017 to 2021 suggest that one catchment containing an abundance of livestock is a nitrate hotspot that contributes high loads of nitrate to the main stem of Shaver's Creek. Mass-balance techniques suggest that the load of nitrate introduced to the main stem via groundwater increases just before Shaver's Creek transitions to a 3rd order stream and larger cultivated catchments begin to discharge into the main stem. $\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^- values suggest that the majority of nitrate lost to the watershed is sourced from manure, and nitrate in the shallow subsurface (2.0 – 4.5 mbls) of our active farmland is sourced from a mixture of manure and inorganic NH_4^+ fertilizer. NO_3^-/Cl ratios paired with $\delta^{15}N$ and $\delta^{18}O$ values suggest that for every 0.5 mols of fertilizer-sourced nitrate introduced to the main stem, 1.2 mols of nitrate are reduced via denitrification.

Laboratory seismic faulting and early observations of slow-slip earthquakes

Raphael Affinito and Chris Marone

PSU Rock Mechanics Laboratory

Earthquakes are frictional instabilities, where elastic energy is suddenly released with the potential for catastrophic damage. The seismogenic zone is the range of depth in the lithosphere where brittle regimes enable dynamic rupture along surfaces. Earthquake phenomena are complex and dependent on temperature, pressure, and temporal processes [Scholz, 2002]. Despite the complexity, simple models and laboratory analogs prove valuable tools in understanding the mechanics which govern earthquake rupture. Traditional stick-slip earthquakes occur with slip durations of seconds, while slow-slip events can last days, months, or years [Schwartz and Rokosky, 2007]. The processes controlling the velocity and propagation of slow-slip events are unknown. Models and theoretical work have proposed dilatancy and other poroelastic mechanics as a possible driving force of quasi-static events [Mead, 1925; Frank, 1965; Segall et al., 2010]. Recent experimental studies have explored the relation of normal stress and stiffness on fault stability [Leeman et al., 2014a; Johnson et al. 2014]. Additionally, extensive work has been done at dry/humid conditions to characterize the velocity evolution of stability on fault mineralogy and normal stress [Carpenter et al., 2016; Ikari et al., 2016; Wojatschke et al., 2016; Leeman et al., 2016; Ryan et al., 2018]. Pore fluids are ubiquitous throughout the earth's crust, and the exact role they play in fault slip is poorly understood. The following work investigates the behavior of laboratory earthquakes in the presence of pore fluids. We produce the full spectrum of fault instabilities with a specific concentration on slow-slip events. We aim to relate slow-slip events to normal faulting, perturb the relation between pore fluid and fault stability, and observe the role of fluids on slip duration and velocity. The results provide valuable insight into the complexity of fault mechanics and conditions governing laboratory earthquakes.

Seismic observations of thunderquakes detected by the Penn State FORESEE array

Samuel Hone and Tieyuan Zhu

Department of Geosciences, The Pennsylvania State University, Deike Building, University Park, PA 16802

Thunderstorms are a common phenomenon that cause acoustic disturbances in the atmosphere which can interact with the ground surface, creating a link between atmospheric and solid Earth processes. These thunder-seismic events (here called thunderquakes) occur frequently in the eastern US and offer an abundant source of seismic waves that may be useful for tracking of lightning strikes and subsurface studies. Our previous study (Zhu and Stensrud, 2019) showed that the motion induced by these storms can be detected by distributed acoustic sensing (DAS), a method that uses existing fiber-optic cable to monitor ground motions and requires little setup while yielding high resolution data on the scale of tens of kilometers.

Using the 4.9 km DAS fiber-optic array on the Penn State Campus in State College, PA, we have detected over 120 thunderquakes associated with four thunderstorms through the spring and summer of 2019. Due to our dense array of sensors on the local scale, we are able to construct the seismic full waveform response of the thunderquakes and track the wave propagation across the array. Using a time-domain gridsearch, we obtain the back azimuth and slowness of the waves and implement a modified Geiger's method to pinpoint source locations of the thunderquakes. Correlated with the time of the recorded signal, this data allows reconstruction of thunderstorm movement. To understand the capabilities of thunderquakes for subsurface studies, we analyze the waveform to distinguish specific phases in the signal which have the potential to yield subsurface information.

Session 3: Oral Session

Thursday 8th April
12:45 pm – 2:00 pm

12:45 pm – 1:00 pm
Jacob Cipar
Ph.D. student, 3rd year, Pre-Comps
Active ultra-high temperature metamorphism in the lower crust of the Rio Grande Rift, NM

1:00 pm – 1:15 pm
Xiaoni Hu
Ph.D. student, 4th year, Pre-Comps, Petroleum Related
The sensitivity analysis of stratigraphic architecture and hydrologic conditions of lacustrine fills with changing climate in tectonic-active basin

1:15 pm – 1:30 pm
Samuel Shaheen
Ph.D. student, 2nd year, Pre-Comps
Investigating the sources and extent of groundwater contamination in areas of extensive oil, gas, and coal extraction using data mining

1:30 pm – 1:45 pm
Ruxue Liao
Ph.D. student, 3rd year, Visiting Student
Chemical weathering and physical erosion in three catchments with different lithologies along Shaver's Creek

1:45 pm – 2.00 pm
Charlotte Connop
Ph.D. student, 2nd year, Pre-Comps
Monazite and zircon petrochronological constraints on LP-HT metamorphism and shallow crustal differentiation: Trois Seigneurs Massif, French Pyrenees.

Active ultra-high temperature metamorphism in the lower crust of the Rio Grande Rift, NM

Jacob Cipar and Andrew Smye

Department of Geosciences, The Pennsylvania State University

Granulites and ultra-high temperature (UHT) metamorphic rocks record the chemical differentiation of continental crust, but determining the geodynamic mechanisms that drive such high-T metamorphism is difficult because granulite terranes are modified during their exhumation. To establish a direct link between active tectonic setting and UHT metamorphism, we conducted a systematic U-Pb petrochronological and thermobarometric investigation of <20 ka lower crustal xenoliths from the southern Rio Grande Rift (RGR), New Mexico. In metapelite xenoliths, zircon with Cenozoic U-Pb ages contain 30-70 ppm Ti, indicative of HT-UHT conditions (861-969°C), and rutile exhibits zero-age U-Pb dates, despite U concentrations between 3 and 30 ppm. Zircon from pyroxene granulite xenoliths exhibit similar Ti concentrations and have REE compositions that vary systematically with age: domains with U-Pb ages between 20 and 40 Ma are characterized by flat chondrite-normalized HREE slopes, whereas zones with younger U-Pb ages (5-20 Ma) have steep HREE slopes. Zircon Ti and rutile U-Pb data imply HT-UHT conditions in the RGR lower crust since the onset of regional extension ~36 Ma to the present day. Changes in zircon HREE concentrations record a transition from shortening to extension; older zircon grew within thickened Laramide crust at higher pressure, garnet-stable conditions, while younger zircon growth occurred at pressures lower than those required for garnet stability. Diagnostic indicators of HT-UHT in the lower crust are contiguous across the US-Mexico Basin and Range tectonic province, suggesting that these conditions represent an area on the order of thousands of km^2. Thermal-kinematic models demonstrate that the RGR likely attained HT-UHT conditions in response to mantle thinning following gravitational collapse of thickened lithosphere. We speculate that this tectonic process may explain the heat source for UHT metamorphism in exhumed terranes with similar *PTt* paths and modern settings where gravitational collapse and loss of a lithospheric root has been recognized (e.g. the Tibetan Plateau, and the Betic-Rif Arc).

The sensitivity analysis of stratigraphic architecture and hydrologic conditions of lacustrine fills with changing climate in tectonic-active basin

Xiaoni Hu and Liz Hajek

Geosciences department, Penn State University

Lacustrine deposits are fundamental elements of sedimentary records in terrestrial basins. They are ideal archive for paleoclimate and paleogeographic analyses due to their high sensitivity to allogenic forcing. The architecture of lacustrine deposits is sensitive to a variety of factors controlling sediment supply and accommodation creation. These external controls include variation of erosion rates, transport efficiency of sediment-routing systems, basin subsidence rate, and precipitation-to-evaporation ratio. Current depositional models divide lake deposits into three major associations according to different hydrological conditions: Fluvial-lacustrine facies association, fluctuating profundal facies association and evaporative facies association. However, few researches have linked the facies associations with quantitative data of climate and tectonics in modern lake system, and discussed the main drivers of the diversity in stratigraphic characteristics. This study aims to understand how different factors of sediment-routing systems respond to climate changes in tectonic-active basin.

We built a 2D mass-balance model to generate sediment packages and lakes in a back-tilted basin analogous to rift half-grabens. In order to understand the sensitivity of back-tilt basin deposits to different types of external forcing, we compared depositional facies, stratal stacking patterns, and lake-depth generated by model runs with different climatic and tectonic conditions. Meanwhile, we generated chronostratigraphic profiles to evaluate sedimentation rate through time and space. Our results indicate that the combinations of tectonic and climate conditions determine whether tectonic-active basins have open or closed hydraulic systems. The depositional systems respond to climate signals based on different hydraulic conditions. Climate acts on deposits by affecting the sediment flux into the basin in open lake systems, while climate put impact on basin fills through varying net water input. Our model demonstrated that lakes with different hydraulic conditions and associated stratigraphic records can exist in the same climate zone when tectonic condition is appropriate. The data compilation of modern lakes also supported our conclusion.

Investigating the sources and extent of groundwater contamination in areas of extensive oil, gas, and coal extraction using data mining

Samuel W. Shaheen[1], Tao Wen[2], Alison Herman[3], Susan L. Brantley[1,3]

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[2] *Department of Earth and Environmental Sciences, Syracuse University, Syracuse, NY, 13244, USA*
[3] *Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA 16802, USA*

The water resource impacts of unconventional oil and gas development (UOGD) can be difficult to delineate from longstanding geogenic and anthropogenic impacts on groundwater chemistry, particularly where UOGD may overlap with decades to centuries of legacy hydrocarbon extraction (conventional oil and gas, coal mining). In this study, southwestern Pennsylvania, U.S.A. was selected as a testbed to investigate how the overlap of intensive recent UOGD and widespread, longstanding hydrocarbon extraction in the region may impact water chemistry and the ability of data mining methods to delineate the impacts of the wide array of geogenic and anthropogenic contaminant sources present. Using a geospatial statistics-based data mining tool, locations where the concentrations of a species (e.g. methane) significantly increase nearby features of interest (e.g. unconventional oil and gas wells) were mapped across the study area. Additionally, unsupervised machine learning (non-negative matrix factorization, NMF) was applied to delineate endmember sources of groundwater species and their contributions to groundwater chemistry in the region. A small number of subregions where UOGD may have contaminated groundwater with methane or brine components were identified. However, the overlap of UOGD with legacy hydrocarbon extraction does not appear to make UOGD more prone to contamination, and methane migration incidents appear less frequent than in other areas of the state with extensive UOGD. However, significant increases in sulfate concentrations are widely observed nearby coal mining areas, and coal mining has elevated concentrations of sulfate above "baseline" on a regional scale. Additionally, chloride concentrations are significantly elevated nearby highways across the study area, and road salting is a regionally significant source of chloride in groundwater. Thus while UOGD may not be more prone to contamination incidents, regions of extensive hydrocarbon extraction are characterized by widespread, often overlapping sources of groundwater contamination that can be distinguished using data-driven methods.

Chemical weathering and physical erosion in three catchments with different lithologies along Shaver's Creek

Ruxue Liao[1, 2*], Xin Gu[1], Susan L. Brantley[1, 3]

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[2]*Lanzhou University*
[3]*Earth and Environmental Systems Institute, Department of Geosciences, The Pennsylvania State University, University Park*

Denudation rate (including chemical weathering and physical erosion), lithology, and soil thickness, determine the soil residence time of a hillslope at steady-state. Partitioning denudation rate into its chemical and physical components across different lithologies and soil properties is complex. Few studies have explored the relationship between denudation rate and soil properties across different lithologies.

We investigate how soil properties impact denudation rates in three small watersheds in central Pennsylvania (i.e., Cole Farm, Shale Hills, and Garner Run), which have different lithologies (i.e., calcareous shale, shale, quartzitic sandstone, respectively). We used geochemical and mineralogical analyses to quantify the extent of clay mineral weathering and chemical weathering flux in these three catchments. Additionally, utilizing geomorphologic analyses, we calculated hilltop curvature and soil diffusivity. Our results highlight three main findings. 1) the study site with longer soil residence time (lower denudation rate) shows clay mineral weathering that has proceeded to a greater extent. 2) Lithology influences the chemical weathering: the study site with more soluble minerals in the bedrock has a larger chemical depletion fraction (CDF) and chemical weathering flux in the soil, in contrast with the smaller extent of clay mineral weathering in this site. 3) Lithology also influences physical erosion: the diffusion coefficient for soil is negatively correlated to the fraction of fine particles (<6 μm fraction) in soil. Particle size is a good predictor for the diffusion coefficient for sites where the CDF is small. Particle size, however, does not reflect the soil diffusivity in landscapes where the CDF is high. This study provides insights into the controls on denudation as a function of lithology and hillslope topography.

Monazite and zircon petrochronological constraints on LP-HT metamorphism and shallow crustal differentiation: Trois Seigneurs Massif, French Pyrenees.

Charlotte Connop and Andrew Smye

Department of Geosciences, The Pennsylvania State University

Melting of continental crust is required for its chemical differentiation and yet is energetically intensive, requiring significant exogenic or endogenic heat. The prevailing paradigm is that granulite facies metamorphism, partial melting and attendant differentiation occur in the lower structural levels of thickened, radiogenic crust (e.g. [1]). Terranes that preserve evidence for partial melting under shallow crustal conditions thus pose a challenge to this paradigm and demand alternative heat sources and transport mechanisms. In this study, we present results from a monazite U-Th-Pb and zircon U-Pb petrochronological investigation of a classic low-pressure high-temperature (LP-HT) metamorphic terrane: the Variscan-age Trois Seigneurs Massif, France [2]. Pseudosections for four Cambro-Ordovician metapelitic samples spanning andalusite+cordierite to migmatite grades constrain the metamorphic field gradient and peak PT conditions. Low-grade andalusite-albite schists with prominent sedimentary layering yield peak conditions of <4kbar and 400-580 °C. Higher-grade garnet-cordierite schists record conditions of 3.8-4.4 kbar and 590-690 °C. A migmatitic gneiss records the onset of muscovite dehydration melting at 3.25-6 kbar and >695 °C. Application of garnet-biotite Fe-Mg exchange thermometry, GASP thermobarometry and average P-T reveals a clockwise metamorphic path with minor pressure loss during cooling (<0.3 kbar decrease per 100 °C cooling). Monazite U-Th-Pb dates from four samples constrain the duration of LP-HT metamorphism to between 317.4±12.1 Ma and 276.2±8.7 Ma. Monazite U-Th-Pb dates are contemporaneous with zircon U-Pb dates derived from a biotite granite unit, contiguous with migmatitic gneisses, constraining the age of crustal anatexis to 306 ± 3.25 Ma. Principal component analysis of monazite REEs identifies a strong influence of garnet growth with decreasing age, as seen in an increasing Gd/Yb with decreasing age.

[1] Clark, C., Fitzsimons, I. C. W., Healy, D., & Harley, S. L. (2011), *Elements*, *7*(4), 235–240.
[2] Wickham, S. M. (1987), *Journal of Petrology*, *28*(1), 127–169.

Session 4: Oral Session

Thursday 8th April
2:15 pm – 3:30 pm

2:15 pm – 2:30 pm
Guangchi Xing
Ph.D. student, 4th year, Post-Comps, Petroleum Related
Seismic velocity and attenuation models by Hessian based multiparameter viscoacoustic full waveform inversion

2:30 pm – 2:45 pm
Elisabeth Clyne
Ph.D. student, 4th year, Post-Comps
Glacial Hydraulic Tremor on Rhone Glacier

2:45 pm – 3:00 pm
Benjamin Hayworth
Ph.D. student, 4th year, Post-Comps
Space Weather and the Origin of Life

3:00 pm – 3:15 pm
Kalle Jahn
Ph.D. student, 5th year, Post-Comps
The fate of perfluoroalkyl acids in vadose zone soils irrigated with wastewater effluent

3:15 pm – 3.30 pm
Julia Carr
Ph.D. student, 4th year, Post-Comps
Orogen and reach scale patterns in rock strength, bedrock river morphology and sediment cover across the Taiwan Central Range

Seismic velocity and attenuation models by Hessian based multiparameter viscoacoustic full waveform inversion

Guangchi Xing, Tieyuan Zhu

The Pennsylvania State University

The traditional full waveform inversion (FWI) yields high-resolution seismic velocity model by iteratively minimizing the waveform residual between the synthetic and the observed seismograms. Beyond seismic velocity, seismic attenuation could provide complementary constraints on subsurface physical properties (e.g., temperature, permeability, and mineral composition) and structure (e.g., gas reservoir). Hence, it would be advantageous to develop the multiparameter viscoacoustic FWI to invert for both velocity and attenuation models simultaneously. However, one major challenge faced by the multiparameter FWI is the crosstalk (or trade-off) phenomenon, where the data-synthetic residual introduced by one model parameter is mistakenly assigned to another. This phenomenon gives rise to poor parameter resolution, which would harm the accuracy of recovered velocity and attenuation models.

One approach to mitigate the crosstalk is to take into account the information of the second-order Fréchet derivative, i.e., the Hessian, which indicates how the objective function derivative with respect to one model parameter changes with the variation of another one. In this study, we base on the fractional viscoacoustic wave equation, and develop the multiparameter FWI algorithms by incorporating the Hessian in three different fashions: Newton-CG (also known as truncated Newton), quasi-Newton (L-BFGS), and Hessian-diagonal-preconditioned conjugate gradient. Numerical experiments have conducted to compare the performances of different methods in different acquisition systems. Preliminary results indicate that the incorporate of Hessian can significantly mitigate the crosstalk issue, especially via the Newton-CG method, which is nonetheless the most computationally expensive.

Glacial Hydraulic Tremor on Rhone Glacier

Elisabeth Clyne[1], Margot Vore, Fabian Walter, Amandine Sergeant, Sridhar Anandakrishnan[1], Richard Alley[1]

[1]Department of Geosciences, The Pennsylvania State University

The hydrologic conditions beneath a glacier have a large impact on basal motion. Glacial Hydraulic Tremor (GHT) can be monitored to observe changes in location and distribution of channels beneath glacial ice, allowing the spatiotemporal evolution of subglacial hydrology to be studied continuously and remotely. We use Frequency Dependent Polarization Analysis (FDPA) to assess the temporal and spatial extent of glacial hydraulic tremor beneath Rhone Glacier, Switzerland, captured by a continuous seismic record through 2018 and 2019 at three moraine-based seismometers. This determines back azimuth to subglacial channels, capturing the seasonal shift from a distributed system to a channelized system, and allows comparison of channel locations within and across seasons, with implications for sediment evacuation and bed erosion. Across the three locations, there are notable sources of hydraulic tremor which vary based on locality and time of year, each with distinct frequency bands and back azimuth angels. The GHT clearly reflects the seasonal hydrologic cycle whereby the glacier transitions between an efficient, channelized system during the summer and to a distributed system in the winter. The successful use of GHT to monitor glacial hydrology on previously Taku glacier (the methods of which this project follows) and now Rhone glacier support passive seismic monitoring can be used to continuously and cost-effectively monitor basal hydrology across a variety of glacial systems for the first time ever.

Space Weather and the Origin of Life

Benjamin Hayworth[1], Guillaume Gronoff[2], Vladimir Airapetian[3], James Kasting[1], Kelly O'Donnell[1], Bradley Hegyi[4], Peng Liu[5]

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[4] *SSAI*
[5] *Ocean University of China*

Using a sophisticated suite of models (magnetohydrodynamic and kinetic models of solar energetic particle (SEP) acceleration and propagation, photochemical, and aqueous chemical), we ascertain the impact of a magnetically active young Sun on the prebiotic atmosphere of the Earth. We find that the enhanced solar wind and heightened flare activity from the young Sun acts to drive atmospheric chemistry on large scales, creating surface conditions favorable for the origin of life. Large fluence hard energy spectra SEPs penetrate, ionize and dissociate the prebiotic atmosphere, delivering large fluxes of prebiotically relevant molecules to the surface such as HCHO, HCN, and NOx – while also creating high mixing ratios of CO in the atmosphere which may have acted as a free-energy source for primitive metabolisms.

The fate of perfluoroalkyl acids in vadose zone soils irrigated with wastewater effluent

Kalle L. Jahn[1], Demian M. Saffer[1,2,3], Katherine H. Freeman[1], Sara A. Lincoln[4]

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Perfluoroalkyl acids (PFAAs), synthetic compounds associated with adverse human health impacts, are commonly discharged from wastewater treatment facilities. If that effluent is used for irrigation, the environmental fate of PFAAs will depend primarily on vadose zone PFAA retention properties. Efforts to determine which soil properties are the primary factors controlling PFAA retention in the vadose zone have consisted predominantly of laboratory studies, so the relative importance of the retention factors under natural conditions remains uncertain. Using soil cores collected from the Living Filter (irrigated with wastewater effluent for ~60 years), we evaluated the soil properties controlling PFAA fate and transport in vadose zone soils under near-natural conditions. Soil organic carbon content and bulk density showed significant correlations ($p < 0.5$) with PFAA concentrations, and correlation strength generally increased with PFAA carbon chain length. Field-based PFAA soil-water distribution coefficients were calculated using soil and effluent PFAA concentrations and normalized to organic carbon content (K_{oc}). Our K_{oc} means were ~2 orders of magnitude higher than means calculated from previously reported K_{oc} values. This discrepancy may be due in part to other retention factors or higher historical effluent PFAA concentrations, but could also be evidence for sorption/desorption hysteresis. Despite the unusually high K_{oc} values, K_{oc} tended to increase with carbon chain length, aligning with previously reported trends, though short-chain PFAA (< 5C) K_{oc} values deviated strongly from that pattern. Simple 1D perfluorooctanesulfonic acid (PFOS) transport models showed that the observed PFOS profile equilibrates in ~1 year, and that the total PFOS mass stored in Living Filter soils is less than the mass applied annually in the effluent. These results indicate that under wastewater irrigation scenarios with relatively low PFAA effluent concentrations, vadose zone soils will not serve as long-term buffers against groundwater contamination or long-term PFAA sources if PFAAs are removed from effluent.

Orogen and reach scale patterns in rock strength, bedrock river morphology and sediment cover across the Taiwan Central Range

Julia C. Carr [1], Roman A. DiBiase [1], and En-Chao Yeh [2]

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The strength of potential orogen-scale feedbacks between surface and deep Earth processes is sensitive to how rock strength influences bedrock river incision. Both the erodibility of in-channel bedrock and the grain size of sediment supplied to the channel can be influenced by rock properties, leading to a complex suite of local and non-local lithologic controls on channel morphology. Quantifying rock strength controls on channel morphology at the orogen scale is difficult, as rock strength can vary at a range of scales and measuring channel morphology and sediment grain size is difficult in steep landscapes. Uncrewed aerial vehicle (UAV) surveys enable mapping at high enough resolution to capture channel geometry and sediment cover, while at large enough spatial scales to account for local heterogeneity.

Here, we focus on the Taiwan Central Range, where both the metamorphic grade and the degree and orientation of metamorphic foliation and fracturing vary systematically depending on rock burial and exhumation history. Paired UAV photogrammetry and field surveys span 60 km of bedrock river channel in 21 reaches, and sample systematically across all formations and lithologies present in the range. We directly measured channel morphology and sediment cover in each surveyed channel and tributary. These measured variations in channel slope, width, and depth indicate that either bedrock erodibility or sediment transport thresholds would need to vary by 1-2 orders of magnitude at the reach scale, or over 4 orders of magnitude at the orogen scale. In addition, the size of hillslope derived coarse sediment systematically increases with metamorphic grade and uplift rates, which can lead to otherwise similar morphologies eroding at very different time scales. While natural systems have abundant local variability, data rich approaches like these can help tease out systematic variations at large scales.

Session 5: Oral Session

Thursday 8th April
3:45 pm – 5:00 pm

3:45 pm – 4:00 pm
Erica Lucas
Ph.D. student, 3rd year, Pre-Comps
Upper mantle seismic anisotropy of Antarctica from shear wave splitting analysis

4:00 pm – 4:15 pm
Clay Wood
Ph.D. student, 4th year, Pre-Comps, Petroleum Related
Relating fracture aperture to hydro-mechanical properties of dynamically stressed tensile fractured rock

4:15 pm – 4:30 pm
Andrew Shaughnessy
Ph.D. student, 3rd year, Pre-Comps
Water Flowpath and Source Chemistry Control C-Q Relationships Across Spatial Scales

4:30 pm – 4:45 pm
Chanel Deane
Ph.D. student, 3rd year, Pre-Comps
Effects of Source Scaling on Local-Distance P/S Amplitude Ratios for Seismic-Source Discrimination

4:45 pm – 5.00 pm
Claire Webster
Ph.D. student, 3rd year, Pre-Comps
Geochemical insights into the roles of endogenous metabolites on phosphate mineral formation in urine

Upper mantle seismic anisotropy of Antarctica from shear wave splitting analysis

Erica Lucas[1], Natalie J. Accardo[1], Andrew A. Nyblade[1], Andrew J. Lloyd[2], Richard C. Aster[3] (), Douglas A. Wiens[2], John Paul O'Donnell[4], Graham W. Stuart[4], Terry J. Wilson[5], Ian W. Dalziel[6], J. Paul Winberry[7], Audrey D. Huerta[7]

[1] *Penn State*
[2] *Washington University in St. Louis*
[3] *Colorado State University*
[4] *University of Leeds*
[5] *Ohio State University*
[6] *University of Texas*
[7] *Central Washington University*

We examine azimuthal anisotropy across the Antarctic continent using 103 new shear wave splitting measurements obtained from teleseismic SKS, SKKS, and PKS phases. After using an eigenvalue technique to estimate the fast polarization direction and delay time for each phase arrival, we stack high-quality measurements to determine the best splitting parameters for each seismic station. Fast anisotropic directions are not consistent with the Antarctic absolute plate motion, indicating that the anisotropic fabric does not result from shear associated with the motion of the Antarctic plate over the mantle. Our results, combined with previously reported shear wave splitting measurements, reveal a number of distinct mantle regimes in West Antarctica, East Antarctica, and the Transantarctic Mountains. We attribute anisotropy observed across much of West Antarctica to Jurassic – Cenozoic tectonism, including subduction along the paleo-Pacific margin of Gondwana, the breakup of Gondwana and concurrent extension of the Weddell Sea Rift System, the extension of the West Antarctic Rift System, and mantle plume impingement in Marie Byrd Land. Anisotropy in the southern Transantarctic Mountains is best associated with the late Cretaceous extension of the West Antarctic Rift System, while anisotropy in the northern Transantarctic Mountains likely reflects both the Cretaceous initiation of West Antarctica Rift System extension and localized Cenozoic extension in the Ross Sea. With the exception of the coastal regions, we attribute much of the anisotropy observed across East Antarctica to Precambrian tectonism. We suggest that relatively uniform fast polarization directions found across the Gamburtsev Subglacial Mountains and Vostok Subglacial Highlands can be associated with the Late Mesoproterozoic Pinjarra Orogeny. Variability of shear wave splitting measurements evident in near-coastal regions of East Antarctica likely reflects processes associated with the early rifting stages of Gondwana.

Relating fracture aperture to hydro-mechanical properties of dynamically stressed tensile fractured rock

Clay Wood[1], Prabhakaran Manogharan[2], Parisa Shokouhi[2], Jacques Rivière[2], Derek Elsworth[3, 1], Chris Marone[1, 4]

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[3]*Dept. of Energy and Mineral Engineering, EMS Energy Institute, and G3 Center, Pennsylvania State University*
[4]*Dipartimento di Scienze della Terra, La Sapienza Università di Roma*

The focus of this study is to elucidate the relation between elastodynamic and hydraulic properties of fractured media subjected to local stress perturbations in relation to fracture aperture distribution. Experiments are conducted on intact then pre-fractured, samples of Westerly granite biaxially-loaded in a pressure vessel with permeability evolution measured from fluid flow-through of deionized water. Oscillations of pore pressure are applied at amplitudes ranging from 0.2 to 1 MPa at 1H. The experiments consider the influence of fracture aperture with perturbations at applied normal stresses 5 to 20 MPa (reducing aperture with increasing effective normal stress). During the dynamic stressing an array of piezoelectric transducers (PZTs) continuously transmit and receive ultrasonic pulses across the fracture to monitor the evolution of elastic response. Concurrent measurements of changes in ultrasonic wave velocity and amplitude due to dynamic stressing are conducted to simultaneously measure the contact acoustic nonlinearity and permeability evolution. The fracture roughness and aperture evolution with stress are imaged using two complementary techniques: (1) high resolution profilometry of fine-scale features and (2) pressure sensitive film at average stresses ranging from 3 to 21 MPa to monitor asperity deformation. The real area of contact and asperity deformation data from these imaging methods allow us to evaluate the openness/closedness across the surface. We compare ultrasonic velocity and RMS amplitude in regions predominately open to closed and then relate these results to the permeability to better understand clogging/unclogging mechanisms prevalent in pore fluid pressure oscillations. Future work includes laboratory experiments with fractures of different roughness and varying amounts of synthetic wear material and developing a physics-based numerical simulation of laboratory experiments (using high-resolution profilometry and experimental boundary conditions) to probe the micromechanical features of fractured rock interfaces.

Water Flowpath and Source Chemistry Control C-Q Relationships Across Spatial Scales

Andrew R. Shaughnessy[1,*], Tao Wen[3], Susan L. Brantley[1,2]

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*(*Correspondence: ars637@psu.edu)*
2. Earth and Environmental Systems Institute, Pennsylvania State University, USA
3. Department of Earth and Environmental Sciences, Syracuse University, USA

Hydrologists are learning to predict concentration-discharge (C-Q) behaviors for solutes in streams, because we need to understand how streams will respond to climatic, hydrologic, and anthropogenic changes in the future. The C-Q behavior of sulfate is complex because different subsurface flowpaths transport sulfate from different sources. For example, pyrite oxidation typically releases sulfate deep in the subsurface; therefore, deeper flowpaths tend to transport this sulfate to streams. Additionally, acid rain and fertilizers can release solute that is transported to streams via shallow flowpaths or surface runoff. We hypothesize that the dominant flowpath and sulfate source control C-Q behavior across spatial scales. Here, we investigate this hypothesis in four nested watersheds in the northeastern United States: Shale Hills (0.08 km^2), the Shavers Creek watershed (165 km^2), the Juniata River watershed (1,960 km^2), and the Susquehanna River watershed (71,250 km^2). Using the major ion chemistry and an unsupervised machine learning model, we separate the sources of sulfate in each sample. Additionally, we quantify the ratio of baseflow to streamflow (baseflow index; BFI) as a proxy for groundwater inputs into the stream using discharge data. We found that in both Shavers Creek and the Susquehanna River, sulfate in the headwaters was predominantly derived from acid rain, and that contributions of pyrite-derived sulfate increased downstream. Sites with low pyrite-derived sulfate and low BFI tended to show slopes on plots of C vs. Q that are close to zero (chemostatic) and sites with high pyrite-derived sulfate and high BFI tended to show steeper negative slopes (dilution C-Q behavior). Based on our finding, we predict steeper C-Q slopes in the future as watersheds recover from the impacts of acid rain and as agricultural best management practices reduce fertilizer runoff. Using machine learning techniques with C-Q data will help predict river chemistry into the future.

Effects of Source Scaling on Local-Distance P/S Amplitude Ratios for Seismic-Source Discrimination

Channel Deane[1], Charles Ammon[1], Azangi Mangongolo[2], Andrew Nyblade[1], Raymond Durrheim[2]

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Methods to discriminate between earthquakes and explosions using observations from teleseismic and regional distances have been widely investigated and employed. These earlier studies explored discriminant performance using observations from high yield (generally > 1kiloton) explosions recorded at distances greater than 200 km. Many discriminants rely on the amplitude ratio of P and S waves, which vary with source type as a result of the strong difference in shear-wave energy radiated by earthquakes and explosions. Recent studies have used a similar strategy to investigate P/S discriminant performance on smaller, low yield events observed at close distances (<200km), which require more scrutiny of path effects, site responses, and source corrections. We use local distance observations (<35km) from the Klerksdorp gold mining region of South Africa to investigate P/S discriminant performance on low-magnitude mining-related events ($1 \leq M_L \leq 4.3$). The dataset includes observations from 192 mining-related events (pillar collapses, rock bursts, etc.), the August 5th, 2014 M 5.5 Orkney earthquake, and 55 suspected aftershocks. Events extend to depths of ~10km but do not include known explosions, so we compare P/S ratios for earthquakes and mining-related events. Network-averaged P/S amplitude ratios show little difference between both event populations in multiple frequency bands (1-30Hz). Most of the events are small and the amplitude observations correspond to frequencies below the expected source corner frequencies. Linear regression analysis with a simple geometrical spreading model (1/distance) show a good fit to the measured data at the farthest distances with strong influence from the source excitation factors. We extend the linear regression analysis to include a piecewise linear function to better fit the portion of our observations that are only a few wavelengths from the source. We discuss the results of both linear regression analyses in an effort to characterize the sources in the available event population.

Geochemical insights into the roles of endogenous metabolites on phosphate mineral formation in urine

Claire Webster[1], Julie Cosmidis[2], Jenn Macalady[1]

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[2]University of Oxford

Phosphate minerals are highly insoluble phases that precipitate in both natural and engineered environments. In environmental engineering, we aim to induce phosphate precipitation to effectively remove dissolved phosphate from wastewater and harvest the precipitate for use as fertilizers. Conversely, in the biomedical filed, we want to inhibit phosphate precipitation in the human body to prevent the formation pathological calcifications such as kidney stones. It is imperative to understand the biogeochemical parameters that influence the rate of phosphate mineralization and the mineralogical properties of the precipitates.

Organics, such as endogenous metabolites, are present in urine. While it has been suggested that some metabolites may act as mineralization inhibitors, many metabolite-mineral interactions remain poorly understood. In a sterile synthetic urine medium, we separately introduced several metabolites, and phosphate precipitation was induced in each experiment by raising the solution's pH. Filtered urine was sampled before, immediately after, and 24 hours after precipitation was induced. Mineral precipitates were also collected immediately following and 24 hours after the precipitation was induced.

Mineral precipitates were analyzed using light microscopy, SEM-EDS, and FTIR. The chemical composition of the urine at each time point was analyzed using ICP-AES. Light microscopy and SEM-EDS showed mineral grains with characteristic struvite morphologies rich in magnesium and phosphorus, as well as a fine-grained mineral phase rich in calcium and phosphorus. FTIR confirmed the presence of struvite and of a calcium-phosphate phase in all experiments. However, the spectra revealed some variability in the mineralogical composition and proportions of phosphate phases precipitated in each experiment. ICP-AES also showed that the amount of calcium, magnesium, and phosphorus removed varied between each system. Ultimately, we determined the metabolites tested do not significantly change the total quantity of phosphate precipitated in the different experiments, but they do alter precipitate mineralogy in ways that deserve further investigation.

Friday 9^{th} April

Session 1: Oral Session

Friday 9th April
9:00 am – 10:30 am

9:00 am – 9:15 am
Opening Remarks

9:15 am – 9:30 am
Emma Hartke
Master's student, 1^{st} year
Lipid biomarker analysis as a tool for understanding human and environmental conditions during the middle Neolithic (Dalmatia, Croatia)

9:30 am – 9:45 am
Copeland Cromwell
Master's student, 2^{nd} year
Reconfiguration of North America – Pacific Plate Motions and Implications for Accretionary Processes Along the Southern Queen Charlotte Fault

9:45 am – 10:00 am
Kaelie Contreras
Master's student, 2^{nd} year
Seismic Imaging of the Bushveld Complex, South Africa

10:00 am – 10:15 am
Kayla Irizarry
Master's student, 2^{nd} year
A Macroecological Perspective on The Cambrian Origins of Rhynchonelliform Brachiopods

10:15 am – 10:30 am
Safiya Alpheus
Master's student, 2^{nd} year, Petroleum Related
Reconstructing river bar morphodynamics in ancient fluvial deposits

Lipid biomarker analysis as a tool for understanding human and environmental conditions during the middle Neolithic (Dalmatia, Croatia)

Emma Hartke and Kate Freeman

Department of Geosciences, The Pennsylvania State University

Records of geologic and anthropogenic change during the middle Neolithic/Upper Holocene show global deglaciation trends coupled with a series of key changes to human activity. Principal among these changes include the slow encroachment of human groups into Europe and the gradual shift from nomadic, pastoral lifestyles to stationary, agrarian (farming) lifestyles. The temporal resolution of these geologic and anthropogenic events, however, is less clear. To to separate geologic versus anthropogenic signals in the paleorecord and to resolve questions of timing requires the use of a suite of geochemical tools. This research study will use lipid biomarker analysis, in addition to carbon and oxygen isotope records; charcoal data; and pollen records to reconstruct the presence and pace of human and environmental changes during this period. We will use lacustrine core samples from a paleolake near a mid-Neolithic human habitation site Krivače, located along the Dalmatia Coast (Croatia), to complete this investigation. By the end of this project, we hope to assess two hypotheses related to the timing and appearance of human-environmental events: (1) the biomarkers present include/indicate early signs of agriculture practices at Krivače, and (2) the biomarker distribution indicates local changes to temperature and hydrology consistent with a warmer and more arid climate. Addressing these points within this study will help us improve the timeline of early human history and reckon with human-environmental changes in a rapidly warming climate.

Reconfiguration of North America – Pacific Plate Motions and Implications for Accretionary Processes Along the Southern Queen Charlotte Fault

Copeland Cromwell and Kevin Furlong

Department of Geosciences, Penn State University

We evaluate recent changes to plate kinematics and associated deformation along the southern portion of the Queen Charlotte Fault (QCF) (~900 km long right-lateral fault) near offshore Haida Gwaii over the past ~6 Ma. The QCF accommodates ~50 $mm\text{-}yr^{-1}$ of margin parallel dextral motion and has hosted two of Canada's largest instrumentally recorded earthquakes: the 2012 M_w 7.8 thrust event which occurred along the base of the Queen Charlotte Terrace (QCT) and the 1949 M_w 8.0 right-lateral strike-slip event which occurred along the QCF. These events imply that the QCT is neither fully coupled with the Pacific or the North American Plate. We investigate the development of the southern QCT in response to recent transpression along the QCF. Utilizing historic offshore USGS seismic reflection surveys and seismic (receiver function) crustal velocity structure we model flexure of the Pacific Plate and constrain the extent of Pacific Plate underthrusting beneath Haida Gwaii. Models indicate a minimum of 30 km of Pacific underthrusting along southern Haida Gwaii and 50km of underthrusting at ~54°N, near the northern extent of Haida Gwaii. Flexural profiles and geometries are further utilized to constrain both the volume and density of the QCT yielding insight into terrace composition and formation. Densities of 2600 kg/m^3 for the QCT are required in flexural models, which is also consistent with seismic velocity models for the QCT. Modeled densities and velocities indicate that the QCT is likely an aggregation of marine sediment and oceanic crust which have been amalgamated along the Pacific-North American plate boundary associated with the reorientation of plate motions at ~6 Ma. Additionally, truncations associated with the Miocene-Pliocene unconformity were used in tandem with plate motions to reconstruct sediment thickness adjacent to Haida Gwaii over the past 6 My allowing development of an accretionary model. These accretionary models indicate that the QCT may have formed rapidly following the onset of transpression. The QCF offshore Haida Gwaii is typically viewed as a dextral strike-slip fault, however our models suggest that there is a sufficient convergent component to drive the rapid development of the QCT through accretionary processes following reconfiguration of Pacific-North America plate motions.

Seismic Imaging of the Bushveld Complex, South Africa

Kaelie Contreras[1], Andy Nyblade[1], Raymond Durrheim[2], Andriamiranto Raveloson[2]

[1]*Penn State University*
[2]*University of the Witwatersrand*

This study addresses the limited understanding of upper crustal structure beneath the Bushveld Complex, South Africa. Upper crustal structure and Moho depths are investigated using the joint inversion of P-wave receiver functions and Rayleigh Wave group velocities with an aim to determine whether there is structural continuity in the subsurface between the western and eastern limbs of the Bushveld Complex. Passive source seismic data are acquired from forty broadband seismic stations, including 2015 - 2020 data from the Africa Array network, Bushveld network, and Global Seismic Network, as well as 1997 - 1999 data from the South African Seismic Experiment. The combination of these networks provides fairly uniform station coverage over most of the Bushveld Complex. Receiver functions are calculated from these teleseismic earthquakes and Rayleigh wave group velocities are obtained from an ambient noise tomography of southern Africa. Prior to the joint inversion of these two datasets, ray parameters and back-azimuths are manually binned using individual station characteristics. Preliminary 1-D shear wave depth-velocity models for each station produced from the joint inversion show complicated upper crustal structure with high velocity zones, indicative of the mafic/ultramafic layering that is present beneath some of the stations across the interior of the complex.

A Macroecological Perspective on The Cambrian Origins of Rhynchonelliform Brachiopods

Kayla Irizarry and Mark Patzkowsky

Department of Geosciences, The Pennsylvania State University

This study examines the environmental origins of the Rhynchonelliformea, a successful clade of brachiopods that dominated post-Cambrian benthic communities. Rhynchonelliform brachiopods were dominant in nearshore environments in the Early Ordovician and then spread offshore. Cambrian environmental distributions are less well known for this group. An important question is, how does the environmental distribution of rhynchonelliform brachiopods in the Cambrian relate to their post-Cambrian environmental distribution?

A database of approximately 350 Cambrian and Lower Ordovician marine faunal assemblages in North America was compiled from the Paleobiological database, and additional literature sources. These data were vetted, and faunal assemblages were assigned to onshore-offshore depth-related habitat zones. Distribution patterns show that Cambrian rhynchonelliforms were widely distributed along the onshore-offshore gradient in the early Cambrian but became more restricted in the Late Cambrian. The Obolellata occurred across the onshore-offshore gradient in the Early Cambrian but were restricted to slope and basin in the Middle Cambrian before going extinct. The Kutorginata occurred across the onshore-offshore gradient in the Early and Middle Cambrian, before going extinct. The Rhynchonellata occurred across the shelf during the Lower Cambrian and Middle Cambrian, with highest diversity in the outer shelf and slope and basin. In the Late Cambrian, the Rhynchonellata shifted their center of diversity into inner shelf environments. These patterns suggest that the rhynchonelliform brachiopods diversified rapidly to occupy the entire onshore offshore gradient in the Early Cambrian. By the Late Cambrian the Obolellata and Kutorginata were extinct and the center of diversity of the remaining classes shifted to inner and middle shelf environments. This group included the Rhynchonellata and the Strophomenata, which went on to dominate Ordovician marine benthic communities. Thus, the onshore diversification of rhynchonelliform brachiopods in the Ordovician had its roots in the Cambrian.

Reconstructing river bar morphodynamics in ancient fluvial deposits

Safiya Alpheus and Elizabeth Hajek

Department of Geosciences, Penn State University

Reconstructing river bar dynamics from the sedimentary record can provide important insight into channel migration and mobility under different boundary conditions and can reveal how channel networks responded to past changes in climate and land cover. While qualitative and descriptive interpretations are useful for comparisons between systems, without approaches for more quantitative, process-based reconstructions, we are limited in our ability to leverage insight from the deep-time sedimentary record for understanding and predicting channel morphodynamics in modern rivers.

Here we explore how bar kinematics and morphodynamics are preserved in the fluvial sedimentary record and how to best use this information to reconstruct channel-belt evolution through time. Using numerical simulations of braided river systems under different flow and sediment supply conditions, we track the growth and reworking of bar packages to develop statistical expectations for bar-package geometry, persistence and preservation. We use digital outcrop models, satellite data and field observations of modern and ancient braided systems to compare the geometry, architecture, facies distribution and kinematics in field settings to model outputs.

Our results show a relationship between the degree of preservation of braided bar deposits and rate of channel-thread reorganization in braided systems; rapidly migrating and deforming channel threads result in more reworking and lower bar-deposit preservation. Additionally, we observe difference in the coherence of bar packages as they migrate during constant and variable flow conditions. We use these results to interpret the degree to which our ancient observations represent rapidly migrating and deforming channel systems, and which represent rapidly avulsing systems.

Session 2: Oral Session

Friday 9th April
10:45 am – 12:00 pm

~~10:45 am – 11:00 am~~ –Withdrawn
~~Youki Sato~~
~~Ph.D. student, 1st year, Pre-Comps~~
~~*Applications of the Orbitrap GC-MS system for Position-Specific Isotope Analyses (PSIA)*~~

11:00 am – 11:15 am
Junzhu Shen
Ph.D. student, 3rd year, Pre-Comps
Seismic noises recorded by telecommunication fiber optics reveal the impact of COVID-19 measures on human activities

11:15 am – 11:30 am
Kaitlyn Horisk
Ph.D. student, 2nd year, Pre-Comps
Climate-Vegetation Dynamics in Dhofar, Oman from the Mid-Holocene to Present

11:30 am – 11:45 am
Adam Benfield
Ph.D. student, 2nd year, Pre-Comps
Terrestrial ecosystem response to abrupt climate change during the last deglaciation at Mono Lake, California, USA

11:45 am – 12:00 pm
Emily Schwans
Ph.D. student, 2nd year, Pre-Comps
Modeling Insights into a Rapidly-Thinning Outlet Glacier in W. Antarctica

WITHDRAWN

Applications of the Orbitrap GC-MS system for Position-Specific Isotope Analyses (PSIA)

Youki Sato and Kate Freeman

Department of Geosciences, The Pennsylvania State University

The Orbitrap gas chromatography-mass spectrometry (GC-MS) system possesses high precision (mass accuracy down to the 5th decimal point) and mass resolution capacities for sample sizes down to 1 ng for a wide variety of compounds. This system offers promise for the position-specific isotope analysis (PSIA) of a variety of applications, including small organic acids relevant to essential biological processes.

Observing the intramolecular isotope fractionations imparted to natural compounds during synthesis will offer new insights regarding the origin and evolution of life on Earth. Analyzing the intramolecular isotopic signature of a given molecule will allow researchers to differentiate molecules formed from biological vs. abiotic sources, including the reactions involved in their formation. These patterns will inform the search for life on other planets as the intramolecular isotopic patterns seen on Earth that are attributed to biological reactions will be a useful reference during the analysis of organics collected from extraterrestrial sources.

The fixation of inorganic carbon species such as CO_2 for growth is one such fundamental biological process. Plants and microbes impart an intramolecular isotope pattern on carbohydrates synthesized as a result of photosynthesis-associated CO_2 fixation (Gilbert et al., 2012), and this pattern affects the isotopic signature of lipids and other biomolecules synthesized from these reactants (Monson and Hayes, 1982). However, the knowledge of isotope fractionations occurring to metabolic intermediates downstream of photosynthesis is very limited, making it difficult to interpret the position-specific patterns of natural compounds.

Using the Orbitrap GC-MS system and beginning with the study of pyruvic acid as a representative organic acid metabolic intermediate, I aim to determine the position-specific fractionations that are imparted to molecules during each step of the metabolic pathway involved in the synthesis of biomolecules. Pyruvate was chosen for its central role in generating energy as well as in the synthesis of certain essential biomolecules, including isoprenoids, fatty acids, and amino acids. The method development process for the PSIA of organic acids via the Orbitrap system will be discussed, along with potential applications of PSIA to answer questions regarding the origin of life on Earth and elsewhere.

Seismic noises recorded by telecommunication fiber optics reveal the impact of COVID-19 measures on human activities

Junzhu Shen and Tieyuan Zhu

Department of Geosciences, The Pennsylvania State University.

Recent world-wide quieting of seismic noise caused by COVID-19 lockdown has been observed by seismometers. However, current seismic networks are sparse in metropolitan areas, making it difficult to reveal the spatiotemporal characteristic of seismic noise impacted by COVID-19 measures. Using noise recordings by a dense distributed acoustic sensing (DAS) array in State College, PA, we highlight not only seismic noise reduction (0.01-100 Hz) in different city blocks during the period of stay-at-home, but also noise recovery in 10-100 Hz in Phase Yellow/Green. Interestingly, we find unexpected loss-to-flat seismic noise in 0.01-10 Hz, suggesting the low level of pedestrian movement in May-June 2020. This is further verified by temporal changes of human activities (e.g. footsteps, road traffics, and machines). Our study suggests that DAS recordings using city-wide fiber optics could be used for quantifying the impact of COVID-19 measures on human activities in city blocks.

Climate-Vegetation Dynamics in Dhofar, Oman from the Mid-Holocene to Present

Kaitlyn Horisk[1], Sarah Ivory[1,2], Joy McCorriston[3]

[1]*Penn State University Department of Geosciences*
[2] *Penn State University Institutes of Energy and the Environment*
[3]*Ohio State University Department of Anthropology*

Dhofar, Oman is a unique region that while arid is highly biodiverse, and arid regions such as this are especially at risk from climate and land use change. However, as of now these drivers of environmental change are poorly understood. The paleoecological record can offer a critical perspective. Rock hyrax (*Procavia capensis*) middens host a variety of paleoenvironmental indicators and preserve fossil pollen effectively. Pollen grains are diagnostic of a plant taxon and identifying the types of plants present and counting their relative abundances allows for the reconstruction of plant communities. Discrete samples of different ages, from the same area, can be assessed for changes in the vegetation community through time. Here I present pollen data of 26 samples from Wadi Dhahabun, located in the Dhofar Nejd (desert), that have calibrated radiocarbon ages spanning the last 4000 years. The Nejd region was characterized by moister conditions during the Holocene, where a stronger Indian monsoon extended further inland. Through time the monsoon weakened, and the Nejd became more arid. Today the geographical extent of monsoonal rainfall is limited to the coastal plain and escarpment regions. The pollen data from the midden samples reveal taxa that now reside on the escarpment, within the modern extent of monsoonal cloud forests, existed in the Nejd region during the mid-Holocene. Arboreal taxa declined through time while more herbaceous taxa increased, representative of a turnover in vegetation composition forced by changing climate.

Terrestrial ecosystem response to abrupt climate change during the last deglaciation at Mono Lake, California, USA

Adam Benfield[1], Sarah Ivory[1], Bailee N. Hodelka[2], Guleed Ali[3], Susan R. H. Zimmerman[4], Michael M. McGlue[2]

[1]*Penn State*
[2]*University of Kentucky*
[3]*University of Maine*
[4]*Lawrence Livermore National Lab*

Terrestrial ecosystems of the western US are threatened by increasing temperatures, aridity, and fire activity, but the long-term effects of abrupt change like we are currently experiencing are poorly understood. Here, we present a microfossil analysis of sedimentary pollen, charcoal, and the dung-fungus *Sporormiella* from Mono Lake, California that documents terrestrial ecosystem response to abrupt climate change during the last deglaciation (16 – 9ka). The record shows that late Pleistocene Juniper-Pine-Sage communities surrounding Mono Lake alternated between more open or closed conditions driven by wildfires in response to abrupt changes in temperature. However, regional vegetation composition remained stable on millennial times scales until sustained aridity, wildfires, and a rapid increase in temperatures at the early Holocene. A decline in xeric shrubs from 14.9 – 12.9 ka indicates that warm interstadials were slightly wetter than the cool Heinrich Stadial 1 and Younger Dryas. This suggests observed regional lake highstands during stadial events were driven largely by reduced temperatures rather than precipitation. In conjunction with climate, herbivory by Pleistocene megafauna reduced herbaceous taxa around Mono Lake until their local decline at 15.0 ka, preceding the warming at the end of Heinrich Stadial 1 and before their final extinction at 11.4 ka. These results show that Sierran hydrology and vegetation are strongly controlled by abrupt temperature changes. Future temperature increases over the next century may pose a significant threat to these ecosystems.

Modeling Insights into a Rapidly-Thinning Outlet Glacier in W. Antarctica

Emily Schwans[1], Byron R. Parizek[1,2], Richard B. Alley[1], Mathieu Morlighem[3], Pierre St-Laurent[4], Ryan T. Walker[5]

[1]*The Pennsylvania State University, University Park*
[2]*The Pennsylvania State University, DuBois Campus*
[3]*University of California, Irvine*
[4]*Old Dominion University*
[5]*University of Maryland, College Park.*

Thwaites Glacier's (TG's) accelerating mass loss and connection to major drainages in the West Antarctic Ice Sheet (WAIS) make it the most likely pathway by which the ice sheet could rapidly contribute to sea-level rise (SLR). As TG's floating ice shelf is melted and weakened from below by warm Circumpolar Deep Water (CDW), flux across the grounded-to-floating transition increases, thinning inland ice to flotation. In this inland-deepening ice sheet, the grounding line is likely to retreat in a positive feedback loop into thicker ice grounded farther below sea-level, eventually allowing CDW to access the interior of the WAIS.

Results using JPL's Ice Sheet and Sea-Level System Model (ISSM) show how the timing and rate of TG's projected contribution to SLR depend on ill-constrained conditions at the bed and the ice/ocean interface. A model ensemble provides insight into the relative importance of these conditions–and their interplay–in TG's evolution over the next few centuries.

<u>Session 3: Oral Session</u>

Friday 9th April
1:00 pm – 2:15 pm

1:00 pm – 1:15 pm
Hee Choi
Ph.D. student, 2nd year, Pre-Comps
The role of continental lithosphere in subduction initiation

1:15 pm – 1:30 pm
Nolan Roth
Ph.D. student, 1st year, Pre-Comps
Simulating Sources of Seismic Energy from Thunderquakes

1:30 pm – 1:45 pm
Haochen Ye
Ph.D. student, 3rd year, Pre-Comps
Considering uncertainties expands the lower tail of maize yield projections

1:45 pm – 2.00 pm
Aoshuang Ji
Ph.D. student, 2nd year, Pre-Comps
Methane fluxes put a constrain on atmospheric O_2 *during the Mid-Proterozoic*

2:00 pm – 2.15 pm
Sierra Melton
Ph.D. student, 1st year, Pre-Comps
Iceberg calving and meltwater drainage at the ice-cliff terminus of Helheim Glacier, Greenland

The role of continental lithosphere in subduction initiation

Hee Choi and Brad Foley

Department of Geosciences, The Pennsylvania State University

Plate tectonics is a unique feature of Earth, not found on any other planets or rocky moons in our solar system. However, how and when plate tectonics initiated on Earth remains enigmatic. Numerous studies have suggested that continents enhance stresses and deformation in the lithosphere near their margins, and therefore might promote modern-style subduction initiation by enhancing the formation of weak shear zones in the lithosphere. We perform numerical mantle convection models with an imposed buoyant continental block to test this hypothesis. While previous studies of subduction initiation were mostly done in plastic yielding rheology that only allows lithospheric shear zones to form during deformation, our models assume grain damage rheology including weak zone memory. however, our model results show that inserting a continental block into the mobile lid of convection models does not dramatically cause subduction initiation, even though stresses enhance and therefore extra damage occur at continental margins. We hypothesis that although continents lead to rheological weakening at their margins, stress from the overall convection is much larger therefore inclusion of continents does not necessarily trigger additional subduction initiation. Model results also show that thicker continents develop long-lasting and more persistent subduction, while thinner continents develop short-lived and more transient subduction, especially with higher internal heating. We are developing scaling analysis for stresses from the overall convection and added from the continents. We are also working on finding the regime boundary between stagnant lid regime and mobile lid regime with continents, so that we can compare it to the regime boundary without continents.

Simulating Sources of Seismic Energy from Thunderquakes

Nolan Roth and Tieyuan Zhu

Department of Geosciences, The Pennsylvania State University

Lightning-induced seismic waves, “thunderquakes”, could be effective sources for near-surface tomography. Thunderquake data have previously been captured by the distributed acoustic sensing (DAS) array run here at PSU. The mechanisms by which these seismic waves are produced and the interactions of the various possible energy sources is currently a mystery, which, if solved, would allow a rich amount of new data to inform traditional tomographic methods. This could be invaluable in areas where low earthquake seismicity limits the resolution of near surface images and velocity models. I aim to simulate three candidate sources for the thunderquake seismic energy: the air-coupled thunder wave produced by the lightning bolt; the ground-coupled component of the thunder wave, which produces a discrete arrival in the DAS data as it travels through the ground; and the electroseismic (ES) wave induced at the air-ground interface by the bolt's electric field. This ES wave propagates through the ground to the seismic receiver. A better understanding of these mechanisms would validate assumptions made in previous studies using this thunderquake data for tomographic models. This simulation will also be the first to study the electroseismic effects of lightning.

Considering uncertainties expands the lower tail of maize yield projections

Haochen Ye[1], Robert Nicholas[2], Samantha Roth[3], Klaus Keller[1]

[1]*Department of Geosciences*
[2]*Earth and Environmental System Institue*
[3]*Department of Statistics*

Maize yields are sensitive to extreme weather events. Understanding the mechanisms and the drivers of the surrounding uncertainties is important to inform decision-making. Previous studies have provided important insights, but often sample a small subset of potentially important uncertainties. Here we expand on a previous statistical modeling approach by refining the analyses of two uncertainty sources. We project eastern U.S. maize yield in this century sampling uncertainties about crop-yield model parameters and climate forcings. We quantify how considering more uncertainties expands the lower tail of yield projections. We quantify the relative importance of each uncertainty source and show that the uncertainty surrounding yield model parameters is the main driver of yield projection uncertainty.

Methane fluxes put a constrain on atmospheric O_2 during the Mid-Proterozoic

Aoshuang Ji and James Kasting

Department of Geosciences

The mid-Proterozoic (1.8 --- 0.8 Ga), also known as the 'Boring Billion', is generally regarded as a transitional time between the anoxic Archean and the well-oxygenated late Neoproterozoic. A postulated rise in O_2 during Neoproterozoic may have helped trigger the Sturtian glaciation at 717 --- 643 Ma, along with the subsequent emergence of multicellular animals. However, estimated pO_2 during the mid-Proterozoic has a very wide range between < 0.1% and 40% of the present atmospheric level (PAL). Recently, Crockford et al. (2018) showed that sedimentary sulfates from the 1.4 Ga Sibley Formation in Ontario, Canada, preserve strong oxygen mass-independent isotope fractionation (O-MIF). This signal can be used to quantify atmospheric pO_2 (or, more accurately, the ratio of pO_2/pCO_2). The O-MIF signal is produced by ozone photochemistry in the atmosphere; it is eliminated when O_2 (and CO_2) enter the surface ocean and are used in photosynthesis and respiration. However, Crockford et al. (2018) ignored the dynamics of the air-sea gas exchange and recycling of oxygen between the atmosphere and the ocean by methane fluxes there. To fill this gap, I will use a 1-D photochemical model of the atmosphere, coupled to a box model of the atmosphere-ocean system. This coupling would allow us to better constrain the air-sea gas exchange, especially for oxygen and methane. As a consequence, we can understand the mechanism causing the O-MIF signal as well as the constrain on the Mid-Proterozoic oxygen levels.

Iceberg calving and meltwater drainage at the ice-cliff terminus of Helheim Glacier, Greenland

Sierra M. Melton[1], Richard B. Alley[1], Sridhar Anandakrishnan[1], Byron R. Parizek[1,2], Michael G. Shahin[3], Leigh A. Stearns[3], Adam L. LeWinter[4], David C. Finnegan[4]

[1]*Department of Geosciences, and Earth and Environmental Systems Institute, Pennsylvania State University, University Park, Pennsylvania, USA*
[2]*Mathematics and Geoscience, Pennsylvania State University, DuBois, Pennsylvania, USA*
[3]*Department of Geology, and Center for Remote Sensing of Ice Sheets, University of Kansas, Lawrence, KS, USA*
[4]*Cold Regions Research and Engineering Laboratory, Hanover, NH, USA*

Calving and melting are the major mass-loss mechanisms at marine-terminating glaciers, and we find that meltwater drainage systems influence calving style and behavior. We use high-resolution satellite and time-lapse imagery to observe variability in calving behavior, terminus position, supraglacial meltwater pooling, and surface expression of a buoyant meltwater plume at Helheim Glacier's terminus from 2011-2019. Helheim, a tidewater glacier in eastern Greenland, terminates in a lightly grounded ice cliff. Terminus position was relatively stable through 2016 except for seasonal changes, but in 2017 and 2019 the terminus retreated ~1.5 km beyond previous positions. A supraglacial lake filled and drained in most summers, typically followed by down-glacier crevasse filling and meltwater plume appearance in a consistent location at the terminus. All full-thickness calving events occurred either when this plume was absent or were spatially removed from the plume. This is consistent with the hypothesis that the plume discharged from a well-established channelized drainage system, indicating a grounded glacial front. As the terminus became ungrounded, calving resumed and the plume disappeared. This relationship between meltwater drainage and calving may exist at other lightly grounded outlet glaciers.