# The $54^{th}$ Annual Graduate Student Colloquium


*Photo: Judit Gonzalez-Santana (Field Work Photo Contest Winner)*

Hosted by the Department of Geosciences
April $7^{th}$ – $8^{th}$ 2022

# 54rd Annual Graduate Student Colloquium

Sponsored by Shell and hosted by the Department of Geosciences
April 7-8, 2022

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:**
Judit González-Santana (chair), Hee Choi (chair), Nolan Roth, Kirsty McKenzie, Young Cheol Kim, Shavonne Morin, Leonie Strobl

# Event Schedule

## Thursday 7th April

Opening Remarks –  9:00 to 9:15 am

**Oral Session 1 – 9:15 to 10:15 am**

Coffee Break – 10:15-10:30 am

**Oral Session 2 – 10:30 am to 11:45 pm**

Lunch Break – 11:45 am to 12:15 pm

**Poster Session 3 – 12:30 to 2:15 pm**

Coffee Break – 2:15 to 2:30 pm

**Oral Session 4 – 2:30 to 3:15 pm**

**Job Talk - 4:00**

## Friday 8th April

Opening Remarks – 9:00 – 9:15 am

**Oral Session 5 – 9:15 to 10:30 am**

Coffee Break – 10:30 to 10:45 am

**Oral Session 6 – 10:45 am to 11:45 pm**

Lunch Break – 12:00 to 12:45 pm

**Poster Session 7 – 1:00 to 2:15 pm**

Coffee Break – 2:30 to :45 pm

**Oral Session 8 – 2:45  to 3:45 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:

2021-22: Julia Carr
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.

# Table of Contents

# Thursday 7th April

## Session 1: Oral Session

**Thursday 7th April**
**9:00 am – 10:15 am**

**9:00 am – 9:15 am**
*Opening Remarks*

**9:15 am – 9:30 am**
Judit Gonzalez-Santana
Ph.D. student, 5th year, Post-Comps
*Investigating links between volcanic activity styles and flank instability behavior at Pacaya Volcano, Guatemala*

**9:30 am – 9:45 am**
Kirsty McKenzie
Ph.D. student, 6th year, Post-Comps
*Development and Evolution of the San Andreas Plate Boundary Faults*

**9:45 am – 10:00 am**
Tsai-Wei Chen
Ph.D. student, 4th year, Post-Comps
*Quantification of strain related to interseismic deformation along subduction interfaces using chemical mass-balance analysis*

**10:00 am – 10:15 am**
Julia Carr
Ph.D. student, 5th year, Post-Comps
*Constraining the fluvial and structural controls on bedrock channel width*

## Investigating links between volcanic activity styles and flank instability behavior at Pacaya Volcano, Guatemala

Judit Gonzalez-Santana[1], Christelle Wauthier[1,2], Michelle Burns[1]

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

Magma intrusions are recognized triggers of instability on volcanic flanks. There is also growing evidence for links between magmatic intrusions and accelerating creep on detachment faults within volcanic edifices. This driver was recently proposed at Pacaya, an active basaltic stratovolcano in Guatemala that shows evidence for a past flank collapse and where magma-driven instability was recorded during major eruptions in 2010 and 2014. To understand the conditions under which flank creep can be initiated and sustained at active volcanoes, we search for links between flank creep behavior and styles of volcanic unrest at Pacaya and propose a conceptual model for the initiation of flank creep. We quantify flank creep through time-series of surface displacements from 2007-2020 using seven radar satellite geodesy (InSAR) datasets, and describe eruptive activity through volcanic activity reports, ash advisories, thermal anomaly time-series, and lava flow maps. We find that large transient flank instabilities coincide with vigorous eruptions in 2010 and 2014, but not with times of similarly elevated activity in 2007-2009 and 2018-2020. Slower creep is recorded during the relatively quiescent 2010-2014 and 2015-2018 intervals, following the 2010 and 2014 transient instability events. Comparisons between our datasets suggest that during times of elevated volcanic unrest with persistent thermal anomalies and degassing, attributed to open-vent volcanism, as in 2007-2009 and 2018-2020, magma movements in an open conduit happen with little associated deformation and flank motion. Conversely, when new vents open outside the summit area, either marking the start or a transition in an eruption, transient flank creep can be initiated, as in 2010 and 2014. Therefore, opening of new vents outside the main summit area at Pacaya, especially along north-northwest to south-southeast alignments, could forewarn an increased likelihood of new or accelerating flank creep.

# Development and Evolution of the San Andreas Plate Boundary Faults

Kirsty A. McKenzie[1] & Kevin P. Furlong[1]

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

The San Andreas plate boundary extends from the Gulf of California to northern California where it meets the Cascadia Subduction Zone and Mendocino Fracture Zone at the Mendocino Triple Junction (MTJ). The MTJ is migrating northward at ~50 km/Myr, meaning that over 5 Myrs the San Andreas plate boundary grows by 250 km. Although the kinematic evolution of the San Andreas plate boundary is well constrained by plate reconstructions, how San Andreas plate boundary faults develop in the upper crust and what controls the location of the main shear zone at depth are still open questions.

North of the MTJ, GPS velocities show right-lateral shear strain developing above the subducting plate across a narrow region, generated from differential NNW-motion of the Franciscan terrane and the Klamath terrane. This shear forms several NNW-striking upper-plate strike-slip faults including the Grogan fault and Lost Man fault that transition into the Bartlett Springs fault (BSF) south of the MTJ. Although these faults straddle the transition from subduction to translation, they do not evolve to become the main plate boundary faults. Instead, a NE-striking profile through the GPS velocity field south of the MTJ shows the existence of a single plate-boundary shear zone, ~20-40 km west of the BSF. Local earthquake seismic tomography (Villanseñor et al., *pers comm.*) shows a region of high p-wave velocity beneath the North America crust to the west of this shear zone that we interpret to be the Pioneer fragment, a remnant piece of the Farallon plate that now migrates northward with the Pacific plate. We hypothesize that the northward motion of the Pioneer fragment produces the mantle shear zone that we see in the GPS velocities. This shear-deformation begins north of the surface expression of the Maacama, suggesting that the Maacama fault develops from the bottom up initiating in this mantle shear zone. Unlike the BSF, that appears to be an inherited structure from the southern Cascadia subduction zone, which eventually dies out south of the MTJ, the Maacama fault becomes the dominant plate boundary fault system ~ 100 km south of the MTJ, after approximately 2 Myrs of deep plate boundary shear strain.

# Quantification of strain related to interseismic deformation along subduction interfaces using chemical mass-balance analysis

Tsai-Wei Chen[1], Donald M. Fisher[1], Andrew J. Smye[1], Yoshitaka Hashimoto[2], Hugues Raimbourg[3], and Vincent Famin[4]

[1] *Department of Geosciences, Penn State University*

[2] *Department of Applied Science, Kochi University*

[3] *Institut des Sciences de la Terre D'Orléans, Université d'Orléans*

[4] *Laboratoire Géosciences Réunion, Université de La Réunion*

Exhumed subduction mélanges preserve a record of deformation and fluid-rock interaction under pressure-temperature conditions within the seismogenic zone. Such rocks have the potential to reveal the processes at the grain scale that control the complex plate boundary slip behaviors. Diffusive mass transfer down chemical potential gradient is considered to be an important interseismic deformation mechanism along subduction interfaces. The strain related to it is hard to quantify because of the magnitude, spatial heterogeneity, and the rarity of geometric strain markers; consequently, we explore the feasibility of a chemical approach. Field investigations from the Shimanto belt and the Kodiak accretionary complex demonstrate that underthrusted rocks along subduction interfaces are characterized by the veining of sandstone blocks along with the development of scaly fabrics in mudstones that records noncoaxial strain and dissolution. Microprobe element maps show that scaly fabrics are depleted of fluid-mobile elements and enriched in fluid-immobile elements, whereas veins show an opposite pattern. Here, we present results from a comprehensive geochemical characterization of the scaly microfaults and wall rocks of the mélanges samples collected from the Shimanto belt and the Kodiak accretionary complex using LA-ICPMS. Isocon analysis shows that Ti is a suitable chemical reference frame to estimate bulk mass change and volume strain. Using Ti as the reference element, our calculations indicate a large variation in the average mass loss in scaly folia between the mélanges experiencing the paleotemperatures corresponding to the updip and downdip limit of seismogenic zones. The result suggests that the strain related to diffusive mass transfer varies as a function of temperature and can be quantified through geochemical mapping of scaly fabric domains. Given typical plate tectonic convergence rates and the thermal structure of active subduction zones, strain measurements further allow estimates of the interseismic diffusive mass transfer strain rate along ancient plate boundaries.

## Constraining the fluvial and structural controls on bedrock channel width

Julia C. Carr[1], Roman A. DiBiase[1]

[1]*Penn State Geosciences*

Understanding the processes controlling lateral erosion in bedrock rivers is important for predicting patterns in channel cross-sectional geometry, which influences sediment transport and river incision. Previous models have assumed that the width of bedrock rivers scales similarly to that of alluvial rivers and can be modelled at a regional scale. However, the processes controlling channel width in bedrock rivers will be dependent on both the fluvial processes present in alluvial rivers, and the structure and material properties of the bedrock of the channel walls. In this study, we will take advantage of a suite of high-resolution 3D datasets in Taiwan to directly characterize the mechanisms controlling channel width along river corridors. Previous analysis of this dataset showed that bedrock channel width can vary by an order of magnitude over length scales of tens to hundreds of meters. Here we will show the range of different mechanisms for channel widening present in the Taiwan Central Range and identify where in the channel network and mountain belt each mechanism dominates. Identifying the active processes in this landscape will inform how channel width should be addressed in bedrock river incision models.

## Session 2: Oral Session

### Thursday 7th April
### 10:30 am – 11:45 am

**10:30 am – 10:45 am**
Sierra Melton
Virtual Talk
Ph.D. student, 2nd year, Pre-Comps
*Enhanced glacial thinning and retreat at an ice-cliff terminus?*

**10:45 am – 11:00am**
Jasmine Walker
Virtual Talk
Ph.D. student, 1st year, Pre-Comps
*Backwater Hydrodynamic Influence on Avulsion Style and Floodplain Character: Case Study from Mungaroo Formation, Northern Carnarvon Basin*

**11:00 am – 11:15 am**
Chanel Deane
Virtual Talk
Ph.D. student, 4th year, Pre-Comps
*Surface-wave relocation of remote earthquakes along the Southwest Indian Ridge*

**11:15 am – 11:30 am**
Kayla Irizarry
Ph.D. student, 2nd year, Pre-Comps
*Did persistently low oxygen conditions slow diversification during the Cambrian?*

**11:30 am – 11:45 am**
Youki Sato
Ph.D. student, 2nd year, Pre-Comps
*Application of the Orbitrap GC-MS system for Position-Specific Isotope Analyses (PSIA)*

## Enhanced glacial thinning and retreat at an ice-cliff terminus?

Sierra Melton[1], Byron Parizek[1,2], Richard Alley[1], Sridhar Anandakrishnan[1]

[1]*Department of Geosciences, and Earth and Environmental Systems Institute, Pennsylvania State University, University Park*
[2]*Mathematics and Geoscience, Pennsylvania State University, DuBois*

Ice stored in the Greenland and Antarctic Ice Sheets largely flows to the ocean through fast-flowing outlet glaciers and ice streams. Most ice flowing from Antarctica across the grounding line into the ocean forms attached-but-floating ice shelves, which provide buttressing that slows ice flow. Ice shelves are susceptible to melting and collapse, which has been observed to speed flow of non-floating ice and to expose grounded ice cliffs that retreat rapidly by iceberg calving, raising sea level. Most ice-sheet models informing the IPCC do not simulate coupled ice-shelf loss and calving-cliff retreat, in part because of difficulty in modeling the governing processes. Some models use a "float-kill" approximation in which all ice crossing the grounding line is removed numerically, but this omits additional, potentially important stresses.

Many of the outlet glaciers in Greenland – including southeast Greenland's Helheim Glacier – have already lost their persistent floating ice shelves and now terminate in lightly grounded ice cliffs, where lack of support from an ice shelf causes a stress imbalance that reaches a maximum at the water line and increases with cliff height. Stresses within the ice compensate for the ice-front imbalance, so these internal stresses must also increase with cliff height. Ice deforms more rapidly under higher stress, with strain rate dependent on deviatoric stresses in all directions. To explore the impact of the additional stresses at an ice cliff on viscous thinning and retreat rates, we will compare rates for a Helheim-like ice cliff with results from the simplified float-kill approximation using the NASA-JPL Ice Sheet and Sea-level System Model (ISSM). Greater deviatoric stresses at an ice cliff should enhance rates of thinning to flotation and retreat, compared to the float-kill model. These results will ultimately help represent ice-cliff retreat more accurately in continuum ice sheet models to improve sea-level rise projections.

# Backwater Hydrodynamic Influence on Avulsion Style and Floodplain Character: Case Study from Mungaroo Formation, Northern Carnarvon Basin

Jasmine Walker[1], Elizabeth Hajek[1]

[1] *Pennsylvania State University, Department of Geoscience*

Understanding controls on river form and scale is important for sustainably managing modern rivers and floodplains, for reconstructing ancient surface conditions on Earth and other planets, and for predicting the distribution and connectivity of subsurface aquifers and hydrocarbon reservoirs. Recent advances have improved understanding of large, network-scale trends in channel size and form due to, for example, fluvial fan development near sediment sources or backwater hydrodynamics near shorelines. The Triassic Mungaroo Formation – deposits of a continental scale, low-slope fluvio-deltaic system (Northern Carnarvon Basin, offshore Northwest shelf of Australia) – provides a unique opportunity to observe and evaluate upstream-to-downstream changes in a paleo-channel network. Previous work has established strong similarities in Mungaroo channel scale, planform, and sedimentary architecture to those of the Mississippi River (Martin et al., 2018), particularly with respect to downstream changes in channel scale and planform in the zone of backwater hydrodynamic influence on river flow.

In this work, I explored connections between channel and floodplain conditions from upstream to downstream in Mungaroo deposits and evaluated how those connections change with, and may be responsible for, shifts in channel planform and paleo-channel mobility. Supply of coarse overbank material to floodplains upstream of the zone of backwater influence is correlated with channels with higher sinuosity and more lateral mobility than channels in regions of backwater influence. These changes are recorded as a shift in the overall style and preservation of floodplain sediments downstream through the Mungaroo system. These results indicate that the coupling between channel and floodplain sedimentation changes downstream as channels encounter the influence of backwater hydrodynamics. This connection is an important control on channel scale, form, and architecture of subsurface channel accumulations.

## Surface-wave relocation of remote earthquakes along the Southwest Indian Ridge

Chanel Deane[1], Charles J. Ammon[1], Chengping Chai[2]

[1]*The Pennsylvania State University*
[2]*Oak Ridge National Laboratory*

Earthquake locations are essential parameters for earthquake processes, tectonics, and subsurface imaging investigations. Most earthquake catalog locations are constructed using P and S-wave arrival times. Still, the relatively large phase velocity of these waves at distance can lead to substantial uncertainty in earthquake locations in remote regions. Thus existing earthquake locations for remote but important tectonic features such as mid-ocean ridges (MOR) are less well constrained than well-instrumented continental regions. The use of full-waveform surface-wave observations in earthquake location can significantly reduce relative location uncertainty for earthquakes that occur in remote MOR environments. Surface waves generally have good signal-to-noise ratios for shallow, moderate-to-large events and thus can be observed at large distances. In addition, the relatively low group velocity of surface waves makes them more sensitive to the source location. Although we cannot precisely measure a dispersed surface-wave arrival time, we can use cross-correlation to precisely measure relative surface-wave arrival times. We use distant surface-wave observations to reduce the relative location uncertainties of more than 800 earthquakes along the Southwest Indian Ridge (SWIR). The improvement in relative arrival time fit is substantial, with residual misfits at the left of the seismogram sample rates. Most earthquakes move a distance on the order of 10 km, forming tight spatial patterns that better align with bathymetric features. The improved earthquake locations allow us to explore seismogenic deformation processes along the ultra-slow spreading SWIR. The structure along the ridge is more complicated than the standard view developed for slow-spreading mid-ocean ridges. The SWIR includes drastically reduced and variable mantle melt generation, significant crustal heterogeneity (crustal thickness ranges from 3-10 km), and exposed mantle (peridotites exposed on the seafloor). We discuss several localized features related to the 1942 Prince Edward Transform earthquake (M 8.0) and the deformation process along several ridge segments.

# Did persistently low oxygen conditions slow diversification during the Cambrian?

Kayla Irizarry[1], Mark Patzkowsky[1], Kimberly Lau [1]

[1]*Department of Geosciences, Pennsylvania State University, University Park, PA 16802, USA*

The latter half of the Cambrian (509 to 485 Ma) is defined by high extinction rates, repeated mass extinction events, and a diversity plateau (Bambach et al., 2004; Knoll et al., 2007). Elevated extinction levels may have been triggered or amplified by persistently low oxygen conditions hypothesized for Cambrian oceans (Stockey et al., 2021). Several carbon isotope excursions, associated with increasing anoxic conditions, occurred during the Cambrian. The Drumian Carbon Isotope Excursion (DICE) records a negative 2 to 4‰ shift in δ13C globally during the lower Drumian and has been interpreted as recording a flux of anoxic 12C-rich water upwelling onto the shelf during a transgression (Pagès et al., 2016). The relationship between this event and palaeoecological change is not well defined. If the DICE records an interval of expanding anoxic conditions that influenced extinction patterns, then marine invertebrates with high O2 requirement should show lower abundances and diversity through this interval.

To test this hypothesis, sections containing the Drumian Carbon Isotope Excursion (DICE) in Western Montana will be studied. I will identify the DICE and establish local redox conditions using geochemical analyses. I will determine selective extinction through the DICE interval using paleontological analyses and pre-existing hypoxia thresholds (Penn et al., 2018; Gill et al., 2011). Geochemical analysis through this interval includes carbon isotopes (δ13Ccarb), sulfur isotopes (δ34Scas and δ34Spyrite), rare earth elements and yttrium distributions (necessary for cerium anomaly calculations, to be measured in carbonate samples). Petrographic analysis will define facies and characterize skeletal grains through the DICE interval. Paleontological data from petrographic analysis will be augmented by macrofossil point counts made in the field.

Preliminary lithological results show a disappearance of burrowing organisms and an increase in flat pebble conglomerate facies (indicative of a lack of bioturbation) through the lower Drumian, Park Shale Formation.

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

Youki J. Sato[1], Katherine H. Freeman[1], Christopher H. House [1], Maxwell K. Lloyd[1]

*[1]Department of Geosciences, Pennsylvania State University, University Park, PA 16802*

Observing the intramolecular isotope fractionations imparted to natural compounds during synthesis will offer new insights regarding life processes and the evolution of life on Earth. For example, analyzing the intramolecular isotopic signature of a given molecule will allow researchers to differentiate molecules formed from biological vs. abiotic sources, including the specific reactions involved in their formation. Therefore, the intramolecular isotopic patterns seen on Earth attributable to biological reactions will be a useful reference during the search for life on other planets.

Carbohydrates such as glucose synthesized as a result of photosynthesis-associated CO2 fixation exhibit a heterogenous intramolecular isotope pattern (Gilbert et al., 2012). This pattern affects the isotopic signature of lipids and other biomolecules synthesized from these reactants (Monson and Hayes, 1982). However, it is difficult to interpret the position-specific patterns of these biomolecules because of the limited knowledge of isotope fractionations occurring to metabolic intermediates downstream of photosynthesis. The patterns observed may be an interplay between an inherited pattern from the original substrate or from kinetic isotope effects associated with reaction steps involved in the synthesis of biomolecules.

Using the Orbitrap gas chromatography-mass spectrometry (GC-MS) system and focusing on glycolysis as a fundamental process in Earth metabolisms, I will determine the intramolecular fractionations imparted to pyruvic acid from the breakdown of glucose. Pyruvate has a 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 position-specific isotope analysis (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.

## Session 3: Poster Session

**Thursday 7th April**
**12:30 pm – 2:15 pm**

Alejandro Giraldo
Master’s student, 1st year
*Insect herbivore assemblages tracking Eucalyptus from Eocene Patagonia to modern Australasia*

Young Cheol Kim
Ph.D. student, 1st year, Pre-Comps
*Pre-collapse ground motion analysis at Anak Krakatau, Indonesia using time-series InSAR*

Esther Munoz
Ph.D. student, 3rd year, Pre-Comps
*Isolating & Measuring Pyrimidine Carbons for Position-Specific Stable Carbon Isotope Values*

Hanna Leapaldt
Master student, 2nd year
*Seasonality of lacustrine carbonate early diagenesis via in situ microbial metabolisms in Green Lake, Fayetteville, NY*

Kate Meyers
Ph.D. student, 1st year, Pre-Comps
*Carbonate-associated Phosphorous: Modern Wastewater Solutions and Paleoclimate Applications*

Emilie Saucier
Master student, 1st year
*Relating Deformation and Gas Flux using a plugged system model at Telica Volcano, Nicaragua*

Shavonne Morin
Ph.D. student, 1st year, Pre-Comps
*Evaluating Vermiculation Patterns in Grotte di Frasassi Cave System*

Carl Fredrick Aquino
Master student, 2nd year
*Probabilistic inversion of expert assessments of potential ice-sheet responses*

Safiya Alpheus
Ph.D. student, 3rd year, Pre-Comps
*Constraining the controls on bar preservation in braided rivers to improve palaeoenvironmental reconstructions*

Fai Chanchai
Ph.D. student, 2nd year, Pre-Comps
*A Carbonate Multi-Proxy Investigation of Oceanic Oxygenation across the Ediacaran–Cambrian boundary*

# **Insect herbivore assemblages tracking *Eucalyptus* from Eocene Patagonia to modern Australasia**

L. Alejandro Giraldo[1], Peter Wilf[1]

[1]*Department of Geosciences and Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA 16802, USA*

The early Eocene Laguna del Hunco locality (La Huitrera Formation, Chubut Province, Argentina) has yielded diverse floras with abundant insect damage and multiple plant lineages that today only survive in Australasian rainforests. These survivor lineages highlight former connections between South America, Antarctica, and Australia. However, whether the ancient insect herbivore assemblages tracked survivor plant taxa –a major question in biogeography– has only been tested for one plant host genus. Here, we describe the abundant and diverse insect herbivore damage found in a subset of *Eucalyptus* leaves from Laguna del Hunco –the oldest macrofossil evidence of the genus– and compare it with modern *Eucalyptus* herbarium specimens to test for the persistence of insect herbivore assemblages. In this subset of 58 fossil *Eucalyptus* specimens, we found 17 different forms of external feeding, three unique galling interactions and at least seven distinct mining associations. Compared to the only other study that has assessed host tracking by insect herbivore assemblages, this represents a 75% increase in the total number of damage types, and more than double the number of mining interactions. Eleven modern analogs for the insect herbivore damage found in the fossils have been recognized in ca. 1000 digitized herbarium sheets, including four mining associations. Although preliminary, the closely similar suites of insect herbivore damage between modern and fossil *Eucalyptus* suggests that insect herbivore assemblages have tracked *Eucalyptus* through geologic time and major plate movements.

# Pre-collapse ground motion analysis at Anak Krakatau, Indonesia using time-series InSAR

Young Cheol Kim[1,2], Christelle Wauthier[1,2]

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

Volcanic flank instability may culminate in disastrous lateral collapse and be accompanied by surface deformation, seismicity, eruption, landslide formation, and tsunami generation which can be a multi-hazard threat. In Indonesia, a volcanic eruption and flank collapse occurred at Anak Krakatau on 22 December 2018. The collapse entailed a tsunami that took the life of hundreds of people living in the surrounding region. Anak Krakatau had been active with Vulcanian eruption to Strombolian eruption and formed a steep slope which led a research group to model tsunami hazards related to a flank collapse of Anak Krakatau in 2012 [Giachetti et al., 2012].

Time-series analysis of Interferometric Synthetic Aperture Radar (InSAR) can retrieve ground motion with statistically valuable pixels. Persistent Scatterer InSAR (PS-InSAR), one method of time-series InSAR, selects persistent scatterers with statistical analysis and obtains time-series results from selected Persistent Scatterers (PS) [Hooper et al., 2012]. Previous research applied PS-InSAR to Anak Krakatau using one year span of 2018 Sentinel-1 data showed trend changes in June and October 2018 [Walter et al., 2019]. However, the number of selected PS were small due to eruptive conditions that caused coherence loss. Since the result of statistical analysis is sensitive to the number of scenes, time span, and PS pixel counts, this study will modify those factors and obtain the time-series trend before the flank collapse. The trend will be retrieved from 2017 to 2018 and the PS pixel counts will be increased using information from dual-polarization (VV and VH) of Sentinel-1 data.

## Isolating & measuring uridine for position-specific stable carbon isotope values

Esther C. Muñoz[1], Christopher H. House[1], Katherine H. Freeman[1], Heike S. Betz[1]

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

When searching for biosignatures, being able to correctly identify whether organic compounds have biogenic origins is crucial in both terrestrial and extraterrestrial samples. In the past it was assumed that only biological organics on Earth were depleted in carbon-13 ($^{13}C$), with biological sources recording average $^{13}C/^{12}C$ ($\delta^{13}C$) values around -25‰. It is now known that abiotic processes can carry similar isotopic signatures. These isotopic values are dependent on the carbon used for biotic synthesis of organic compounds, which can lead to misidentification when the isotopic compositions of the source carbon are not known. However, measuring the intramolecular isotope patterns holds promise as a new means to distinguish biotic from abiotic signatures than merely speculating bulk compound isotope composition.

Here, we present a method to analyze the $\delta^{13}C$ value of the carbon-1 (C-1) of uridine. This carbon is of interest in the biosynthesis of pyrimidines because it is sourced from carbon-dioxide ($CO_2$). Uridine will be isolated using liquid chromatography, followed by chemical degradation to liberate C-1. The C-1 carbon isotope value will be analyzed using a high-resolution mass spectrometer. Constraining any isotopic offsets will allow use of the C-1 of uridine as an indicator for the isotopic composition of source $CO_2$. Future work will include measuring fractionation between uridine and source carbon for different metabolisms.

# Seasonality of lacustrine carbonate early diagenesis via *in situ* microbial metabolisms in Green Lake, Fayetteville, NY

Hanna Leapaldt[1], Juliana Olsen-Valdez[2], Carie Frantz[3], Kathryn E Snell[2], Lizzy Trower[2], Miquela Ingalls[1]

[1]*Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
[2]*University of Colorado Boulder*
[3]*Weber State University*

Lacustrine carbonates are a powerful archive of environmental information but are susceptible to post-depositional alteration. Dissolution/precipitation of carbonate within sediment pore spaces can result from microbial metabolism-driven changes in carbonate saturation state and may cause an overprinting of the primary $\delta^{18}O$ and $\delta^{13}C$ values of lacustrine carbonate. To study how seasonal cycling of temperature and biogeochemistry impact the subsurface microbial communities and affiliated porewater carbonate precipitation and dissolution, we seasonally cored the upper ~ 30 cm of sediment from two shoreline sites at Green Lake, Fayetteville, NY (one site characterized by a thrombolite bioherm and another at the fluvial inlet). We link seasonal changes of carbonate saturation state at each depth to changes in microbial community composition, *in situ* carbon cycling (using $\delta^{13}C$ values of carbonate, dissolved inorganic carbon, and organic matter), and dominant carbonate facies at each depth.

The thrombolite site cores contained facies equivalent to microbial boundstone whereas a core taken near the lake's inlet was dominantly organic-rich (top 15 cm) micritic mudstone equivalent. We found that the $\delta^{13}C_{carb}$ of samples from the same depth horizons varied more among samples from the same site taken over different seasons than $\delta^{13}C_{carb}$ varied from samples taken from different sites in the same season. We also found that across all seasons and locations, porewater $\delta^{13}C_{DIC}$ decreased with sediment depth in the upper ~10-15 cm and increased with depth below 10-15 cm; however, the depth of the inflection shifted with season and location. Petrographic observations show organic matter closely associated with micritic microbial intraclasts within the boundstone facies indicating potential microbial mediation of carbonate precipitation and organic matter remineralization. We interpret these observations to point to a biologic control on porewater $\delta^{13}C$, and thus authigenic carbonate $\delta^{13}C$.

# Carbonate-associated Phosphorous: Modern Wastewater Solutions and Paleoclimate Applications

Kate Meyers[1], Miquela Ingalls[1], Megan Martin[1], Lee Kump[1]

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

In the Florida Keys National Marine Sanctuary (FKNMS), shallow injection wells are commonly used to dispose of wastewater. These wells pump treated effluent 90 feet into the porous Key Largo Limestone (KLL) bedrock. After injection, phosphorus remediation relies on the rapid adsorption of phosphate onto the carbonate mineral surfaces of the KLL before the effluent emerges into nearshore waters. However, laboratory studies have demonstrated there is a limit to this mode of remediation. The lattice sites that phosphate adsorbs onto can become saturated and/or seawater incursions can cause desorption. To protect the water quality of the FKNMS, we need to understand the permanent and temporary interactions between phosphate and carbonate. My research will (1) determine the phosphate absorption capacity of carbonate under high phosphorus concentration fluxes and (2) determine the mode of permanent phosphorus incorporation into carbonate minerals by synchrotron-based phase identification.

## Relating Deformation and Gas Flux using a plugged system model at Telica Volcano, Nicaragua

Emilie Saucier[1], Peter C. Lafemina[1]

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

Recent eruptions at Telica volcano have been primarily driven by a sealing system. This system is comprised of a seal which forms at the top of the volcanic conduit with time. This seal then prevents gas from escaping the conduit, which causes the gas to accumulate in the conduit, increasing the pressure until the system fails and erupts. This interlink between deformation, degassing, and failure of the system is what is studied here. This is achieved by using a combination of observations and modeling. The deformation at Telica is being recorded using cGPS, and the $SO_2$ gas flux is measured in the degassing plume from a fixed station. The 2015 eruptive event is used to calibrate the model in terms of geometry and rock properties. The results of the model are then compared in terms of scale and timing to the 2020 eruptive event, only varying the sealing of the system to yield a different output then the one of 2015. This model could then give valuable insights into forecasting eruptions at Telica Volcano, using real time data.

# Evaluating Vermiculation Patterns in Grotte di Frasassi Cave System

Shavonne Morin[1], J. L. Macalady[1]

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

Vermiculations are surface patterns of dense, yet irregular lines found globally in many cave systems, and are extensive in the Grotta Grande del Vento-Grotta del Fiume (Frasassi) cave system in central Italy. The Frasassi system is an active sulfidic limestone cave system containing a thick bottom deposit of gypsum. Active sulfidic caves can host isolated ecosystems supported by microbial chemolithoautotrophic primary production. In this system, biofilms (vermiculations) are found on the cave walls, and are dominated by filamentous gamma-proteobacteria. The origins of vermiculations are uncertain, though biological influence has been hypothesized for decades (Bini et al., 1978). Our new data suggest roles for Archaea and Bacteria in vermiculation formation, drawing links between sulfur, nitrogen, iron, and methane cycling in a subsurface setting. During a decade-long experiment, vermiculations regrew on cleared patches of cave wall; regrowth was contiguous to intact vermiculations and was faster at sites proximal to chemical energy sources (e.g. $NH4+$ degassing from the aquifer or from bat guano). The main focus of this research will be a rock billet incubation experiment modeled from Kelly 2021. This involves incubating samples of limestone and gypsum in vermiculation enriched media to investigate biological controls on biofilm pattern formation. Novel to this experiment, indigenous *Androniscus dentiger* isopods will be added to some incubations and abiotic controls will also be included to assess the potential non-microbial impacts on formation. In order to further investigate in-situ pattern formation, a long term timelapse will be set up in the Pozzo dei Cristalli cave where these biofilms are especially abundant. Lastly, samples will be collected for fungal genomics which have not yet been investigated in vermiculations. Our hypothesis based on initial observations is that the vermiculations are a biological phenomenon linked to the chemical energy available at the water-air interface up to 400 m below ground surface.

# Probabilistic inversion of expert assessments of potential ice-sheet responses

Carl Fredrick G. Aquino[1], Vivek Srikrishnan[2,3], Klaus Keller[1,3,4]

*[1]Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
*[2]Department of Biological & Environmental Engineering, Cornell University, Ithaca, NY, USA*
*[3]Earth and Environmental Systems Institute, The Pennsylvania State University, University Park, PA, USA*
*[4]Thayer School of Engineering, Dartmouth College, Hanover, NH, USA*

Ice-sheet responses to global temperature change impact projected sea levels and coastal flood hazards. Projections of ice-sheet contributions to sea-level rise are deeply uncertain. Key drivers for this deep uncertainty are the sparse data and the disagreement among experts about the importance of physical processes such as marine ice-sheet instability, hydrofracturing, and ice-cliff instability. Here we use a probabilistic inversion approach to combine a recent expert assessment of potential ice-sheet responses with paleoclimatic and instrumental observations to infer joint probability distributions of parameters for a simple ice-sheet model. We demonstrate how the method can shed light on implicit assumptions held by the experts and discuss strengths and limitations of the probabilistic inversion approach.

# Constraining the controls on bar preservation in braided rivers to improve palaeoenvironmental reconstructions

Safiya Alpheus[1], Elizabeth Hajek[1]

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

The fluvial stratigraphic record is an important resource for exploring, understanding, and reconstructing the history of Earth's surface environments. In rivers, feedbacks between water flow and sediment transport control the scale, form, and movement of channels, and the style and pace of bedform and bar migration. Fingerprints of these dynamic movements are recorded in sedimentary deposits and provide a lens through which we can reconstruct palaeo-flow dynamics from ancient river systems.

Observations from satellite imagery have documented episodes of bar deformation and reworking at zones of channel-thread splitting, and bar expansion and accretion at channel-thread confluences in braided rivers. Similarly, the internal architecture of ancient channel bodies has been qualitatively and quantitatively interpreted to infer channel morphodynamic processes in ancient fluvial systems. Here we aim to connect plan-view kinematics to stratigraphic preservation of braided river bars.

We use the numerical model NAYS2DH to explore how channel-thread movements are recorded in braided river stratigraphy. We map the trends in the preservation of bar deposits formed under known flow conditions, and investigate the degree to which the preserved internal architecture, facies distribution, and geometry of bar packages record bar kinematics and channel morphodynamic processes observed in steady state braided rivers. We document characteristic architectures and preservation dynamics that correspond to instances of channel-thread confluence, splitting and migration, preserved as trends in bar preservation. Simulated bar facies assemblages also record changes in the local and reach-scale morphodynamics within the system.

Our results aid in establishing statistical baselines for reach-scale stratigraphic variability that results from the internal dynamics of braided rivers which will help geologists identify the range deposits that could have resulted from quasi-steady-state braided river conditions. Finally, these models also help to provide insight into the sensitivity of active fluvial systems to local and reach scale changes in sediment supply and hydrology.

# A Carbonate Multi-Proxy Investigation of Oceanic Oxygenation across the Ediacaran–Cambrian boundary

Watsawan Chanchai[1], Emmy Smith[2], Lyle Nelson[2], Mary Lonsdale[2], Dalton Hardisty[3], Janet Burke[3], Kimberly Lau[1]

[1]*Department of Geosciences, Pennsylvania State University, University Park, PA, USA*
[2]*Deparment of Earth and Planetary Sciences, John Hopkins University, Baltimore, MD, USA*
[3]*Department of Earth and Environmental Sciences, Michigan State University, East Lansing, MI, USA*

The origin and timing of biotic diversification and environmental change across the Ediacaran–Cambrian boundary (ca. 541-537 Ma) are strongly debated, in part, due to the lack of geochronological constraints. The BAsal Cambrian carbon isotope Excursion (BACE), identified by a 4–7‰ decrease in carbon isotopes ($\delta^{13}C_{carb}$), is commonly used as a secondary marker for the Ediacaran–Cambrian (EC) boundary. Although the BACE has been interpreted as a global perturbation to the marine carbon cycle, its driving mechanisms and relationship to paleoredox conditions—both of which can impact biotic turnover—remain poorly understood. Here we present geochemical redox analyses, including cerium anomalies (Ce/Ce*) and iodine-to-calcium-magnesium ratios (I/(Ca+Mg)) of carbonate successions from three study sites (southwestern USA, northern Mexico, and northern South Africa) to investigate the pattern of marine oxygenation associated with the EC boundary. This multi-site approach will spatially constrain redox variability across different paleocontinents. Because each setting has distinct depositional and diagenetic histories, synchronous local redox changes would support interpretations of global environmental perturbations, while variability between the sites may indicate local redox fluctuations or diagenetic alteration. Primary and global redox signatures may support the use of the BACE as a robust marker for the EC boundary in carbonate successions. Our preliminary results indicate predominantly low or zero I/(Ca+Mg) ratios and Ce/Ce* values of ~0.9–1.1 prior to and during the BACE. These proxy values are consistent with local anoxia (i.e., I/(Ca+Mg) < 2.6 μmol/mol, Ce/Ce* > 1.0), with potential minor redox fluctuations following the BACE. Observed Eu anomalies (>1.5) in the southwestern USA section may indicate the presence of Eu-bearing minerals or possible hydrothermalism. We suggest the shallow marine waters during the early Cambrian were locally anoxic, with slight variations in redox conditions. Alternatively, discrepancies of Eu anomalies from different sites could imply variable diagenetic alterations. Ultimately, this study provides spatial and temporal redox constraints across the EC transition. Although the local proxies do not show a significant shift in local redox conditions with the BACE at these sites, small redox instability during this period could have reshaped marine ecosystems and encouraged biotic turnover across the EC.

## Session 4: Oral Session

## Thursday 7th April
## 2:30 pm – 3:30 pm

**2:30 pm – 2:45 pm**
Adam Benfield
Ph.D. student, 3rd year, Post-Comps
*Fire, Climate, and the Giant Sequoia: Terrestrial ecosystem response to late Pleistocene abrupt climate change around Mono Lake, California*

**2:45 pm – 3:00 pm**
Shelby Bowden
Ph.D. student, 3rd year, Post-Comps
*The continental basalt conundrum: reassessing the basic question of how the mantle melts*

**3:00 pm – 3:15 pm**
Erica Lucas
Ph.D. student, 4th year, Post-Comps
*Shear wave splitting across Antarctica: Implications for upper mantle seismic anisotropy*

**3:15 pm – 3:30 pm**
Clay Wood
Ph.D. student, 5th year, Post-Comps
*Probing the micromechanical features of a fracture interface using a multi-physics approach: A numerical investigation relating asperity deformation with fluid flow*

# Fire, Climate, and the Giant Sequoia: Terrestrial ecosystem response to late Pleistocene abrupt climate change around Mono Lake, California

Adam J. Benfield[1,*], Sarah J. Ivory[1,2], Bailee N. Hodelka[3], Susan R. H. Zimmerman[4,5], and Michael M. McGlue[3]

[1]*Department of Geosciences, The Pennsylvania State University, University Park, USA*
[2]*Earth and Environmental Systems Institute, Pennsylvania State University, University Park, USA*
[3]*Department of Earth and Environmental Sciences, University of Kentucky, Lexington, USA*
[4]*Berkeley Geochronology Center, Berkeley, USA*
[5]*Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory, Livermore, USA*

The semi-arid terrestrial ecosystems of eastern California are changing in response to increasing temperatures, drought, and wildfires. However, the long-term ($10^2$ – $10^3$ year) resistance or vulnerability of these semi-arid ecosystems to climate change projected for this century is largely unknown. Here, we examine the last major reorganization of Californian terrestrial ecosystems during the last deglacial period (16,000 – 9,000 years ago), an interval characterized by numerous abrupt environmental changes, vegetation turnover, and megafaunal extinctions, which provide analogues to future warming. In eastern California, deglaciation is poorly documented due to dating difficulties and the limited temporal resolution of past studies in the region. We present a multi-proxy paleoecological record of pollen, microcharcoal, and megafauna populations (*Sporormiella* spores) from a well-dated sediment core from Mono Lake, California, USA to document the deglacial period. We completement our paleoecological record with a regional analysis of modern pollen rain, geochemical proxies, and a deglacial-age shoreline reconstruction of Mono Lake.

Our record shows that abrupt hydroclimate change produced rapid structural alterations in pine – juniper woodlands facilitated by increases in wildfires at 14.8, 13.9, 12.7, and 11.5 ka. The rapid canopy changes produced changes in herbaceous understory plants, likely putting pressure on megafauna populations which declined in a step-wise fashion at ~14.7 and 12.7 ka before final extirpation from Mono Basin at 11.5 ka. However, woodland vegetation communities remained overall resistant to abrupt hydroclimate changes of the late Pleistocene, instead gradually declining and becoming replaced by xeric, Alkaline sink communities in the lowlands as solar insolation increased into the Early Holocene and Mono Lake regressed. Taken together, our study documents that terrestrial ecosystems were sensitive to both rapid and gradual environmental changes but that the sustained dryness and increased summer temperatures of the Early Holocene produced the greatest vegetation turnover and biogeographic changes in eastern California.

# The continental basalt conundrum: reassessing the basic question of how the mantle melts

Shelby Bowden[1], Tanya Furman[1], Mansour Alhumimidi[2]

[1]*Pennsylvania State University*
[2]*King Abdulaziz City of Science and Technology*

Continental basalts are the most common subaerial volcanic feature on Earth; however, as melting beneath continents is difficult to achieve, their presence presents a thermodynamic conundrum (e.g., ref 1). Mantle melting has traditionally been described by one of three mechanisms: 1) depressurizing, as beneath mid-ocean ridges, 2) raising the temperature, such as by a mantle plume, or 3) altering the mantle composition, such as at a subduction zone. In continental provinces such as the Colorado Plateau, East African Rift, and the Middle East, basalt volcanism cannot be attributed to any one of these mechanisms (e.g., ref 2 and 3). Thus, these traditional melting methods fail to describe the geological processes responsible for some of the most tectonically significant areas of the world.

We investigate an alternate method for mantle melting focused on continental basalts from the Arabian Peninsula, which sits at the confluence of several interesting tectonic settings: rifting is manifested by the Red Sea and Gulf of Aden to the south and west; a mantle plume sits beneath Ethiopia to the south; the Dead Sea fault cuts through the western side of the Peninsula; and collision is recorded by a series of suture zones and a subduction zone at Peninsula's northern terminus. Nearly 5% of the Peninsula is covered by primary mantle melts that erupted on thick continental crust, which is an observation inconsistent with the three traditional melting models. Here we demonstrate that mantle melting beneath continents can be achieved via Rayleigh-Taylor instabilities that transport lithosphere into deeper areas of a higher potential temperature. This process has implications beyond geochemistry, as it presents a method by which lithospheric thinning, rapid exhumation, and lithospheric differentiation may occur far from a plate boundary. This thus serves as a case study for how the Earth may have differentiated before plate tectonics.

# Shear wave splitting across Antarctica: Implications for upper mantle seismic anisotropy

Erica M. Lucas [1*], Andrew A. Nyblade [1], Natalie J. Accardo [1], Andrew J. Lloyd [2], Douglas A. Wiens [3], Richard C. Aster [4], Terry J. Wilson [5], Ian W. Dalziel [6], Graham W. Stuart [7], John Paul O'Donnell [8], J. Paul Winberry [9], Audrey D. Huerta [9]

[1] *Department of Geosciences, Pennsylvania State University*
*503 Deike Building, University Park, PA 16802, United States of America*
[2] *Lamont-Doherty Earth Observatory, Columbia University*
*61 Route 9W, Palisades, NY 10964, United States of America*
[3] *Department of Earth and Planetary Sciences, Washington University in St. Louis*
*1 Brookings Dr., St. Louis, MO 63130, United States of America*
[4] *Department of Geosciences, Warner College of Natural Resources, Colorado State University*
*400 University Ave., Fort Collins, CO 80523, United States of America*
[5] *School of Earth Sciences, Ohio State University*
*125 Oval Dr. S, Columbus, OH 43210, United States of America*
[6] *Jackson School of Geosciences, University of Texas at Austin*
*2305 Speedway, Austin, TX 78712, United States of America*
[7] *School of Earth and Environment, University of Leeds*
*Leeds LS2 9JT, United Kingdom*
[8] *Geological Survey of South Australia*
*11 Waymouth St., Adelaide, South Australia*
[9] *Department of Geological Sciences, Central Washington University*
*400 E. University Way, Ellensburg, WA 98926, United States of America*

We examine upper mantle anisotropy across the Antarctic continent using 102 new shear wave splitting measurements obtained from teleseismic SKS, SKKS, and PKS phases combined with 107 previously published results. For the new measurements, an eigenvalue technique is used to estimate the fast polarization direction and delay time for each phase arrival, and high-quality measurements are stacked to determine the best fit splitting parameters at each seismic station. The ensemble of splitting measurements shows largely NE-SW oriented fast polarization directions across Antarctica, with a broadly clockwise rotation in polarization directions evident moving from west to east across the continent. Although the first-order pattern of NE-SW oriented polarization directions is suggestive of a single plate-wide source of anisotropy, we argue the observed pattern of anisotropy more likely arises from regionally variable contributions of both lithospheric and sub-lithospheric mantle sources. Anisotropy observed in the interior of East Antarctica, a region underlain by thick lithosphere, can be attributed to relict fabrics associated with Precambrian tectonism. In contrast, anisotropy observed in coastal East Antarctica, the Transantarctic Mountains, and across much of West Antarctica likely reflects both lithospheric and sub-lithospheric mantle fabrics. While sub-lithospheric mantle fabrics are best associated with either plate motion-induced asthenospheric flow or small-scale convection, lithospheric mantle fabrics in coastal East Antarctica, the Transantarctic Mountains, and West Antarctica generally reflect Jurassic – Cenozoic tectonic activity.

# Probing the micromechanical features of a fracture interface using a multi-physics approach: A numerical investigation relating asperity deformation with fluid flow

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

[1]*Dept. of Geosciences, Pennsylvania State University*
[2]*Dept. of Engineering Science and Mechanics, Pennsylvania State University*
[3]*Chevron ETC, San Ramon, CA, 94583, USA*
[4]*Dept. of Energy and Mineral Engineering, EMS Energy Institute, and G3 Center, Pennsylvania State University*
[5]*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 rock subjected to local stress perturbations in relation to fracture aperture distribution. The goal of our integrated numerical and experimental investigations is to understand the mechanisms responsible for changes in fault zone permeability and elasticity in response to dynamic stressing in the subsurface (anthropogenic or seismic in origin). High-resolution (micron-scale) optical profilometry measurements combined with pressure sensitive films have been used to characterize fracture properties such as 'true' contact area, aperture distribution and morphology, as well as asperity deformation under applied loads in our experiments. These measurements allow a direct correlation between fracture properties and our lab measurements of fracture elastic nonlinearity and permeability. Using micron-resolution profilometry of centimeter-scale samples, we calculate the elastic deformation of fracture asperities to varying applied stresses (static and dynamic) using Hertzian contact mechanics. Then, permeability is calculated for each applied stress (deformed asperities) using the parallel plate approximation, in which the Reynolds equation is solved using the finite difference method. This study is uniquely constrained, wherein we investigate the effect of measured deformation of real asperities on creating flow pathways through a fracture. Future work will include implementing contact acoustic nonlinearity (CAN) to model the change in transmission of acoustic waves across the fracture interface during stress perturbation.

# Friday 8th April

## Session 1: Oral Session

**Friday 8th April**
**9:00 am – 10:30 am**

**9:00 am – 9:15 am**
*Opening Remarks*

**9:15 am – 9:30 am**
Guangchi Xing
PhD student, 5th year, Post-Comps
*Incorporation of seismic attenuation into full-waveform inversion and its application to critical zone*

**9:30 am – 9:45 am**
Jacob Cipar
PhD student, 4th year, Post-Comps
*Ultra-high temperature metamorphism in the Basin and Range-Rio Grande Rift lower crust*

**9:45 am – 10:00 am**
Ben Barnes
PhD student, 5th year, Post-Comps
*Investigating the Rare Earth Elemental Response to Ocean Acidification Across the Paleocene-Eocene Thermal Maximum*

**10:00 am – 10:15 am**
Andrew Shaughnessy
PhD student, 4th year, Post-Comps
*Linking Stream Chemistry to Subsurface Redox Architecture*

**10:15 am – 10:30 am**
Xiaoni Hu
PhD student, 5th year, Post-Comps
*Climate-driven Sediment Transport and Stratigraphic architecture in Tectonic Basins*

# Incorporation of seismic attenuation into full-waveform inversion and its application to critical zone

Guangchi Xing[1]

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

Seismic wave propagation through the Earth is often described as an elastic process by ignoring the rock anelasticity. However, the anelasticity quantified by seismic attenuation could significantly modulate the characteristics of seismic signals by reducing the amplitude and distorting the waveform. On the other hand, seismic attenuation is particularly sensitive to the existence of fluids (water/gas), differences in mineral composition, fractures, and high-temperature anomalies, and could serve as a valuable physical constraint of the subsurface. Therefore, we need to develop a forward modeling algorithm to incorporate seismic attenuation effects into wavefield simulation accurately and further construct the inversion algorithm to map the seismic attenuation structure of the Earth.

In this study, we developed a multiparameter full-waveform inversion (FWI) algorithm under the adjoint-state framework for estimating the 3-D subsurface seismic attenuation structure. This algorithm adopts the L-BFGS method to mitigate the “crosstalk” artifacts between the velocity and attenuation, and can thus produce a reliable and independent attenuation model. Synthetic experiments have been conducted to benchmark this algorithm. In addition, we applied the FWI to a field dataset from an active-source seismic survey at the Garner Run site of the Susquehanna Shale Hills Critical Zone Observatory, where the P-wave attenuation (Qp) structure of the critical zone is imaged. At this site (down to a few tens of meters), low P-wave velocity and high P-wave attenuation potentially suggests the presence of fractures and subsurface water pathways and accumulation. Future investigation of interrelations between Vp, Qp, and even shear-wave attenuation (Qs) could be critical to distinguish fractures from subsurface water saturation.

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

Jacob H. Cipar[1] and Andrew J. Smye[1]

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

Granulites and ultra-high temperature (UHT) metamorphic rocks record the chemical differentiation of continental crust, but determining the geodynamic mechanisms that drive such high-temperature 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 investigation of lower crustal xenoliths from the Rio Grande Rift (RGR) and Mexico Basin and Range province. Thermobarometric analysis and phase equilibria modeling of xenoliths from four sites across this region suggests that they originated from the lower crust at HT-UHT conditions (870-960°C, 8-12 kbar). Zircon with Cenozoic U-Pb dates contains 25-100 ppm Ti, indicating that high-temperature metamorphic conditions (840-1030 °C) occurred during regional extension. Elevated surface heat flow (70-100 mWm-2) and a thin mantle lithosphere — diagnostic indicators of HT-UHT in the lower crust — are contiguous between these xenolith sites, implying that UHT metamorphism is ongoing over an area that spans >10,000 km2. In the RGR, thermal-kinematic models demonstrate that the lower crust attained HT-UHT conditions in response to mantle thinning following extension of thickened lithosphere. We speculate that this tectonic process may explain the heat source for UHT metamorphism in exhumed terranes with similar pressure-temperature-time paths and modern settings where it has been proposed that orogenic extension was caused by the removal of a lithospheric root (e.g., the Tibetan Plateau, the Altiplano and the Betic-Rif Arc).

# Investigating the Rare Earth Elemental Response to Ocean Acidification Across the Paleocene-Eocene Thermal Maximum

Ben Davis Barnes[1], Sara R. Kimmig[2], Matthew S. Fantle[1], Lee R. Kump[1]

*[1]Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
*[2]Earth and Environmental Systems Institute, The Pennsylvania State University, University Park, PA, USA*

The rare earth element (REE) composition of modern seawater is impacted by numerous processes, including weathering inputs and the relative effectiveness of scavenging sinks, which are themselves dependent on redox state, pH, and carbonate chemistry of ambient seawater. Due to these sensitivities, REE relative enrichment indices preserved in carbonate sediments represent promising and complex paleoenvironmental proxies. Despite the large corpus of modern oceanic and ancient sedimentary analyses, the REE paleoproxy has rarely been applied to pelagic carbonate records across major paleoclimatic perturbations. Furthermore, the strong relationship exhibited between REEs and complexation by the carbonate anion (CO32–) in the modern ocean has not been thoroughly tested during ocean acidification events.

Here we present planktic foraminiferal REE and trace elemental analyses across the Paleocene-Eocene Thermal Maximum (~55 Mya) drawn from several Northern Atlantic seafloor sampling sites. Shifts in relative enrichments in the carbonate REE compositions illustrate a dynamic and multifaceted water column response to the paleoclimate crisis: 1) fluctuations in bottom-water oxygen levels as evidenced by Ce-anomalies, 2) spikes in local hydrothermal activity as evidenced by Eu-anomalies, and 3) a sudden drop and subsequent recovery in heavy REE enrichment paced with the sedimentary signal of ocean acidification. This latter observation supports the use of REE relative enrichments as a novel paleo-proxy for seawater [CO32–]. In total, the stratigraphic record of planktic foram REE compositions suggests that the North Atlantic basin experienced a rapid onset of low-[CO32–] acidified conditions coeval with pulses of low-oxygen and hydrothermally sourced deepwaters, each of which persisted up to 100,000 years following the onset of the PETM. These results demonstrate that despite their complexity, through stringent laboratory methods and model-data comparison the signatures preserved in sedimentary REE compositions can yield insight into various critical paleoenvironmental responses to global climate events.

# Linking Stream Chemistry to Subsurface Redox Architecture

Andrew R. Shaughnessy[1], Susan L. Brantley[1,2]

[1]*Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
[2]*Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA, USA*

Beneath our feet, minerals dissolve in localized zones called reaction fronts. The subsurface distribution of minerals that constitute these reaction fronts define the redox architecture of a watershed. For example, pyrite is absent from the upper layers of most watersheds, and its reaction front might define the oxic-anoxic boundary in groundwater. Although underlying geology is a major control on river chemistry, few studies relate river concentrations to subsurface mineral distributions. If such linkages could be made, our ability to predict river chemistry would improve markedly. Here, we utilize an oxidation model to explore if sulfate concentrations, C, that vary with discharge (q) document presence or absence of pyrite in the subsurface. We apply this model to 15 increasingly larger watersheds within the Susquehanna River Basin (SRB, 0.08 to >70,000 km2). On average, small watersheds show constant C with increasing q (chemostasis) while large watersheds show decreasing C with increasing q (dilution). We hypothesize that pyrite oxidation in small watersheds is limited by transport of dissolved oxygen (DO) to the reaction front, which leads to chemostasis. In larger watersheds, which tend to contain coal in the SRB, pyrite oxidation is limited by interfacial kinetics, which leads to dilution behaviour. To deconvolute the importance of spatial scale versus coal, we investigated 291 additional watersheds outside the SRB. When coal is absent, C-q behaviour is consistent with the transport DO across all spatial scales. In small watersheds, C values tend to be low, and in large watersheds C values are consistent with complete consumption of DO by pyrite. These observations are consistent with shorter flowpaths partially within the pyrite oxidation zone in small watersheds, but longer flowpaths through the oxidation zone in large watersheds. Linking mineralogy of the subsurface to river chemistry opens new horizons for predicting chemistry of water resources worldwide.

# Climate-driven Sediment Transport and Stratigraphic architecture in Tectonic Basins

Xiaoni Hu[1], Liz Hajek[1]

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

In terrestrial basins, active tectonics and regional climate play significant roles in shaping sediment-transport systems and determining the stratigraphic architecture during basin development. While tectonics is likely to affect the sediment records on ~10s to ~100s thousands of years timescale, the effects of climate could change dynamically due to orbital cycles. The ratio of precipitation to evapotranspiration and basinal cumulative water volume determine the sediment transport efficiency and the base level condition, further control the facies distribution and architecture of stratigraphic records. Therefore, terrestrial tectonic basins are highly sensitive to climate signals, especially for those with short and less buffered river networks.

We built a 2D mass-balance model to explore how tectonic basin fills are sensitive to changes in sediment supply and accommodation creation, connecting with the eccentricity cycles of climate. The model generated upstream-to-downstream 2D slices of strata, presenting a variety of lake conditions and depositional facies associations based on the precipitation to evapotranspiration ratio in different climate zones. Our results reveal that the overall architecture and stacking patterns of strata are mainly determined by the long-term subsidence rate of basement. However, facies distributions are extremely sensitive to lake-level dynamics, especially in arid and semi-arid climate. In general, we consider how climate signals (e.g., orbital frequencies) are manifested in tectonic basins is characterized by different baseline climate conditions and the drainage types (local vs. regional).

## Session 2: Oral Session

### Friday 8th April
### 10:45 am – 12:00 pm

**10:45 am – 11:00 am**
Sam Shaheen
PhD student, 3rd year, Pre-Comps
*Trace element contamination in groundwaters impacted by oil and gas extraction*

**11:00 am – 11:15 am**
Teng-Xiang Wang
Ph.D. student, 1st year, Pre-Comps
*Origins of modern vegetation in mainland Southeast Asia: Paleobotanical evidence from Vietnam*

**11:15 am – 11:30 am**
Claire Shaughnessy
Ph.D. student, 4th year, Pre-Comps
*Organic-Enhanced Chemical Weathering of Basalt and Granite during a Fifteen-Year Laboratory Experiment*

**11:30 am – 11:45 am**
Junzhu Shen
Ph.D. student, 4th year, Pre-Comps
*DAS can record storm-induced seismic signals in urban areas*

**11:45 am – 12:00 pm**
Raphael Affinito
Ph.D. student, 2nd year, Pre-Comps
*The Effect of Undrained Fluid Boundary Conditions on Fault Stability*

## Trace element contamination in groundwaters impacted by oil and gas extraction

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

[1]*Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
[2] *Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA, USA*

Groundwater contamination from both legacy and contemporary oil and gas extraction has sparked concerns surrounding potential human health impacts. However, many trace elements that may be hazardous to human health are either not widely analyzed in groundwater monitoring datasets or are only detectable by commercial laboratories at concentrations that exceed regulatory limits. Using a large groundwater chemistry dataset from the Appalachian Basin in Pennsylvania, U.S.A., we use data mining techniques to identify subregions in which groundwater supplies may be impaired by contamination resulting from oil and gas extraction. Our calculations suggest that concentrations of thallium are likely to exceed the EPA limit in a small number of such hotspots across the region, and other trace elements (arsenic, beryllium, and cadmium) may exceed 70% of the EPA limit in such hotspots. These results are supported by field measurements of thallium concentrations close to or exceeding the EPA maximum contaminant level in groundwater samples from active oil and gas extraction regions in Pennsylvania. In some instances, we hypothesize thallium contamination results from a shallow source in which the anaerobic oxidation of methane leaked from oil and gas wells mobilizes thallium associated with iron oxide minerals via iron reduction. Additionally, we identify a deep source in which formation brines rich in thallium reach water resources via leaks or spills of oil and gas wastewaters. These results suggest that trace element contamination may be an underrated threat to water quality and human health in regions of intensive oil and gas extraction.

## Origins of modern vegetation in mainland Southeast Asia: Paleobotanical evidence from Vietnam

Teng-Xiang Wang[1]

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

Mainland Southeast Asia (MSEA), one of the world's biodiversity hotspots, is suffering from species extinction under severe anthropogenic pressures. Effective conservation requires decision-making based on well-informed evolutionary history of the vegetation revealed by the fossil record. However, despite an early start of paleobotanical research in MSEA, there is hardly any work since the 1920s, despite a few fossil occurrences reported recently in the northernmost part of the region. This lack of paleobotanical study limits our understanding of the origin and evolutionary history of MSEA's plant diversity and vegetation. In 2020, a new fossil leaf flora was discovered from the Neogene Kon Tum Formation of central Vietnam by an international team with Penn State's involvement. The fossil leaves are mostly well-preserved with fine venation and in-situ cuticles, making detailed taxonomic work possible. To date, the flora contains 572 fossil leaves with more than 30 morphotypes recognized, which are predominantly of entire-margined angiosperms. The fossil assemblage is dominated by Syzigium (Myrtaceae), Ficus (Moraceae), Dipterocarpus (Dipterocarpaceae), and Lauraceae. The botanical affinities of many other morphotypes remain to be clarified. The Kon Tum flora appears to indicate floristic similarity to modern monsoonal tropical Asian vegetation in southern MSEA. This idea is supported by our preliminary palynological study of the same strata, demonstrating a highly diverse palynoflora with more than 200 taxa recognized. With the recognition of Lecythidaceae, Casuarina, Alangium, Dacrydium, and multiple Poaceae pollen types, an age of Pliocene is inferred for the Kon Tum flora, agreeing with the Miocene-Pliocene age based on previous lithological correlation. The Kon Tum flora is the first Cenozoic flora that will be comprehensively studied in MSEA and also the only Neogene flora reported in southern MSEA. The discovery of Kon Tum flora suggests that the Pliocene MSEA vegetation already had a modern composition.

# Organic-Enhanced Chemical Weathering of Basalt and Granite during a Fifteen-Year Laboratory Experiment

Claire W. Shaughnessy[1], Susan L. Brantley[1,2]

[1]*Department of Geosciences, Pennsylvania State University, University Park, PA, USA*
[2] *Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA, USA*

Laboratory weathering studies have provided robust insights into many of Earth's surface processes. In natural settings biota produce organic acids, such as citrate, that affect weathering by changing the solubility of elements and increasing mineral dissolution rates. However, most laboratory studies are too short in duration to thoroughly explore long term biogeochemical processes such as organic-enhanced weathering that would occur in natural settings. In this study we investigate the role of citrate in a long term (>15 years) laboratory weathering study of basalt and granite.

Four columns were set up using powdered Tuolomne River Series granite and Columbia River Basalt both with and without 0.01M citrate at pH=6. For the duration of the experiment, flow rates and effluent pH were recorded, and effluent from the columns was collected for major and trace elemental analysis. Surface area was measured at the beginning and conclusion of the experiment. Reacted rock samples from multiple depths throughout each column at the end of the experiment were analysed by X-ray diffraction (XRD) and inductively coupled plasma atomic emission spectroscopy (ICP-AES) to determine mineralogy and bulk chemistry.

Flow rates significantly decreased over the course of the experiment, and elemental release rates largely decreased over time. Potassium release rates fell to below detection limits, as did other elements in the columns without citrate. Despite overall decreased elemental release rates, the addition of citrate enhanced mineral weathering within both the basalt and granite columns for the entire duration of the experiment. In both the granite and basalt columns aluminium, calcium, iron, magnesium, and silicon, among others, showed enhanced weathering in the presence of citrate. The continued enhancement of weathering rates in the presence of citrate highlights the importance of biogeochemical interactions on long time scales when developing a comprehensive understanding of rock weathering processes.

## DAS can record storm-induced seismic signals in urban areas

Junzhu Shen[1] and Tieyuan Zhu[1]

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

Natural hazard events (windstorms and floods) could threaten life and property in populated areas. Estimating the disaster level in different parts of the affected zone will facilitate timely and precise warning and benefit risk management. Currently only limited meteorological monitoring stations are available in cities. Recent studies have shown that seismometers are sensitive to noise induced by wind and rain. Distributed acoustic sensing (DAS) could turn existing optic fibers into dense seismic arrays in cities and can serve real-time sensors to detect vibrations at the meter scale over the long distance. The goal of this study is to search for and characterize the storm-induced seismic signals in DAS recordings in urban areas.

Here, we analyze 2-month DAS recordings from Penn State FORESEE array and identify numerous weather-induced signals across 4-km-long fiber path from July to September, 2021. These events agree with meteorological data (wind speed and rainfall) recorded by nearby weather stations. Further data analysis shows that surface objects (light poles and trees) swaying in the wind could generate seismic noise in low frequency band (0.5-10 Hz). The energy decay fast while propagating and we develop an inversion algorithm to determine attenuation factor of shallow subsurface (~ 1 m). The correlation between seismic energy and wind speed observations can be observed around the natural frequency of vibrating objects. We also show that channels near the drainage system record low frequency noise (1-10 Hz) possibly caused by water flowing in the sewer. Moreover, debris picked up by stormwater flowing in the drainage system could generate strong noise in the frequency band of 20-120 Hz. These findings show the possibility of extracting quantitative wind speed and precipitation estimates from DAS arrays.

# The Effect of Undrained Fluid Boundary Conditions on Fault Stability

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

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

Pore fluids are ubiquitous throughout the lithosphere and are a major part of the stress distribution along faults. Elevated pore fluid pressure reduces the effective normal stress, allowing slip and potentially changes the mode of faulting. Mature brittle faults are characterized by deca- to hecto-meter damage zones composed of gouge and complex shear localization fabrics which can host zones of low, anisotropic permeability. Such zones can include undrained pore fluid conditions that may result in a spectrum of slip behaviors including slow slip events. Despite the obvious importance of pore fluids for fault mechanics, their role in dictating fault stability is poorly constrained. Early results for rate-strengthening accretionary wedge materials suggest pore fluids have a stabilizing effect, as the friction parameter (a - b) increases in response to increased pore fluid pressure (Pf ). Here we present experimental results from rate-weakening synthetic gouge samples at a range of pore fluid pressure conditions. Experiments use a servo-controlled biaxial load frame enclosing a pressure vessel to apply a triaxial stress-state with pore fluid pressures. Samples are assembled in a double-direct shear configuration with two uniform 3-millimeter-thick gouge layers. We conducted stable sliding experiments at both drained and undrained conditions to explore the role of pore fluids on the RSF parameters. Undrained stick-slip experiments were also done at a range of pore fluid pressures to investigate the role of fluid pressure on the nature of fault slip. We explore differences between drained and undrained conditions with particular attention to changes from rate-weakening to rate-strengthing friction behavior due to localized overpressure. In subduction environments pore fluid pressures can approach lithostatic pressures. Therefore, it is important to understand the contributions of fluids and effective stress state on frictional stability and the mode of fault slip, whether it be aseismic creep, slow slip, or earthquake rupture.

## **Session 3: Poster Session**

### Friday 8th April
### 1:00 pm – 2:15 pm

Cristy Ho
Master's student, 1st year
*Magmatic Processes in the Naibor Soito distributed field area, Tanzania constrained from satellite geodesy and seismicity*

Nolan Roth
Ph.D. student, 2nd year, Pre-Comps
*Investigating the Effects of Source-Receiver Azimuth on Thunderquake Signal Amplitude*

Zi Xian Leong
Ph.D. student, 4th year, Pre-Comps
*Estimating CO2 saturation maps from seismic data using neural networks*

Adam Stone
Master's student, 1st year
*Assessing the Habitability of Waterworld Exoplanets*

Hee Choi
Ph.D. student, 1st year, Pre-Comps
*Dynamics of subduction initiation: Where subduction initiates with respect to continents*

Gabriel Rocha Dos Santos
Master's student, 1st year
*Temporal Monitoring with Seismic Interferometry Applied in Mine Blast Data*

Kaitlin Taylor
Master's student, 2nd year
*Early Triassic Weathering Intensity and Climate Recovery After the end-Permian Extinction*

Leonie Strobl
Ph.D. student, 1st year, Pre-Comps
*Noble gases as a tracer for metamorphic dehydration*

# Magmatic Processes in the Naibor Soito distributed field area, Tanzania constrained from satellite geodesy and seismicity

Cristy Ho[1], Christelle Wauthier[1,2]

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

Active rifts experience volcanic activity and seismicity, however the interplay between the two processes is not clearly understood. An ideal location to study magmatic-tectonic interactions is the Naibor Soito distributed field area in Tanzania. The area is part of the East African Rift System and hosts a field of cones bounded by Gelai Volcano and Ol Doinyo Lengai Volcano, the latter being the only active volcano in the world that exhibits carbonatite eruptions. It has been proposed that these volcanic features are connected by an underground network of magmatic conduits, yet the extent of coverage is unknown. In previous geodesy studies, subsidence was detected in the Naibor Soito volcanic field which was caused by a dike intrusion that preceded the explosive eruption of Ol Doinyo Lengai in 2007. More investigation is needed to further constrain the magmatic processes occurring at the Naibor Soito distributed field area. In this study, we analyze a temporally dense COSMO-SkyMed SAR dataset spanning the period 2013 – 2014 for which a dense seismic catalog of microseismicity is available. The goal is to use geodetic and seismic datasets to constrain published models of magma sources, which has implications for characterizing the structure of the volcanic plumbing system and ultimately, improving predictions of eruptions and earthquakes at rift systems.

# Investigating the Effects of Source-Receiver Azimuth on Thunderquake Signal Amplitude

Nolan Roth[1], Tieyuan Zhu[1]

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

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. Prior simulations have eliminated the source possibility of electroseismic waves, though the contribution of air-coupled thunder waves (acoustic waves) and ground-coupled thunder waves (surface waves) is still unknown. This work is an in-depth investigation of thunderquake signal amplitude as a function of relative source-receiver azimuth, which will reveal the presence or lack of surface waves. A conclusive understanding of thunderquake energy propagation would validate assumptions made in previous studies that used thunderquake data for tomographic models.

## Estimating CO2 saturation maps from seismic data using neural networks

Zi Xian Leong[1], Tieyuan Zhu[1,2], Alexander Y. Sun[3]

[1]*Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
[2]*EMS Energy Institute, The Pennsylvania State University, University Park, PA, USA*
[3]*Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA*

Current methods to monitor sequestered CO2 involve extensive petrophysical and geophysical processing steps which are tedious, expensive, and subjected to human error, all of which impede accurate CO2 estimation in the subsurface. Monitoring underground sequestered CO2 content is paramount to prevent unwanted environmental issues (e.g., CO2 plume subsurface contamination) from occurring. To date, the direct estimation of CO2 saturation from seismic gathers is not well-studied. Neural networks (NNs) have seen burgeoning applications in highly non-linear inversion problems pertaining to geophysics such as in seismic inversion and location estimation. We investigate the use of NNs to estimate CO2 saturation maps directly from seismic data. Our work will be divided into three phases (Phase I, II, and III). Phase I explores the use of NNs to invert CO2 directly from synthetic viscoacoustic seismic gathers. Viscoacoustic data is used as it contains attenuation dynamics which better mimic real-world seismic wave propagation. Results from Phase I shows promising seismic-to-CO2-saturation inversion with high accuracies. We are currently at Phase II, which explores the process of generating training dataset tailored to Frio-II CO2 injection site in Texas. Phase III will focus on tuning the NN model to ensure the inversion is reasonable and results are interpretable along with their estimated uncertainties. We will compare the inverted field results with observation well data.

# Assessing the Habitability of Waterworld Exoplanets

Adam Stone[1]

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

Liquid water is an essential component in the search for life on exoplanets, but there may be an upper limit at which too much water prohibits the development of life. We propose a study that will use waterworlds (ocean-covered planets) as case studies to address the question: In the absence of continental weathering, can deep-ocean waterworlds develop and sustain habitable environments? We will develop a box model that quantifies 1) mantle chemical and heat fluxes, 2) water-rock interactions, and 3) ocean-atmosphere dynamics. This study will combine expertise across disciplines in geodynamics, biogeochemistry, and astrobiology. Our results will constrain waterworld geochemistry and help to guide future space-based observatories in search of biosignatures.

## Dynamics of subduction initiation: Where subduction initiates with respect to continents

Hee Choi[1], Brad Foley[1]

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

Plate tectonics is a unique feature of Earth, which has played an important role in the physical, thermal, and chemical process of this planet. Despite its importance, geoscientists know very little about how and why plate tectonics takes place on Earth. While a numerical model with plasticity suggested adding continents leads to mobile lid convection, our previous modelling work with grain damage rheology showed rheological weakening due to the continent is limited and hence the continental impact on subduction initiation is really small. Similarly, our grain damage model also showed subduction does not start at continent margins, contrary to another plastic model that has proposed buoyant continents spread and it leads to subduction initiation at the continent margin. Thus, where subduction initiates need to be answered.

Here, we developed a novel approach of tracking subduction zone over time in numerical mantle convection model using the derivative of horizontal surface velocity to identify zones of convergence in the lithosphere. We find this to be a powerful for tracking subduction zone locations that works well across all numerical models. We use our newly developed method to find subduction zone locations, from the initiation to the termination, with respect to the margins of continental blocks. In particular, we will track locations of subduction initiation, and their characteristic distance from continent margins, thickness of the lithosphere at the time and site of subduction initiation, and other key properties. Using these results, we will perform scaling analysis to shed light on the physics controlling the preferential location sites of subduction initiation. Since this study focus on the fundamental physical principles of subduction initiation, the results can be used for both early Earth and modern Earth.

## Temporal Monitoring with Seismic Interferometry Applied in Mine Blast Data

Gabriel Fernando Rocha dos Santos[1], Tieyuan Zhu[1]

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

Aquifers are vital resources of water for human subsistence and diverse ecosystems. However, with the aggravation of climate change and poor management of water resources, more cases of drought and water depletion have been reported on the planet. Conventional techniques of direct measurements are made in order to obtain observations of the dynamics of a water table. Nonetheless, their results are sparse and do not characterize the fluctuations of an aquifer on scales of a few meters. Geophysical methods emerged as a non-intrusive practice of measuring subsurface properties. Recently, environmental seismology studies, with ambient noise interferometry techniques, correlate the variations in the mechanical properties of the medium with the changes in the wave velocity. This method makes use of natural and urban noise as a continuous seismic source. The proposed work focuses on using seismic interferometry techniques, combined with distributed acoustic sensing (DAS) methods, in order to monitor changes in the groundwater level on the campus of the Pennsylvania State University. We will make use of mine explosions around State College as a repetitive seismic source. The cross-correlation results will give us estimates of wave velocity over two years, and we will compare them with rainfall, streamflow, and water observation wells information near campus. We will show preliminary results of seismic interferometry applied in DAS data for two blast events.

# Early Triassic Weathering Intensity and Climate Recovery After the end-Permian Extinction

Taylor, Kaitlin[1]; Kalderon-Asael, Boriana[2]; Payne, Jonathan[3]; Ibarra, Daniel E.[4]; Lehrmann, Daniel[5]; Yu, Meiyi[6]; Altiner, Demir[7]; and Lau, Kimberly[1]

[1]*Department of Geosciences, The Pennsylvania State University, University Park, PA, USA*
[2]*Yale University, New Haven, CT, USA*
[3]*Stanford University, Stanford, CA, USA*
[4]*Brown University, Providence, RI, USA*
[5]*Trinity University, San Antonio, TX, USA*
[6]*Guizhou University, Guiyang, China*
[7]*Middle Eastern Technical University, Ankara, Turkey*

The Permian-Triassic extinction event was compounded by an extended recovery interval of 5 Myr characterized by a greenhouse climate and extensive marine anoxia. Perturbations to the carbon cycle leading to excessive warming normally return to pre-perturbation levels. within 0.5 to 1 Myr under typical conditions, leaving the cause of persistent warm temperatures poorly understood. The intensity of silicate weathering reactions, defined as the formation of secondary minerals relative to release of cations from the dissolution of primary minerals, can be assessed using lithium isotope ratios (7Li/6Li, commonly denoted as δ7Li. Shallow-marine carbonates from south China, Turkey, and Japan were analyzed for δ7Li to determine weathering intensity over the extinction and the recovery (ca. 252.2-243.5 Ma). The data show a decrease in δ7Li of ~10‰ coincident with the extinction event, followed by a gradual increase over 7 Myr to values ~7‰ higher than latest Permian values. The initial decline in δ7Li may reflect increased weathering due to the high pCO2 in the atmosphere and an increase in the availability of fresh mineral surfaces coincident with increases in erosion. The increase in δ7Li to levels higher than before the extinction event reflect a reduction in weathering, most likely due to both lower CO2 levels and decreased erosion rates. The reason for persistent elevated temperatures during the recovery is therefor more likely due to the reactivity of silicate minerals being weathered rather than the flux. A decrease in reactivity right after the extinction interval would remove less CO2 from the atmosphere, while a gradual increase in the reactivity of the minerals weathered would be more effective at removing CO2 and bring temperatures back to pre-perturbation levels.

# Noble gases as a tracer for metamorphic dehydration

Leonie Strobl[1], Andrew Smye[1]

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

Understanding how Earth was able to preserve its surface water is crucial to understand planetary development towards habitability. Subduction zones are a key link between the Earth's surface and its interior, and a major control on the distribution of volatile elements. The release of water (H2O) and other volatiles, such as noble gases, is regulated by metamorphic processes occurring within the subducting slab. The flux and pathways of fluids released from subducting oceanic crust, however, remain unquantified. Direct tracing of crustal fluids is limited by the small number of isotopes in the O and H systems, and the impact discontinuous but progressive metamorphic dehydration has on the H2O flux collected from volcanic outgassing. In contrast, noble gases exhibit a rich array of isotopes, are strongly incompatible, and are fractionated by physical processes such as diffusion and advection; these factors make the noble gases well suited as isotopic tracers of fluid processes. Remarkably, there are an extraordinarily small number of noble gas data from subduction-related lithologies. Furthermore, the distinct similarity between the noble gas signature found in mid-oceanic ridge basalt (N-MORB) mantle, sea water and atmosphere suggest that the subduction process experiences minimal fractionation of noble gases. The aim of my thesis is to develop noble gases as a tracer for progressive metamorphic dehydration to provide a novel method to quantify the H2O flux associated with subduction. The systematic development of this method involves i) establishing the dominant noble gas trapping mechanism (crystal lattice vs fluid inclusion) and the main mineral carrier phase, ii) understanding the degree of coupling between H2O and noble gases, iii) determining the time and length scale over which dehydration occurs, and iv) quantifying the flux of H2O past arc magma genesis using noble gas fractionation. This involves noble gas isotope data analysis of eclogite samples from the Tauern Window, Austria, at Woods Hole Oceanography Institute, and the use of thermodynamic calculations to constrain the P-T path the samples experienced during subduction.

## Session 4: Oral Session

### Friday 8th April
### 2:45 pm – 4:00 pm

**2:45 pm – 3:00 pm**
Eric Hasegawa
Ph.D. student, 1st year, Pre-Comps
*Constraining organic origins using triple oxygen isotopes of soluble organic compounds in meteorites*

**3:00 pm – 3:15 pm**
Karen Pham
Ph.D. student, 2nd year, Pre-Comps
*Impacts of Miocene climate change on palm trait evolution in Madagascar and mainland Africa*

**3:15 pm – 3:30 pm**
Charlotte Connop
Ph.D. student, 3rd year, Pre-Comps
*Assembly of continental lower crust: constraints from garnet Lu-Hf geochronology of metapelites from the Ivrea-Verbano Zone, Italy*

**3:30 pm – 3:45 pm**
Paul Volante
Ph.D. student, 1st year, Pre-comps
*Source determination of phytane via position specific δ13C analysis*

**3:45 pm – 4:00 pm**
Emma Hartke
Master's student, 2nd year
*Lipid biomarker analysis (n-alkanes, PAHS) as a tool for understanding human-environmental interactions during the middle Neolithic (Dalmatia, Croatia)*

## Constraining organic origins using triple oxygen isotopes of soluble organic compounds in meteorites

Eric M. Hasegawa[1], Katherine H. Freeman[1], Max K. Lloyd[1]

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

Soluble organic compounds are essential components in metabolism and other biological processes on Earth. They are also likely pre-biotic building blocks. These compounds, such as carboxylic acids, ketones, and aldehydes, are constituents of carbonaceous chondrites (carbon-rich meteorites) and are possible ingredients for the emergence of life on early Earth. The physical environments and chemical conditions of soluble organic compound synthesis in meteorites are uncertain but important for understanding life's origins. Triple oxygen isotope compositions ($\delta 17O$ and $\delta 18O$) of meteorite components are sensitive to provenance because different formation and alteration processes fractionate oxygen isotopes in different ways. However, such analyses have been restricted to insoluble organic matter in meteorites. Extending these results to the sources of small, soluble, organic building blocks assumes that all organic carbon in carbonaceous chondrites has the same origins, which is uncertain. Here, I propose to test this assumption by analyzing the triple oxygen isotope compositions of soluble organic compounds using Orbitrap mass spectrometry. Additional experiments will involve pyrolysis and aqueous alteration of insoluble organic matter, which will determine associated oxygen isotope fractionations. This proposed work will provide new constraints on the formation of small organic compounds in space.

# Impacts of Miocene climate change on palm trait evolution in Madagascar and mainland Africa

Karen V. Pham[1], Lee Hsiang Liow[2], Sarah J. Ivory[1,3]

[1]*Department of Geosciences, Pennsylvania State University, USA*
[2]*Natural History Museum, University of Oslo, Oslo, Norway*
[3]*Earth and Environmental Systems Institute, Pennsylvania State University, USA*

Throughout the late Miocene (~10 Ma), climate changes facilitated grassland expansion in the Afrotropics, greatly influencing patterns of modern-day plant biodiversity. Previous work has documented that a Miocene radiation shaped present-day palm species richness in continental Africa; however, little is known about how such climatic shifts shaped trait evolution and diversification dynamics of >200 endemic palm species in Madagascar. As climate continues to warm in the tropics, understanding species' evolutionary responses to past climate shifts is essential for monitoring ecosystem health and function.

Here, we compiled seed lengths from existing literature for palm species in Madagascar and mainland Africa and compared the fit of seven models of seed size evolution using the largest available species-level palm phylogeny. The best-fit model was an Ornstein-Uhlenbeck model, implying trait evolution toward an optimum, where each region has its own ideal seed size. The modeled seed size optimum for Madagascar was smaller than for Africa, suggesting that Malagasy palms have evolved toward smaller seeds over time. Ancestral trait reconstructions based on the best-fitting model suggest that seed sizes diverged in the two regions 20 mya, coinciding with late Miocene grassland expansion. The species that radiated and evolved in each area in response to Miocene climate shifts continue to shape modern differences in regional seed sizes.

We conclude that Afrotropical palms evolved during Miocene grassland expansion in fundamentally different ways: in Africa, open-habitat palms pre-adapted to semi-arid grassland environments thrived. In contrast, in Madagascar, rainforest palms evolved smaller seeds to adapt to increasingly seasonal climates and radiated in forests fragments. We suggest that Madagascar's greater topographic relief and smaller spatial scale may have led to the different evolutionary patterns observed. Our results emphasize the importance of considering the roles of spatial heterogeneity and spatial scale in shaping evolutionary processes and outcomes.

## Assembly of continental lower crust: constraints from garnet Lu-Hf geochronology of metapelites from the Ivrea-Verbano Zone, Italy

Charlotte H. Connop[1], Andrew J. Smye[1], Joshua M. Garber[1], Jeffrey D. Vervoort[2]

[1]*Department of Geosciences, Pennsylvania State University, University Park, PA, USA*
[2]*School of the Environment, Washington State University, WA, USA*

Characterizing the formation and evolution of continental lower crust is vital to understanding the Earth's structure, chemistry, and dynamics. The Ivrea-Verbano Zone (IVZ), northwestern Italy, is considered an archetypal section of continental lower crust, comprising kilometer-scale tracts of metasediments, interspersed with mafic and ultramafic rocks. To better constrain the timescales and timing of emplacement of these lower crustal metasediments, we present results of a comprehensive garnet Lu-Hf geochronological investigation.

Garnet-whole-rock Lu-Hf dates from five metapelites, collectively spanning the amphibolite-granulite transition, range from ~239 Ma to 291 Ma. Sample dates do not vary systematically with structural depth in the section: amphibolite facies samples yield ages of 276.6±2.4 Ma (MSWD = 4.3; IVZ18MW36) and 291.0±7.7 Ma (MSWD = 16; M91003H01); granulite facies samples yield dates of 238.6±7.8 Ma (MSWD = 0.3; M91005D01), 263.9±1.3 Ma (MSWD = 0.6; M91005E02), and 274±10 Ma (MSWD = 9.1; M91002B01)

These dates are significantly younger than published zircon U-Pb constraints on the age of peak high-temperature metamorphism, ~316 Ma (Ewing et al., 2013), implying that either the Lu-Hf system in garnet records cooling of the crustal section following regional high-temperature metamorphism, or the age of the thermal peak—and attendant garnet growth—is younger than previously thought. The absence of systematic age variation with structural depth goes against the former interpretation. We incorporate EPMA and LA-ICPMS constraints on the distribution of major, minor and trace elements in garnet to discriminate between these competing hypotheses.

## Source determination of phytane via position specific $\delta^{13}C$ analysis

Paul Volante[1], Katherine H. Freeman[1] and Max Lloyd[1]

*[1]Pennsylvania State University, University Park, State College, PA*

Phytane is one of the most prevalent lipid biomarkers on Earth. Phytane is a twenty-carbon isoprenoid that can be produced by bacteria, eukaryotes and archaea. In bacteria and eukaryotes, phytane originates from chlorophyll; as chlorophyll breaks down, the phytyl side chain detaches and weathers to form phytane. In the case of archaea, cell membranes degrade, resulting in phytane. Prokaryotes and archaea use two separate metabolic pathways, the MEP and the MVA (or MEV) pathways respectively, to form isoprenoid lipids, like phytane. Isoprenoid lipids built from these different pathways contain carbon atoms from different positions within glucose. The six carbons contained in glucose possess unique $\delta^{13}C$ values, and as a result, the two pathways potentially imprint distinctive position-specific isotope patterns within isoprenoid lipids.

We will use Orbitrap mass spectrometry as a tool to document intramolecular isotope signatures of phytane, with the goal of developing a novel means for source determination (bacteria vs. archaea) of phytane. By measuring the differences in $\delta^{13}C$ values between distinctive phytane mass fragments, we will be able to determine whether a phytane sample was predominantly produced by a bacterial or archaeal source. An analytical precision close to 1 ‰ will be required to differentiate sources based on this technique.

Phytane has been extracted from rocks more than 2 Ga in age and from marine sediments more than 300 Ma in age, which makes it an ideal biomarker for paleoclimate studies. Phytane and bulk $\delta^{13}C_{phytane}$ values have recently been used a paleoclimate tool to study past levels of atmospheric $CO_2$ over the last 300 Ma and as a redox indicator. We are interested in applying source determination of phytane to shed new light on existing paleoclimate applications and to uncover new paleoclimate uses of phytane.

# Lipid biomarker analysis (n-alkanes, PAHS) as a tool for understanding human-environmental interactions during the middle Neolithic (Dalmatia, Croatia)

Emma Hartke[1], Kate Freeman[1]

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

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 more stationary, agro-pastoral lifestyles. The temporal resolution of these geologic and anthropogenic events, however, is less clear. 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 uses lipid biomarker analysis of n-alkanes (plant wax compounds) and polycyclic aromatic hydrocarbons (PAHS; fire indicator compounds), in addition to carbon and oxygen isotope records; charcoal data; pollen records; and archaeological findings to reconstruct the presence and pace of human and environmental changes during this period. We used lacustrine core samples from a paleolake near a mid-Neolithic human habitation site Krivače, located along the Dalmatia Coast (Croatia), to complete this investigation.

Primilimary n-alkane data suggests subtle differences in pre-, mid-, and post-habitation plant wax abundances. PAH data (in-progress) will contextualize these findings by providing information about local fire regimes and burning conditions at each of these time intervals. By the end of this project, we hope to assess two hypotheses related to the timing and appearance of human-environmental events: **(1) biomarker distributions indicate that human groups at Krivače altered the landscape in measurable ways to fit a new, stationary agro-pastoralist lifestyle, and (2) the biomarker distributions indicate local changes to temperature and hydrology consistent with a warmer and more arid regional 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.