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# 28th Geosciences Student Research Symposium

**February 23rd & 24th, 2023**

GSRS
2023
Geoscience Student Research Symposium

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# 28<sup>th</sup> Annual
# Geosciences Student Research Symposium

Welcome to the Geosciences Student Research Symposium (GSRS), a conference produced and organized by graduate students of the Department of Geosciences at Virginia Tech. The main objective of the symposium is to help students gain experience in developing communication skills, event preparation, leadership, mentorship, and team building. GSRS provides a platform for students to communicate their research to all the corners of the far-reaching disciplines of our department. This promotes student growth as scientists as well as strengthens our department. GSRS offers a unique opportunity for students to prepare for future talks and presentations through the gained practice of presenting their research to a broader audience of scientists.

GSRS 2023 is very excited to announce a new addition to the symposium this year! GS(art)S is a geoscience themed art exhibition, featuring hand-made pieces from graduate and undergraduate students on display during both days of the symposium. Art is an often-underutilized form of communication, so by adding this exhibit we are diversifying students' options to communicate science. Through scientific talks, poster sessions, and discussions during breakfasts, lunches, and the department's favorite banquet, we can all learn and grow together. As always, GSRS will feature an exciting series of talks and posters presented by VT Geoscience graduate and undergraduate students. Constructive feedback on student presentations from faculty, students, and visiting guests is highly encouraged. On both days of the symposium, we will have live oral and poster presentations in Conference Room 310 in Kelly Hall. We will also have light snacks and refreshments in the Derring Hall lounge followed by our banquet and awards ceremony Friday evening in the VT Geosciences Museum on the second floor of Derring Hall.

GSRS would not be possible without the help of our greater geoscience family and friends. Thank you very much to everyone who donated to GSRS through our Virginia Tech Crowdfunding Campaign this last fall. GSRS would not be possible without your generosity. Thank you to Carol Lee Donuts, Our Daily Bread, Mezeh, Next Door Bake Shop, Benny's Pizza, Your Dessert Bar, Corbin's Confections, Top Shelf Event Services, and 3112 Catering Company for providing our delicious victuals and refreshments, services, and catering. Thank you very much to everyone in the Department of Geosciences (students, faculty, and staff) for helping to make GSRS possible. We would also like to thank Dr. Holbrook and Dr. Romans for their continuous support. Last, but not least, thank you to our amazing alumni who are joining us to share their memories of how GSRS started back in 1996!

# 2023 GSRS Coordinating Committee:

**Chairs:** Faisal Adams (Chair) and Tara Putri (Vice-Chair)

**Fundraising:** Cecelia Wood (Chair), Cassie Becker, Amy Hagan, Kayla McCabe, Natalia Varela

**Communications:** Cassie Becker (Co-Chair), Emily Keeble (Co-Chair)

**Workshop Series:** Kayla McCabe (Chair), Cecelia Wood

**Abstract Book/Scheduling:** Elizabeth Curtiss (Chair), Asenath Kwagalakwe, Alina Valop

**Judiciary:** David Bruce (Chair),

**Moderators:** Carmen Atkins (Chair),

**Food/Banquet:** Rose McGroarty (Chair), Alaina Helm, Matt Tascione, Alexander Ankamah

**Senior Advisors:** Yezi Yang, Priyanka Bose

**Undergraduate Poster Session:** Erika Goldsmith (Chair), David Bunin

**UpGoer5:** Ben Kligman (Chair), Amy Hagen

**GS(art)S:** Amy Hagen (Chair), Cecelia Wood, Erika Goldsmith, Jessica DePaolis

**Photographer:** Khanh To, Molly Stroud, Priyanka Bose

# Special thanks to:

**Faculty Advisor**: Dr. Brian Romans

**Workshop Leaders:** Dr. Madeline Schreiber, Prescott Vayda, Amy Hagen, Cecelia Wood, Erika Goldsmith, Jessica DePaolis, Dr. George Allen, and Ben Eppinger.

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**And thanks to our many anonymous donors!**

# 2023 GSRS Schedule

| Thursday, February 23rd, Kelly Hall | |
|---|---|
| 8:45-9:00 | Breakfast |
| 9:00-9:15 | Opening Remarks |
| **Talk Session 1** | |
| 9:15-9:30 | Sonia Zehsaz |
| 9:30-9:45 | Asenath Kwagalakwe |
| 9:45-10:00 | Alexander Ankamah |
| 10:00-10:15 | Prescott Vayda |
| 10:15-10:30 | Coffee Break |
| **Talk Session 2** | |
| 10:30-10:45 | Rose McGroarty |
| 10:45-11:00 | Cassie Becker |
| 11:00-11:15 | Amy Hagen |
| 11:15-11:30 | David Bunin |
| 11:30-12:00 | **Up-Goer Five presentations** |
| 12:00-1:30 | Lunch & Poster Session 1<br>**Poster Session 1 Presenters:**<br>P1: Gavin Moore<br>P2: Amanda Wyche<br>P3: Madeline Kronebusch<br>P4: Joe Phillips<br>P5: Mary Verne |
| **Talk Session 3** | |
| 1:30-1:45 | Helen Burch |
| 1:45-2:00 | Shuyang Sun |
| 2:00-2:15 | Molly Stroud |
| 2:15-2:30 | Priyanka Bose |
| 2:30-2:45 | Kayla McCabe |
| 2:45-3:15 | **GS(art)S & Coffee Break** |
| **Talk Session 4** | |
| 3:15-3:30 | Jessica DePaolis |
| 3:30-3:45 | Michael Priddy |
| 3:45-4:00 | Mohammad Khorrami |
| 4:00-4:15 | Denise Burgett |
| 4:15-4:30 | Ella Davis |
| 4:30-4:45 | Closing Remarks |

| Friday, February 24th, Kelly Hall | |
|---|---|
| 8:45-9:00 | Breakfast |
| 9:00-9:15 | Opening Remarks |
| **Talk Session 5** | |
| 9:15-9:30 | Tarisa Ross |
| 9:30-9:45 | Max Garvue |
| 9:45-10:00 | Lars Koehn |
| 10:00-10:15 | Ben Eppinger |
| 10:15-10:30 | Cissy Ming |
| 10:30-10:45 | Coffee Break |
| **Talk Session 6** | |
| 10:45-11:00 | Elizabeth Curtiss |
| 11:00-11:15 | Alix Ehlers |
| 11:15-11:30 | Isaac Pugh |
| 11:30-11:45 | Ethan Conley |
| 11:45-12:00 | Alaina Helm |
| 12:00-1:30 | Lunch & Poster Session 1 <br> **Poster Session 1 Presenters:** <br> P6: Esha Islam <br> P7: Jonathan Stallings <br> P8: Nicholas McFadden <br> P9: Cade Toth |
| **Talk Session 7** | |
| 1:30-1:45 | Ntambila Daud |
| 1:45-2:00 | Cecelia Wood |
| 2:00-2:15 | Carmen Atkins |
| 2:15-2:30 | Alina Valop |
| 2:30-2:45 | Jack Stack |
| 2:45-3:15 | **GS(art)S & Coffee Break** |
| **Talk Session 8** | |
| 3:15-3:30 | Erika Goldsmith |
| 3:30-3:45 | John Ogunleye |
| 3:45-4:00 | Karen Williams |
| 4:00-4:15 | Matthew Tascione |
| 4:15-4:30 | Closing Remarks |
| 4:30-6:00 | Social with light snacks (Lounge in Derring) |
| 6:00 onwards | Banquet and Prize Ceremony (Geosciences Museum) |

# Presentation Format, Logistics, and Code of Conduct

**Oral presentations:** Graduate students will be presenting 12-minute talks followed by 3 minutes for questions.

**Poster Presentations:** Undergraduate students will be presenting posters on Thursday and Friday between 12:00 and 1:30. Presenters will be present during this timeframe to show their posters and field questions.

**Up-Goer Five:** The 'Up-Goer Five' Challenge is a presentation format where scientists communicate their research using only the 1,000 most commonly used words in the English language, a talk format geared towards science communication to a broad audience. Our Up Goer Five challenge, scheduled from 11:30 – 12:00 on Thursday, February 23rd in Kelly, will feature 5-minute graduate student presentations in the Up-Goer 5 format. This talk format practices science communication skills accessible to a broad audience. GSRS 2023 Up-Goer Five presentations are famous for their humorous aspects – attend to join in on the fun!

**Code of conduct:**
1. GSRS 2023 is dedicated to providing a harassment-free experience for everyone, regardless of gender, age, sexual orientation, disability, physical appearance, race, ethnicity, and religion.
2. We do not tolerate harassment of conference participants in any form.
3. Sexual language and imagery are not appropriate for any conference venue, including talks, poster sessions, the banquet, and on social media.
4. We expect participants to follow these rules during GSRS 2023. Participants who are asked to stop or amend any behavior are expected to comply immediately.

# Abstracts for Graduate Student Oral Presentations
## (In alphabetical order)

# IMPROVING DEPTH CONTROL OF MINING-INDUCED SEISMICITY USING A DENSE UNDERGROUND ARRAY

ANKAMAH, Alexander, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

Mining operations can cause earthquakes, which pose a safety hazard primarily to mine workers but also to nearby communities. Miners create excavations which disrupt stability of rock mass and cause deformation and movement of the rock mass towards the excavations. Some underground mining methods such as longwall mining deliberately allow the roof to collapse, inducing earthquakes. Mine operators often install 5-15 seismometers at the surface to monitor and characterize mining-induced seismicity. However, surface seismic networks alone are limited in their ability to accurately detect event hypocenter locations due to surface noise and distance from the underground environments where the events are induced. For longwall coal mines, it is challenging to deploy traditional seismometers underground for safety reasons since they can spark fire to cause explosions. Additionally, longwall coal mining advances quickly and may require frequent relocation of sensors to effectively detect events. Here, we capitalize on recent advances in a recent safe and effective approach of recording seismic data underground by using Distributed Acoustic Sensing (DAS). The DAS system uses laser interferometry within a fiber-optic cable to measure ground shaking everywhere along the cable. A DAS system with a ~5.6-km fiber cable was deployed within a longwall coal mine near the active longwall. At this mine, earthquakes of magnitude 2-4 have been hazardous. An existing surface seismic array successfully detects small events but is not capable of accurately determining their depth due to being at the surface. The goals of the DAS deployment were to test the ability and practicality of DAS in an underground coal mine and to improve the depth accuracy of the seismic events. The fiber-optic cable had sensors at 5.7 meters spacing, far denser than previous mine arrays. In ~7 weeks of data acquisition, hundreds of earthquakes were recorded. The largest event was magnitude 1.2 and the smallest event was magnitude –1.0 detected near the sensing fiber. Mining activities were also recorded, such as the longwall shearer, conveyor belt, and movement of large mining machinery. Using the DAS data and the surface seismic network combined, we will determine the seismic wavespeed structure and determine earthquake depths and rupture mechanisms with improved resolution.

# IMPROVING RELATIVE SEA LEVEL RISE PROJECTIONS BY ESTIMATING VERTICAL LAND MOTION RESULTING FROM CHANGES IN TERRESTRIAL WATER STORAGE

ATKINS, Carmen, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

When global warming and sea level rise are discussed, references to projected sea level rise often cite global mean sea level (GMSL) rise, which is only an average for the entire globe. In reality, sea level is changing at highly differing rates, strongly dependent on location. Relative sea level (RSL) refers to the sea level with respect to the land in a given region. For governments and stakeholders to make actionable policies and mitigation plans, projections of RSL rise should be continuously improved, specific to location, to prepare for the future. Multiple processes affect RSL rise, with the most impactful being vertical land motion (VLM). Many factors contribute to VLM itself, such as glacial isostatic adjustment (GIA) and sediment compaction. One specific contributor to VLM is changes in terrestrial water storage (TWS). Changes in TWS are analogous to an elastic loading problem: when TWS (i.e., mass) changes, the crust undergoes elastic deformation, therefore inducing VLM, which affects RSL when near the coast. We can calculate the VLM resulting from changes in TWS through a geophysical disk load function (Bevis et al., 2016) in MATLAB. For the input, or load (TWS), we gather a multi-model ensemble of TWS projections from global circulation models (GCMs), similar to that in Pokhrel et al. (2021). To improve TWS change projections, we calibrate the models with observational data from the Gravity Recovery and Climate Experiment (GRACE) satellite (data spanning 2002-present). We perform RMS calculations, weighted means, and wavelet analysis to inform calibration details. Once the models are calibrated via simple regression, we use them as input (TWS change) to calculate VLM. Through this method we will produce a global map of coastal VLM induced from changes in TWS, projected through the rest of the 21st century. These results will further improve projections of relative sea level rise, a crucial factor to climate change related hazard mitigation.

# SHEARING ON THE GREAT GLEN FAULT: KINEMATIC AND MICROSTRUCTURAL EVIDENCE PRESERVED AT DIFFERENT CRUSTAL LEVELS

BECKER, Cassie, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

The Great Glen Fault (GGF) is one of mainland Scotland's most significant crustal-scale faults, although our understanding of its early kinematics is in question. Previous studies generally agree that the GGF was initiated as a Silurian sinistral strike-slip fault displacing c. 425 Ma isotopically dated granitic plutons. Stewart et al. (2001) argued that dikes fed by these plutons were sinistrally sheared by the GGF while in the sub-magmatic state, suggesting continuous strike-slip motion on the GGF by 425 Ma. Strike-slip offset post-dating the Devonian is likely only a few tens of kilometers, requiring substantial Silurian-aged GGF strike-slip movement in plate reconstruction models for the Caledonian mountain belt, now exposed in East Greenland, Scandinavia, and Scotland. In contrast, a recent study has argued that motion on the GGF may instead have initiated in the Upper Paleozoic (Searle 2021), bringing current restoration models into question.

Several papers report widespread field-and-microstructural evidence from crystalline bedrock and Devonian age sedimentary rocks for brittle upper-crustal shearing on the GGF. However, evidence for high-temperature crystal plastic shearing at lower crustal levels on the GGF, potentially of Silurian to Early Devonian age, is limited. During summer 2022, I collected suites of oriented bedrock samples from the NW side (Moine/Lewisian gneisses and quartzites), center (Moine quartzites), and SE side (Dalradian quartzites) of the GGF. Additional samples included plutonic rocks from locations adjacent to the GGF and associated faults that were believed to have been intruded during strike-slip motion. Microstructures and quartz c-axis fabrics from samples on the NW side and in the center of the GGF indicate oblique sinistral motion with a NW side up to the SW sense of displacement. These results are compatible with oblique sinistral motion on the GGF below the brittle-ductile transition zone during Silurian - Early Devonian times. However, radiometric dating is needed to prove the absolute timing of syn-shearing mineral phases. In contrast, on the SE side of the GGF, oblique dextral motion with a SE side up to the NW sense of displacement is found. Brittle fracturing is observed in all collected samples, overprinting the earlier high-temperature (500-600 °C) crystal fabrics and microstructures. Early lower-crustal shearing on the GGF is recorded by these crystal fabrics and was followed by transpression, exhumation, and fracturing along the GGF of these initially lower-crust rocks. No convincing microstructural evidence for shearing during pluton emplacement was found.

# MERCURY'S MANTLE MELTING: A GEODYNAMIC AND GEOCHEMICAL INVESTIGATION

BOSE, Priyanka, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

Mercury's unique composition and structure indicate that the innermost planet formed differently from the other rocky planets, and thus Mercury requires more research. The MErcury Surface Space ENvironment GEochemistry and Ranging (MESSENGER) mission collected data about Mercury's surface and interior from 2011-2015. MESSENGER's X-ray and gamma spectrometers found Mercury's surface basalts contained abundant Mg, S, and moderately volatile elements compared to Earth mid-ocean ridge basalts, but were poor in Fe and Ti, indicating the planet's surface was dominated by Mg-rich minerals and sulfides. These sulfides, and a high metal-silicate ratio, suggest Mercury formed under highly reducing conditions, unlike Earth, and the mantle contains similar concentrations of low Fe and high S. To understand how these non-Earth-like conditions affected Mercury's thermochemical evolution, a thermal model and set of high pressure-temperature experiments will be used to provide insight into the Mercurian mantle evolution. To ground our model and experiments to real-world data, we use the 3.5 Ga Northern Volcanic Plains region as a compositional, volumetric, and temporal constraint from prior Mercury research. Prior Mercury thermochemical evolution models used MESSENGER data to understand how Mercury's interior evolved as the planet cooled. However, these models do not consider the geochemical ramifications of a Fe-poor, reduced mantle. Using a modified geodynamical 1D thermal model, we track the cooling and evolution of the interior of the planet and include the growth and formation of an inner core based on a given concentration of sulfur in the core, and assuming a homogeneous mantle composition with a given concentration of chondritic heat producing elements. A geochemically evolving mantle, with a parameterized mantle liquidus and solidus, will be added to determine how mantle melting and subsequent crustal growth affect the evolving planet. With this addition, we can track how much melt is present in Mercury's mantle and see how the different mantle melting parameterizations affect the amount of melt occurring within the mantle. The mantle melting parameterization also affects the growth of the crust and lid of the planet as well. This model will provide insights into how Mercury's mantle melted and evolved under these reducing conditions as well as add geochemical context to prior models of Mercury's thermochemical evolution.

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Advisor: Dr. M. S. Duncan and Dr. S. D. King

# ANALYSIS OF CRUSHED QUARTZ PARTICLE BREAKAGE IN AN AIRCRAFT TURBINE ENGINE

BUNIN, David, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

A Rolls-Royce M250-C20B turboshaft engine test rig is located at Virginia Tech's Advanced Propulsion and Power Lab and has been used to test how minerals interact with jet engines. This test rig was developed with funding from the Office of Naval Research and supported by Rolls-Royce North America. A series of tests were run in September 2022 in which C-Spec crushed quartz was ingested into the engine. The purpose of these tests was to determine the effects the particles had on the engine as well as the effects the engine had on the particles. A valve that bleeds air and particles directly from the compressor is built into the fifth (out of six) axial compressor stage of the engine. We sampled particles here and compared them to particles sampled from the engine exhaust and from the original, unaltered C-Spec. These were imaged using an electron microprobe, and the images were analyzed to determine two-dimensional size and shape characteristics. It was found that the particles decreased to approximately 5% of their original volume during their journey from the intake to the compressor bleed valve. No further change occurred between the compressor bleed and the exhaust, despite the particles passing through the last axial compressor stage, the centrifugal compressor, the combustor, and four turbine stages between the compressor bleed valve and the exhaust. The particles also became slightly more spherical, suggesting that their erosive potential may progressively decrease as they traverse an engine. By studying how particles change throughout engines, we can develop an understanding of the damage they may do. This will help future engine development by identifying the specific sources, locations, and mechanisms of engine damage.

Advisor: Dr. M.J. Caddick

# TEETH TO TONS: BODY MASS ESTIMATIONS FOR EXTINCT REPTILES FROM ISOLATED TEETH

BURCH, Helen, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

Isolated teeth are some of the most commonly preserved parts of the skeleton in the fossil record for extinct reptiles. Teeth have long been essential in our understanding of vertebrate fossils, as they allow us to learn about diet and aid in the classification of species, especially for those that are known only from teeth. In these cases, it is especially important to use teeth to look for functional traits, or factors that determine an organism's role in its community. Generally, diet has been the only functional trait we can determine for these animals. The morphology (form) of a tooth, including whether it is straight, curved, serrated, etc. provides information about the probable diet of an organism based on observed diets in modern animals with analogous teeth. However, while it is feasible to determine this functional trait from isolated teeth, other functional traits for these animals remain unknown. Here, my goal is to estimate body size, a critical ecological character, using the same teeth we have diet information for. I will accomplish this by comparing the crown height of teeth attached to jaw bones to estimates of overall body mass for a range of well-studied extinct reptiles in order to determine the relationship between tooth size and body size in reptiles, a relationship which has been well studied in other groups (particularly mammals). I have determined that the maximum height of the tooth crown is limited by the depth of the jaw, constraining crown height to minimum jaw depth, which can be used as a predictor of body size. Computed tomography data of various jaw elements and teeth from a selection of diverse extinct reptile specimens (obtained through Morphosource) were measured using Mimics and analyzed using R Studio to look for trends. An emerging relationship between tooth and body size in these model specimens allows for estimates of body size well within an order of magnitude for species known only by isolated teeth. I will then use the obtained body size for isolated teeth in the Virginia Tech collections as another functional trait input to model community structure in long extinct communities.

# THE VIRTUAL CRITICAL ZONE

BURGETT, Denise, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

The critical zone (CZ) is the outermost layer of Earth where rocks, water, soil, biological life, and air interact in a wide array of processes. The CZ is challenging to observe and study because it mostly lies hidden underground. We plan to look at the critical zone from a new perspective by creating a virtual representation of the CZ on a road cut, where the CZ is exposed in a cross-section (i.e., the Virtual Critical Zone (VCZ)). The VCZ will provide unprecedented measurements of the physical and chemical properties of the CZ at multiple scales. It will also provide an interactive, virtual platform for teaching and outreach. The VCZ will help us answer the question, do CZ processes create heterogeneity or destroy it? In general, weathering processes are expected to homogenize chemical composition by transforming weatherable bedrock minerals into clays. However, we also might expect near-surface CZ processes to increase heterogeneity, e.g., through opening fractures, bioturbation by roots and animals, and infiltration of surface water. Both compete, leading us to ponder which dominates in the subsurface. We are studying a roadcut in weathered biotite gneiss at the Fieldale Boxley Quarry that exposes a cross-section of the CZ that includes everything from vegetation to fractured bedrock. We have collected LiDAR and photogrammetry data of the road cut, which create the base of our 3D model, as well as near-surface geophysical surveys, including ground-penetrating radar (GPR) and seismic refraction data. Our goal is to create both refraction and surface wave velocity profiles, as well as a radargram that can then be displayed on the 3D image of the roadcut. Our next step is to collect rock samples throughout the entire outcrop and analyze them using a handheld XRF spectrometer to determine their chemical makeup and infer subsurface weathering patterns. We hope to create a virtual model with a simple user interface that will both provide new scientific insights and an interactive educational platform that will bring CZ science into K–12 and college classrooms.

# THERMODYNAMIC MODELING FOR SEABED TEMPERATURE INTERPRETATION OF THE NEARSHORE ARCTIC OCEAN

CONLEY, Ethan, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

During the last glacial period (~115,000–11,700 years BP), permafrost formed on exposed portions of the continental shelves surrounding the Arctic Ocean. Billons of tons of undecomposed plant material accumulated in the frozen sediments of these unglaciated regions. Methane ($CH_4$) from biogenic and thermogenic sources accumulated both within and below permafrost deposits, with some as methane hydrates. After the Last Glacial Maximum (LGM ~26,500 years BP), the warming climate melted ice sheets and glaciers, increasing global sea level by ~134 m on average, inundating more than 3 million $km^2$ of permafrost. This marine transgression changed the thermal conditions of the submerged permafrost, initiating a sequence of thawing. As a result, subsea carbon stocks are able to escape, contributing to one of the least constrained ecosystem feedbacks in Earth's climate system. To characterize the evolution of submarine permafrost, gas hydrates, and greenhouse gas emissions as frozen sediments thaw, data from a seafloor fiber optic communications cable equipped with both distributed acoustic and temperature sensing (DATS) off Oliktok Point, AK are monitored. In addition, we will model the thermodynamic state of marine sediments offshore of Oliktok Point along the cable path, mapping the 2-D distribution of temperature, pressure, permafrost, and fluid velocity (liquid and gas). As a first step, we generated a 2-D model domain with dimensions of 800 m deep and 12.5 km wide, following the fiber optic cable location beginning at ~ 3 km offshore and extending out to ~15.5 km offshore. Boundary conditions applied to the top of the domain drive the evolution of temperature and submarine permafrost over the last 120,000 years. The resulting temperature and ice saturation (permafrost) distribution are shown at the present day and compared against the DATS observations.

Advisors: Dr. R. M. Pollyea & Dr. J. M. Frederick

# EVIDENCE OF SURFACE-RUPTURING EARTHQUAKES IN WESTERN NEPAL

CURTISS, Elizabeth, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

The understanding of the earthquake potential and kinematics of active faults in the upper plate of Western Nepal is limited. Recent studies of the Western Nepal Fault System (WNFS) expand the known fault geometry and segmentation of the fault system, based on the mapping and documentation of the tectonic geomorphology and offset landforms. The WNFS is an oblique-dextral-slip system of splay faults that cuts obliquely across the Himalayan orogen, connecting to the Main Himalayan Thrust décollement at depth. The WNFS trends along the northern bifurcation (PT2-N) of the physiographic transition between the Lesser and the Greater Himalaya (PT2), a lithologic contact that marks a topographic change between low-relief and high-relief regions. The WNFS contains a large, greater than 100 km wide, right-stepover between the primary NW-SE-oriented Talphi-Tripurakot fault segments and the Bari Gad fault. These segments are connected by ~N-S oriented faults, such as the Tumtu Pauwa and the Dhorpatan fault segments. To investigate whether the WNFS is a seismic source for this region, we seek to characterize the earthquake history of the WNFS, through paleoseismic excavations across the fault system. Throughout three field seasons, we established seven paleoseismic excavation sites: two on the Talphi fault which yielded evidence for at least three events, one site on the Tripurakot fault which yielded evidence for one event, two sites on the Dhaulagiri Southwest fault yielded evidence for at least three events, one site on the Dhorpatan fault yielded evidence for at least two events, and one site on the Tumtu Pauwa fault which yielded evidence for at least one event. These events are evidence that the WNFS is a local source for earthquakes and has recent activity in the last 15,000 years. These findings allow for speculation on whether the WNFS ruptures coseismically with the Main Himalayan Thrust at depth, or independently. Lastly, these events also establish the recent paleoearthquake chronology of the WNFS that, when combined with new slip rates and fault geometry data, will help update and improve seismic hazard and risk models for the region, contributing to risk mitigation and resilience development in the High Himalayas of Western Nepal.

# DETERMINING TECTONIC TRANSPORT DIRECTIONS IN THE SOUTHERN PART OF THE NORTHERN HIGHLANDS TERRAIN, SCOTLAND

DAVIS, Ella, Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061

Understanding the directions, senses, and timing of rock movement during orogenic events is a fundamental step in understanding the tectonic evolution of the mountain belt. The Moine metasedimentary rocks in northern Scotland have played an important role in characterizing tectonic transport directions associated with thrust faulting in the Northern Highland Terrane (NHT) during Caledonian orogenesis (450-435 Ma). Microstructural, crystal fabric, and isotopic analyses of samples in the northern part of the NHT show that tectonic transport changed from top to the north at 450-440 Ma in the core of the orogen to top to the west at 435 Ma along the western foreland margin (Law et al. 2021). These types of kinematic and isotopic analyses for determining the direction and timing of transport during mountain building in the NHT have been limited to the northern half of the terrain.

In summer 2022 I collected reconnaissance samples along four transects across the Sgurr Beag thrust in the southern part of the NHT to determine if similar optical microscope based microstructural and crystal fabric analysis are appropriate for the southern NHT. Thin sections cut from these reconnaissance samples indicate that they are suitable for these types of analyses. Optical measurements of quartz c-axis fabrics in reconnaissance samples, together with the presence of rare microstructural shear sense indicators, have so far demonstrated a ubiquitous top down to the south-east/east sense of shearing. This marks a distinct difference in tectonic movement from top to the north and west shearing which was previously documented in the northern part of the NHT.

In summer 2023 I will carry out detailed sampling along the reconnaissance transects across the Sgurr Beag thrust in the southern part of the NHT and also run larger scale foreland to hinterland sampling transects across all the thrust sheets and bounding thrust faults in the southern NHT. Microstructures and quartz fabrics from these samples will be integrated with similar data sets from the reconnaissance samples to produce a more comprehensive picture of any spatial variations in transport direction within the southern part of the NHT. Integration of data sets from the northern and southern NHT will ultimately allow the tectonic history of the entire NHT to be determined and compared more meaningfully with similar studies in other parts of the North Atlantic Caledonides in Eastern Greenland and Norway.

# DIATOM EVIDENCE OF REPEATED COSEISMIC UPLIFT ABOVE THE PATTON BAY SPLAY FAULT SYSTEM, ALASKA, USA

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The 1964 $M_w$9.2 Great Alaska Earthquake ruptured >900 km of the eastern Alaska Aleutian Subduction Zone (AASZ) and is the largest earthquake ever recorded along this boundary. Secondary faults, called splay faults, within the Patton Bay Splay-Fault System (PBFS), were also triggered in 1964 and contributed to local tsunami generation and as much as 10 m of uplift on the southern end of Montague Island, Prince William Sound (PWS). The abrupt ~3-4 m of uplift on the island's northwest coast, in an area we refer to as Hidden Lagoons, resulted in the gradual draining of coastal lagoons and wetlands and created a sharp, laterally continuous lithologic contact between silt and peat. Despite the observations of coseismic coastal uplift, the limited historical record along the PBFS leaves questions about the rupture history and potential hazards threatening PWS, leaving us to primarily rely on the geologic record for information. Hidden Lagoons preserves a stratigraphic record of abrupt uplift in 1964 and three other laterally continuous silt-peat contacts that we infer signal prior instances of abrupt coastal uplift that coincide with prehistoric megathrust earthquakes in ~ 870 yr BP, ~2.6 kyr BP, and ~4.2 kyr BP. Here, we characterize the sedimentology and microfossil signature of the 1964 earthquake contact at Hidden Lagoons to act as an analog of calculated coseismic uplift for the assessment of three inferred instances of prehistoric earthquake-induced environmental changes (e.g., shift from marine tidal flat to freshwater peat). Diatoms, a type of siliceous microalgae preserved within the coastal sediments, act as paleoecological indicators of pre- and post-uplift environments and can provide means of examining the timing and minimum estimated amount of prehistoric uplift. Results across the inferred earthquake contacts reflect ecological shifts consistent with repeated draining of inland wetlands due to coseismic shoreline uplift, like the coastal changes observed in 1964. Our stratigraphic, microfossil, and geomorphic analyses and observations examine the ecological effects of sudden earthquake-induced uplift and assess the splay fault rupture history to determine the PBFS-megathrust rupture relationship and improve hazards assessment in PWS.

# EXPLORING TEMPORAL EFFECTS ON MINERAL-MELT PHASE TRANSITIONS

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The ingestion of atmospheric mineral particulates into jet engines can result in severe damage and erosion to the engine, particularly in the engine's "hot" regions where fuel is burned and which can reach temperatures up to 1900°C. Ingested particles can reach these regimes within milliseconds, experiencing extreme heating rates not previously explored in experimental petrology. Within these hot regions, minerals can get stuck to the engine's coatings and melt, potentially damaging and infiltrating the underlying machinery, and they can form partial melts and "clump" together, potentially blocking important flowpaths in the engine; these possibilities can cause costly damages and disastrous consequences, including engine failure, at worst. Therefore, defining the reactions a mineral undergoes in this thermodynamically-unstable environment is key to developing solutions aimed at protecting engine components. Although the literature is thorough regarding constraints to a mineral's relationship with pressure and temperature at equilibrium, the effects of rapid heating rates on a mineral's phase stability are relatively unexplored. Using an upright tube furnace at a maximum temperature of 1250°C, particles of halite of various grainsizes were loaded into a platinum capsule and experienced a heating rate of approximately 1100 °C/s, remaining at maximum temperature for a fraction of a second; despite experiencing a temperature ~450°C above its nominal melting point, only the smallest fraction of halite grainsizes (20 μm) experienced physical changes. Using the same experimental setup and heating rate, gypsum grains of all sizes (from 20 μm to 2 mm) fully transitioned into anhydrite. We therefore conclude that extremely high heating rates are sufficient to cause physical and structural changes to some minerals, and illustrates limitations of using equilibrium models to describe rapid heating events.

Advisor: Dr. M. J. Caddick                    19

# FULL WAVEFORM INVERSION IMAGING OF THE CRITICAL ZONE: A CASE STUDY FROM BLAIR-WALLIS WYOMING

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The critical zone (CZ) comprises the portion of Earth's surface spanning the top of the vegetation canopy to the bottom of weathered bedrock. The subsurface portion of the CZ acts as the habitable substrate for terrestrial life and the means by which shallow groundwater is stored and transmitted. Therefore, understanding the structure and properties of the subsurface CZ helps inform how ecosystems take root in landscapes and how bedrock geology may affect shallow groundwater hydrology.

Seismic imaging methods are commonly used to estimate near-surface structure and properties, the most ubiquitous methods being multi-channel analysis of surface waves and ray-based travel time tomography. These methods use different approximations of the seismic wave equation to estimate the wave speed of subsurface materials. Although these methods have been used for decades and continue to be robust tools of study for the CZ, improvements in shallow seismic imaging can be made by applying full waveform inversion (FWI).

FWI is a technique capable of increasing the flexibility, fidelity, and resolution of seismic imaging. FWI is more flexible than other methods because it can be applied to fit any part of the waveform using any misfit measurement. Moreover, increases in fidelity arise from FWI leveraging better approximations of the physics governing wave propagation. Furthermore, imaging resolution can be enhanced because of FWI's ability to fit more data than other inversion methods. However, despite these potential upsides, FWI is not typically used in the near-surface.

Here we show how various open-source technologies can be combined to apply FWI to the CZ. The data set we use was collected in Blair-Wallis Wyoming using a 240 channel array of geophones at 1 m spacing and hammer sources located approximately every 12 m. Using this data set, we show how the flexibility of our workflow leads to increases in model fidelity and resolution. We hope our work will serve as an example and motivation for others wishing to apply FWI in the CZ.

# A MULTI-METHODOLOGICAL APPROACH TO INVESTIGATING THE KINEMATIC EVOLUTION OF RESTRAINING BENDS IN THE EASTERN CALIFORNIA SHEAR ZONE

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Restraining bends are characterized by discrete zones of crustal shortening and uplift due to compressional curves in strike-slip faults. While previous work has improved understanding of their development and noted their important influence on topography and earthquake rupture dynamics, it is not clear what drives the initial formation of restraining bends (i.e., changing stress regime or growth of a young fault system) and what conditions most control their form. Grasping incipient restraining bend evolution is crucial to addressing these matters; however early-stage natural examples are rare because they are progressively dissected, translocated, and eroded over time. Numerous km-scale restraining bends of the southern Eastern California shear zone (SECSZ) are at various stages of development and occur due to transpression along the dextral low-net slip faults. We conduct neotectonic mapping and morphometric analyses of these nascent transpressional features (n=22) to investigate their kinematic and topographic evolution in the context of regional plate motion, slip-rates, and local fault trends and their intersection angles. Furthermore, we supplement with regional and local 3D deformational modeling to test uplift patterns and subsurface fault geometries estimated from mapping efforts. Restraining bends of the ECSZ are relatively gentle (~15° bend angle) and can be categorized into 7 basic fault configurations, the majority of which are doubly-fault bound with positive flower structures. Despite varying fault geometries, bends typically have an arrowhead shape in plan view and are morphometrically self-similar with ~2.8:1 length-to-width ratio and relief that scales with length. The tops of the bends are flat relict granite erosional surfaces which constrain vertical displacements and relate to the magnitude of relief. Local conditions such as the intersection angle of primary and secondary faults correlate with bend size (wider intersection angle ≈ larger restraining bend structure), though it is not clear what controls the initial intersection angle and its development with increasing displacement. The regional 3D deformational model shows uplift throughout the Mojave block supporting a transpressional regime for the SECSZ and local "toy" models support mapping and subsurface interpretations of restraining bend fault geometries and gives insight into uplift patterns. Overall, our kinematic analysis of SECSZ restraining bends indicate a long history of transpressional deformation in which individual bends have undergone continuous geometric rearrangement leading to characteristic forms and polydeformational histories that may be partially controlled by local conditions.

# TRENDS OF ALVEOLAR SPACING IN AN GROWTH SERIES OF MYSTRIOSUCHIN PARASUCHIDS: IMPLICATIONS FOR THE EVOLUTION OF DENTAL COMPLEXITY IN PHYTOSAURIA

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Investigating the variability of morphological characteristics of rostra (i.e. snouts) may reveal insights into the tooth-bearing bones that compose the feeding systems of extinct organisms. Variation in rostral shape and dental characteristics such as the distance between tooth sockets (i.e. alveoli) can be attributed to ontogenetic (i.e. growth), phylogenetic, or functional changes in dental complexity where rostral elongation may influence the spacing or number of alveoli. For example, alveolar spacing (AS) in some archosaurs (the group that includes birds and crocodylians and their closest relatives) may increase in length between alveoli or remain the same through growth suggesting developmental, phylogenetic, and functional differences related to AS. Qualitative analyses of phytosaur (large, semi-aquatic archosaur-relatives) tooth-bearing bones reveal larger AS in some small specimens (rostral width < 2cm) than in large specimens (rostral width < 2cm); however, whether AS in phytosaurs is an ontogenetic, phylogenetic, or functional character remains unclear. To investigate and quantify the trends in AS in a size-series of mystriosuchin phytosaurs (n=20; skull lengths= ~200-1200mm), we used linear models and ANCOVA analyses to test the effects of ontogenetic stage (=skeletally immature or mature), rostral width (=cross-sectional width at the premaxilla-maxilla suture), and rostral shape (=narrow and lacking a crest, or wide and possessing a crest) on the distance between alveoli normalized to alveolar diameter (=AS/AL). Additionally, we compared these results to AS/AL measurements of *Alligator mississipiensis* to determine whether AS/AL trends are convergent between these two groups. In phytosaurs, the best predictive model using Akaike information criteria (AIC) indicates a significant relationship (AICwt=1) between AS and the interactive effect of ontogenetic stage, rostral width, and shape. This is supported by ANCOVA analyses that found significant relationships between alveolus spacing and ontogenetic stage and rostral shape. Phytosaur rostral shape significantly influences alveolus spacing (p<0.01) and plays a larger role in alveolar spacing than ontogeny, indicating more dental complexity related to phylogenetic or functional drivers. In our sample, phytosaur alveolar spacing decreases through ontogeny and is significantly affected by rostral shape, suggesting a link between the formation and elongation of rostra and alveolar characteristics. However, we found a statistically insignificant AS/AL trend in *A. mississipiensis* rostra indicating that phytosaur dentition through rostral elongation behaves differently than in crocodylians. The results of this study suggest AS/AL may elucidate trends in dental evolution within Phytosauria but also throughout Archosauria and should be considered in future phylogenetic and ontogenetic studies.

# IODINE TO CALCIUM RATIOS (I/CA) REVEAL SHALLOW WATER OXYGEN TRENDS AND DELINEATE A MINIMUM ATMOSPHERIC OXYGEN CONCENTRATION DURING THE CAMBRIAN SPICE EVENT

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Iodine to calcium ratios (I/Ca) in carbonate rocks have recently emerged as a proxy for local marine water column oxygenation. The proxy relies on the principle that iodine can substitute into the carbonate mineral lattice when oxygen is present but is excluded under anoxic conditions. Here we apply I/Ca ratios to assess deoxygenation during the Steptoean Positive Isotopic Carbon Excursion (SPICE event), a +3-6 ‰ excursion in $\delta^{13}C$ at ~497 Ma hypothesized to be the result of widespread marine deoxygenation. Analysis of the I/Ca records from six globally distributed sections (Scotland, Utah, Newfoundland, Australia, North China, and Maryland) suggest a relative decrease in oxygen levels during the rising limb of the SPICE. They also indicate an increase in I/Ca ratios and subsequently marine oxygenation afterwards. These findings suggest that the SPICE was associated with transient shallow water deoxygenation across varied paleocontinents and shallow marine environments.

Given that I/Ca is related to dissolved oxygen concentrations, we also discuss the possibility of using I/Ca to constrain marine and potentially atmospheric oxygen concentrations in the later Cambrian. A wide range of estimates currently exist for the late Cambrian, confounding our understanding of how oxygen impacted early animal evolution and global geochemical cycling. Records from across the SPICE show overall low I/Ca ratios, suggesting that oxygen levels were consistently less than the fully oxygenated portions of the oceans today. We present calculations to bracket minimum marine and atmospheric oxygen concentrations using the highest I/Ca ratios measured during our study.

# PREDICTING THE FLUID-MEDIATED ALTERATION OF SUBDUCTING ROCKS

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Subducting lithologies typically contain a variety of hydrous minerals that dehydrate as pressure and temperature increase, causing fluids to be transported along the slab or into the overlying mantle wedge. These fluids carry a complex solute load that will potentially be far from equilibrium with any rock other than that from which they were sourced. This can lead to pervasive metasomatism in and above subduction zones. Volume changes associated with these reactions can trigger earthquakes, and fluid ingress into the mantle wedge lowers its solidus, leading to melt generation that drives arc volcanism. To improve our understanding of these fluid-rock reactions, we have calculated thermodynamic models of the stable mineral assemblage and attendant fluid composition and abundance across a range of pressure and temperature ($P$ & $T$) conditions for representative subducted sediments, mid-ocean ridge basalt, and mantle harzburgite. These models, which take advantage of newly developed methods for predicting fluid speciation at elevated $P$ and $T$, allow for a greater understanding of the details of subduction-related metasomatism. Preliminary observations show how pulses of fluids generated at different conditions each have unique compositions. Results suggest that mid-ocean ridge basalt (MORB) within the subducting slab should be entirely depleted of K as temperature and depth increase, becoming fully dissolved in the fluid over a range. At lower temperatures (around 500°C), K from MORB is fully absorbed in the fluids at around145 km in depth, while at higher temperatures (around 750°C) K from MORB is fully depleted by 45 km in depth. This K doped fluid could then enrich the overlying mantle wedge. Na is also likely to be mobilized from sedimentary rocks in the subducting slab over a similar $PT$ interval, while Al moving upwards from the down going hydrated mantle lithosphere may actually enrich the slab at these conditions.

# INVESTIGATING $CO_2$ LEAKAGE IN CARBON CAPTURE AND STORAGE SITES EMPLOYING INSAR OBSERVATIONS AND POROELASTIC MODEL

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Increasing human activity puts more $CO_2$ into the atmosphere than natural processes can remove, thus, the amount of $CO_2$ in the atmosphere increases yearly. To address this issue, Underground Carbon Storage (UCS) is a promising approach to lower carbon concentration in the atmosphere, combating global warming. Despite its successful demonstrations, UCS remains controversial for large-scale deployment because of long-term leakage, engineering viability, and associated hazards, mainly induced earthquakes. In this research, we address how the injection of $CO_2$ into deep geological units can lead to ground surface displacement, and leakage to the ground surface. For this purpose, we chose the Century Plant, one of the largest UCS projects worldwide, located in Texas, USA. Applying an advanced multitemporal Interferometric Synthetic Aperture Radar (InSAR) technique to a large set of Sentinel-1 A/B data for period 2014-2022 shows an uplift signal of ~5 mm, in line-of-sight direction, surrounding the injection area. We implement a coupled poroelastic model to establish a link between injection operation, surface deformation, and leakage. The results from this study enable authorities to develop safe practices for underground $CO_2$ storage.

# UNCERTAINTY ANALYSIS FOR CO$_2$ STORAGE IN A HETEROGENOUS OFFSHORE RESERVOIR

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Global warming is the result of unmitigated CO$_2$ emissions, which is contributing to catastrophic damage across natural and human ecosystems worldwide. Carbon capture and storage provides an opportunity for countries to reduce carbon emissions as they transition to renewable-based energy, while also mitigating CO$_2$ emissions from industrial processes that cannot be decarbonized. The Gulf of Mexico provides an excellent location for future carbon storage in the United States as it is located near major carbon emission sources, existing energy infrastructure, and potentially holds storage volume in excess of 500B tons of CO$_2$. Unfortunately, past CO$_2$ storage projects have been hampered by poor reservoir performance because of uncertainties in reservoir permeability. It is difficult to characterize micro- and meso-scale permeability changes across an entire reservoir volume; however, these changes significantly impact reservoir performance. This project seeks to quantify the uncertainty in reservoir performance in a heterogeneous reservoir using an ensemble numerical modeling approach. This project develops a representative model of a study site on the Gulf of Mexico continental shelf using available 3D seismic data. The permeability within the model reservoir is assigned using the distribution of Gulf of Mexico Miocene reservoir permeabilities from the BOEM Sands Atlas. Results from fifty model realizations with variable permeability indicate that there is the greatest uncertainty in CO$_2$ flow paths in a ring adjacent to the injection well and in a ring at the leading edge of the CO$_2$ plume. Numerical uncertainty near the injection well is approximately +/- 20% CO$_2$ saturation, and uncertainty at the leading edge of the plume is approximately +/- 10% CO$_2$ saturation. Additionally, a heat plume from CO$_2$ dissolution in water and H$_2$O Joule-Thomson heating develops in the reservoir. The magnitude of the temperature change and the timing of the heat plume arrival also appear to be highly dependent on reservoir permeability. These model results suggest that both near and far field permeability substantially influence reservoir performance and must be characterized to accurately plan a CO$_2$ storage project. Model results also demonstrate the potential for temperature changes to be used as a precursor for CO$_2$ flow, which would be valuable for future CO$_2$ storage monitoring efforts.

# THE ROLE OF PRE-EXISTING STRUCTURES IN THE INITIATION OF THE NORTHERN WESTERN BRANCH OF THE EAST AFRICAN RIFT

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The northern Western Branch of the East African Rift (EAR) consists of two segments, the magma-poor Albertine-Rhino graben and the magma-rich Lakes George-Edward graben. Recent studies of the northern Western Branch suggest that rifting is unlikely to be initiated by sublithospheric melt in the Albertine-Rhino graben, implying that pre-existing structures may play a dominant role in the extension of this graben. In this study, we investigate the role of pre-existing structures in the initiation of the northern Western Branch by modeling the evolution of faults over time using the 3D finite element code ASPECT. We use fault trace data available in the study region together with the average fault dip angles to create a 3D fault geometry using the Geodynamic World Builder (GWB) software package. The fault geometry created with GWB is then used as an initial condition in a 3D regional ASPECT model, where deformation is driven by extensional velocity boundary conditions. The instantaneous (i.e., single time step) solution provides velocities on faults that are representative of long-term slip rates averaged over many earthquake cycles. The fault velocities and dips are used to calculate theoretical scrap heights based on the age of the rift (or specific fault stand). Those predictions can then be compared against observed scarp heights. This information can then be used to infer whether pre-existing structures are responsible for the initiation of the northern Western Branch.

# CONNECTING THE DOTS: A NITROGEN ISOTOPE COMPARISON ACROSS THE END-TRIASSIC MASS EXTINCTION

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The end-Triassic to early Jurassic interval represents one of the most intense intervals of disturbance to marine ecosystems over the past 500 million years. Perhaps the most striking single event in this interval is the end-Triassic mass extinction (ETME) which is characterized by a notable loss of diversity as well as environmental perturbations to biogeochemical cycles at that time. Although the ETME marks one of the largest extinction events in the Phanerozoic (with up to ~80% loss amongst marine species), the environmental changes surrounding the extinction remain a subject of discussion but are thought to be linked to the emplacement of the Central Atlantic Magmatic Province. Previous studies of the ETME have utilized redox proxies, such as $\delta^{15}N$, and found evidence of marine oxygen depletion leading up to and across the extinction horizon in sedimentary records from British Columbia, Germany, England, and Japan. However, how oxygen depletion progressed both spatially and temporally and how it relates to the extinction event remains subjects of hot debate within the community.

Here, I present a comparison of $\delta^{15}N$ records from sites located in a variety of paleoenvironments encompassing both the Panthalassa and Tethys oceans in order to better understand progression of marine deoxygenation during the ETME. During episodes of oxygen depletion, the terminal electron acceptor in organic matter oxidation shifts from oxygen ($O_2$) to nitrate ($NO_3$), termed denitrification. Episodes of partial water column oxygen depletion result in incomplete denitrification, subsequently leaving behind a pool of residual nitrite that carries a positive $\delta^{15}N$ value. In the case of the end-Triassic extinction event, we propose that elevated $\delta^{15}N$ values reflect a transition from widely oxygenation water columns to increasingly oxygen depleted water columns. The comparison of these $\delta^{15}N$ records allow us to better track the global spread of oxygen depletion using $\delta^{15}N$ as a local redox proxy and while documenting regional and global marine redox variability. The timing of this initial water column deoxygenation will help provide key constraints to our understanding of the relationship between deoxygenation and ecosystem decline immediately predating the ETME.

# RADAR IMAGING OF STRATIGRAPHIC WEAKNESS IN A SALT MINE

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Among the most dangerous occupations is mining, accounting for 3,421 non-fatal injuries and 37 fatalities in 2021 (NIOSH). Among the primary dangers are those from rock falls, either from the roof or the walls. These falls are caused by mining excavations in addition to planes of weakness caused by variations in rock strength. Because these fractures can grow over time, stability must be constantly monitored as long as the mine is active. Underground salt mines are not exempt from these rock fall risks, and in fact, these risks can be exacerbated in the salt mine environment. Because salt is ductile on the scale of years, there is increased risk from rock movement. Additionally, salt is often overlaid stratigraphically by shale, a notoriously weak and brittle sedimentary rock. The layers of shale and salt without stronger layers can increase the rock fall hazard within the mine.

We are using ground penetrating radar (GPR) in a salt mine in which the salt layer is stratigraphically overlain by shale, acquiring data from both the side of a pillar and along the roof in two locations. Results to date indicate evidence of fracturing within the salt layer, with a regional reflection less than 2 m above the roof that is tentatively interpreted as the salt-shale boundary. However, measured fractures within the shale have not been identified using the GPR. Despite dense bolting in the roof, the rock bolts, while visible, do not obstruct imaging of the shallow fractures within the salt. Future work will test additional processing methods as well as acquire additional data.

# GEOCHEMICAL DRIVERS OF MANGANESE REMOVAL IN DRINKING WATER RESERVOIRS UNDER HYPOLIMNETIC OXYGENATION

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Manganese (Mn) is a drinking water contaminant found worldwide in regions of Mn-rich bedrock. Consumption of drinking water with elevated Mn concentrations has possible adverse health effects in children. Hypolimnetic oxygenation (HOx) is a water treatment method deployed in lakes and reservoirs to control bottom water (hypolimnion) concentrations of metals and nutrients, including Mn. HOx systems restore dissolved oxygen to the hypolimnion, promoting oxidation and the subsequent precipitation of metals in the water column. Previous work in two Southwestern Virginia drinking water reservoirs documented significant cross-site disparities in HOx system efficacy for Mn removal. The contrasting geochemistry of both reservoirs suggests an influence of geochemical drivers, including pH and alkalinity, on Mn removal rates in lakes and reservoirs with HOx systems. My batch experiments simulated the individual and combined effects of pH and alkalinity on Mn removal rates in oxygenated lakes and reservoirs. In the absence of light, we observed substantial Mn removal within 14 days under high pH conditions (pH 10–11) and negligible removal in solutions under pH 8. In experiments with pH 10–11 and alkalinity over 80 mg/L $CaCO_3$, near-total Mn removal occurred within 24 hours. Mn removal co-occurred with the precipitation of particles (~300 um diameter) in these experiments. We analyzed selected particulates formed in batch experiments using electron diffraction spectroscopy and scanning electron microscopy. Analytical results show MnOx with sheet-like and amorphous textures, consistent with Mn removal driven by oxidation in our experimental solutions. Our observations of a positive correlation between pH and Mn oxidation rates are consistent with Morgan (1969) and Diem and Stumm (1984). Elevated alkalinity in high pH solutions promotes Mn oxidation by maintaining initial high pH conditions through buffering and may promote Mn carbonate formation, which can catalyze Mn oxidation. Our research elucidates the impacts of individual and multiple geochemical variables on Mn oxidation and removal in freshwaters, which may inform water resource managers' decisions on installing HOx systems for Mn removal. In addition, our results can improve the understanding of Mn cycling in natural waters.

# TRANSIENT SIGNAL DETECTION USING GNSS MEASUREMENTS AT THE ACTIVE VOLCANO OL DOINYO LENGAI, TANZANIA

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Ol Doinyo Lengai is an active stratovolcano located in the magma-rich southern Eastern Branch of the East African Rift System. It is characterized by alternating periods of longer lava flow, shorter-term activity of explosions with ash eruptions (VEI 3) followed by periods of relaxation dominated by fumarolic activity. In the last six decades, the volcano has shown periods of unrest with inflation and deflation resulting in observable surface deformation. This study uses Global Navigation Satellite System (GNSS) data from the TZVOLCANO Network in Tanzania to monitor surface deformation and detect potential transient signals by employing the Targeted Projection Operator (TPO) technique. TPO establishes a target pattern of pre-defined surface deformation and projects GNSS daily position time-series onto the target pattern using a weighted least squares estimation. First, we produce daily position time-series of the TZVOLCANO network for 6.5 years of observations from 2016 to 2022. Second, we remove outliers, estimate velocities, apply offsets at breaks, and model seasonal terms. Third, we establish spatial target patterns determined from Coulomb 3.3 forward modeling. Fourth, we apply the TPO program to project the daily position time series onto the target patterns. Finally, we assess the presence of temporal changes in the time series of the projection amplitudes. Preliminary results show spikes in late 2017, mid 2019, and mid 2022 that are indicative of potential transient signals. Transient uplift signals of ~7 mm have been observed since April 2022.

# MODELING THE INFLUENCE OF MANAGED AQUIFER RECHARGE ON GROUNDWATER REPLENISHMENT AND MITIGATION OF SALTWATER INTRUSION IN THE VIRGINIA COASTAL PLAIN AQUIFER

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Due to the difference in densities, seawater and freshwater are at equilibrium in a coastal aquifer. However, excessive groundwater withdrawal from a coastal aquifer causes an imbalance between these two bodies of water, resulting in seawater intrusion (SWI), groundwater depletion, and land subsidence. Groundwater depletion and SWI in the Virginia Coastal Plain Aquifer (VCPA) is due to the excessive abstraction of the Potomac aquifer. To mitigate SWI and replenish groundwater in the VCPA, the Sustainable Water Initiative for Tomorrow (SWIFT) research site in Suffolk, Virginia, started injecting treated wastewater into the aquifer in 2018. A hydrogeological model was built to evaluate the impact of managed aquifer recharge (MAR) on SWI, and groundwater replenishment within the Potomac aquifer. The hydrogeological characteristics of the research site were used to build the model. Also, the study site's salinity, pressure, and temperature as of 2018 were used to set up the initial conditions. Freshwater was injected into the model at the SWIFT operational rate for four years and three months. The model's output indicates that it is reliable because the change in the hydraulic head ($\Delta H$) closely fits the trend in $\Delta H$ of the USGS well. Additionally, if 1 million gallons of water was injected daily as intended, the model estimated a change in the $\Delta H$ of 1.2, 1.0, and 0.6 meters in the Upper, Middle, and Lower Potomac monitoring wells, respectively. These over-predict the values of $\Delta H$, further supporting the model's assertions. Finally, the scale of the model affects how saltwater intrusion dynamics behave. During injection, freshwater produces a plume that spreads into the denser saline water on a local scale of roughly 40 x 20 km$^2$. The salinity change also depends on how much water is injected into the aquifer's pore spaces because it is a density-dependent problem. If SWIFT could achieve its goal of 100 M gallons/day across five injection wells, it could mitigate saltwater intrusion in the VCPA on a regional scale.

# EXAMINATION OF MAXIMUM TSUNAMI INUNDATION EXTENT USING MICROFOSSILS IN A LOW-ENERGY COASTAL MARSH ENVIRONMENT IN THE SALMON RIVER ESTUARY, OREGON

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Although the Cascadia subduction zone (CSZ) has not experienced a megathrust earthquake (>M8) recorded during the historical or instrumental period, coastal marshes along the CSZ preserve widespread evidence of coseismic subsidence and tsunami inundation from the last great earthquake in 1700 CE. Many previous geologic studies have employed qualitative methods to document and characterize the coupled 1700 CE earthquake and tsunami evidence along the CSZ; however, to use this data in forward model validations and slip model reconstructions, high-resolution, quantitative methods are essential. Here, we conduct high-resolution tsunami sand deposit mapping to define the extent of the 1700 CE tsunami inundation in a low-energy coastal marsh environment at the Salmon River estuary, Oregon. Unlike previous low-resolution tsunami deposit mapping efforts, we will employ an innovative technique that both maps the tsunami sand deposit in high resolution using sediment cores and also analyzes microfossils in the cores beyond the extent of tsunami sand deposition for evidence of marine inundation. Delineating the full extent of tsunami inundation will help validate tsunami inundation forward modeling techniques and aid in reconstructing the offshore slip characteristics from the 1700 CE earthquake, contributing to the body of knowledge that continues to improve our understanding of how the subduction zone may behave in the future. Other benefits of this research include providing constraints to tsunami inundation maps that help mitigate tsunami hazards in populated coastal zones along the CSZ and informing coastal management efforts that aid in disaster risk analysis and contribute to infrastructure assessment and protection.

# USING MICROVERTEBRATES TO BETTER UNDERSTAND SPECIES DIVERSITY, MORPHOLOGY, AND EXTINCT COMMUNITIES

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Large, complete skeletons are often the most recognizable specimens in paleontology, but many small animals leave behind abundant, recognizable bones. Microvertebrate assemblages—collections of small vertebrates from one locality—excel at yielding numerous diagnostic, fragmentary specimens. Though sometimes overlooked, these assemblages can include dozens of species important to reconstructing ancient communities. Homestead is a new microvertebrate assemblage locality from the Late Triassic, yielding thousands of fossils from numerous animals, including two new species of drepanosauromorph, a group of small, peculiar reptiles. Rare animals, drepanosauromorphs possessed odd features like tail claws and atypical arm structures that make them difficult to understand. Most skeletons of this group (known from other localities) are flattened and distorted, therefore, much of their anatomy is not well understood. Homestead specimens occur as isolated and frequently fragmentary bones but are preserved in 3D, with bones not previously reported in the group. Drepanosauromorphs are represented by two claw morphotypes of what I hypothesize to be enlarged claws of digit II of the hand, based on the claws of other species of drepanosauromorphs. One morphotype is relatively wide and flat with little recurvature, like hypothesized burrowers, whereas the other morphotype is deeper, narrower, and more strongly recurved, as seen in presumably tree-dwelling species. These are like other drepanosauromorphs such as *Skybalonyx skapter* and *Ancistronychus paradoxus*, respectively, but represent distinct forms. Homestead also yields the first described 3D claws of the group from other digits, as well as an elusive 3D preserved tail claw. These specimens are not as diagnostic for species but still offer some of the first insight into previously unobserved morphology. Claw diversity suggests different life modes among drepanosauromorphs, but these animals alone do not tell the whole story. Homestead is from an undersampled formation, preserving a poorly documented community that includes such diverse clades as freshwater sharks, lungfish, ray-finned fish, metoposaurs, phytosaurs, aetosaurs, and dinosauromorphs. The presence of these groups alongside abundant coprolites—fossilized feces—reflect a complex ecosystem likely associated with an oxbow lake that dried out seasonally. Though not all material can be identified at the species level, some material indicates the presence of new groups with diverse life modes and otherwise unknown morphology, which is likely not limited to drepanosauromorphs. Continued study of Homestead and other microvertebrate sites holds great potential for understanding the structure and function of an ancient ecosystem.

PHOSPHORUS DELIVERY TO PLANETS VIA ASTEROIDAL DUST

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Phosphorus is a biogenic element found in the deep reaches of space and in various forms in plants and animals on our planet, Earth. All known life forms need phosphorus to live, function, and thrive, and we are quickly running out of it. Phosphorus is synthesized in supermassive stars to supply planets like ours with biocritical compounds. Its journey to Earth was influenced by two distinct processes that were common in the early stages of solar system evolution: planetary bombardment and the constant stream of cosmic dust and micrometeorites accreted by Earth. Planetary bombardment involves impacts by meter- to centimeter-sized meteorites and comets during the planet formation process. A larger mass of smaller, sub-mm-sized micrometeorites is also accreted by earth and other planets even to this date. The accretion of phosphorus onto earth and proto-earth (including proto-planets) via the latter, smaller size fraction is unknown and is the subject of this research project. Utilizing laboratory techniques, I measured phosphorus in a suite of micrometeorites that lie in the range of 0.01 and 1.108 P wt.% and then estimated that ~3,812 t/yr of phosphorus is accreted at the present time and ~$6.27 \times 10^{15}$ t/yr was accreted by proto-Earth during late heavy bombardment about 4 billion years ago. Bootstrapping was chosen as the model of choice to display the accretion rates due to the resampling method used to normalize the small number of P spots collected. The delivery of P during modern times supplies us with a steady flux to the surface of the planet, while P delivered during LHB could be stored in the core of the planet.

# THE EVOLUTIONARY RELATIONSHIPS OF AN ANCIENT FISH REVEAL THAT ANATOMICAL INNOVATIONS ARE NOT UNIQUE TO LIVING GROUPS

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One out of every two vertebrates on Earth are ray-finned fishes, 99.8% of which belong to the neopterygian group. The high living diversity of neopterygians is thought to be due to specialized traits in the upper jaw that are absent in their extinct counterparts. The ray-finned fish *Platysomus schultzei* appears in the fossil record 50 million years prior to the first recorded neopterygian but has strong anatomical similarities to neopterygians. Although *Platysomus schultzei* is known from a series of well-preserved fossils, its evolutionary relationship to neopterygians has never been analyzed. We examined specimens of *Platysomus schultzei* in museum collections to integrate this species into a phylogenetic framework of ray-finned fishes. We conducted a statistical phylogenetic analysis with this framework, searching for patterns of evolutionary relationships that best explain the observed anatomical data from each species. We designed the analysis to partition the features between the head, body, and fins to account for potential differences in how these parts have evolved in ray-finned fishes. Our partitioned analysis of evolutionary relationships inferred that *Platysomus schultzei* is not a neopterygian, strongly suggesting that the similarities between it and neopterygians evolved independently. More broadly, our results indicate that versions of specialized neopterygian traits evolved multiple times in the history of ray-finned fishes. Therefore, earlier groups of ray-finned fishes may have been more anatomically diverse and specialized than previously thought. Our research contributes to the emerging picture of ancient, diverse radiations of ray-finned fishes preceding neopterygians.

# ASSESSING OPTICAL REMOTE SENSING AND GAUGE PRODUCTS TO STUSY GLOBAL SEDIMENT TRANSPORT DYNAMICS IN RIVERS

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The movement and deposition of total suspended solids (TSS) throughout inland waters and coastal regions are being significantly altered via the construction of dams, which impound vast quantities of sediment, as well as climate and land use change, which can deliver additional sediment to inland waters. Gaining a better understanding of how these large-scale changes affect global sediment transport dynamics is key to mitigating their effects. Satellite remote sensing has the potential to provide frequent, high-quality, global-scale observations of inland water quality. Recent advances in small satellite technologies enable innovative and cost-effective mission designs. Here I present a tradespace exploration study of an inland water quality-based optical satellite mission concept, with a specific emphasis on observing TSS in rivers, lakes, and reservoirs. I examine the optimal spatial, spectral, and temporal resolution for estimating TSS in inland waters through a data degradation study. Using ultra high-resolution NASA AVIRIS-NG airborne hyperspectral data and paired in situ data from the ongoing Delta-X mission in the Atchafalaya Basin, I analyze the tradeoffs of varying spatial and spectral resolutions and signal-to-noise ratios to analyze how observational resolution affects estimation accuracy. I also study the temporal requirements needed to capture the dynamics of TSS variability in rivers using near-continuous USGS turbidity data from ~ 600 gauges across the United States. Preliminary results indicate that a fine spectral resolution (< 10 nm) is key for optimal TSS estimation, while spatial requirements are less stringent and depend on the desired smallest observable water body size. Temporal analysis based on wavelets suggests that a ~ 5-day revisit period will adequately capture TSS variability and unique events. The results from this research will help inform and optimize future space mission designs focused on remote sensing of inland water quality.

ROUGHNESS OF THE GLOBAL OCEANIC 220-KM DISCONTINUITY AND
IMPLICATIONS FOR SPREADING RATE DEPENDENT SMALL-SCALE CONVECTIONS

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A global discontinuity at a depth of 220 km was first introduced in PREM in the 1980s as the lower boundary of the asthenosphere. Later studies suggested that this interface may not be a global feature as it is rarely observed in oceanic regions. In this study, we process twelve years of SS precursors recorded at the global seismological network. We observe SS precursors reflected off this boundary across the global oceanic areas. The amplitudes of the SS precursors require about 6% of a velocity increase across the 220-km discontinuity, roughly consistent with that in PREM. We apply finite-frequency tomography to obtain depth perturbations of the discontinuity in the global oceans. We show that the depth perturbations roughly follow the age contours, however, the average depth of the 220-km discontinuity is independent of seafloor age. The most interesting observation on the topography of the 220-km discontinuity is that the roughness of the discontinuity increases with the seafloor spreading rate. The geodynamical processes responsible for this positive correlation are unclear, but it indicates small-scale convection in the oceanic asthenosphere may be controlled by seafloor thermal structures formed during the initial melting processes at spreading centers. In addition, the increase in boundary roughness is distinctly different for slow-spreading seafloors and fast-spreading seafloors. The Atlantic Ocean is dominated by slow-spreading seafloors, and the roughness of the 220-km discontinuity increases rapidly with the spreading rate, while in the Pacific Ocean and the Indian Ocean, the increase in roughness is much slower. The differences in the rate of increase in roughness indicate that seafloors may have a "permanent memory" of their birthplaces, and the (different) melting processes at the spreading centers may have been imprinted in their chemical compositions and physical properties (e.g., porosity and thermal properties) millions of years after they have moved away from the spreading centers.

RADAE IMAGING OF FRACTURES IN SALT FOR MINE SAFETY

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A significant challenge of underground mining is worker safety. In the United States, the fatal injury rate of underground mining is more than five times the national average of other industries. Many injuries and fatalities are related to roof falls and often stem from pre-existing weak geologic structures. In underground salt mine operations, fractures and voids hidden behind the rock face are major components of roof fall. At lithostatic pressures, salt undergoes ductile deformation, but near the free faces of excavation, the salt deforms in a brittle manner (Kannenberg, 1997). The development of expansion joints near these free faces affects the supporting capability of mine pillars, but methods to identify them are restricted in fear of damaging the overlying water-protective strata. This study set out to determine whether ground-penetrating radar data can successfully identify and characterize fractures in a mine roof to improve mitigation of mining hazards. Radar images were acquired on the mine roof and pillars in an underground salt mine. Surveying across pillars displayed radar reflections from adjacent mine tunnels 30 to 45 meters away. Data acquired on the ceiling observed distinct reflections from <1 meter to ~50 meters into the mine roof. Clear, shallow radar reflections resolved in the roof data are interpreted to be fractures hidden behind the rock face. Such reflections are caused by the strong salt/air dielectric contrast and minimal background noise within uniform salt rock. Preliminary results indicate that ground-penetrating radar is an effective technique for detecting structural instabilities in the mine roof. Calibration of radar images with drilling results demonstrated that radar is capable of resolving fractures at the centimeter scale in salt. Routine radar monitoring of the mine roof will enable mining personnel to identify and remediate areas that pose serious threats to worker safety.

EFFECTS OF CORE-MANTLE BOUNDARY TOPOGRAPHY IN GEODYNAMIC MODELS OF THE LOWER MANTLE.

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Current research supports the theory that Large Low Velocity Provinces (LLVPs) are a consequence of the subduction cycle and have assembled over hundreds of millions of years. Similarly, studies found the core-mantle boundary (CMB) topography has subtle variations up to $\mp$ 30 km vertically across wavelengths of 50-400 km. However, the most accurate geodynamic models that explain LLVPs' assemblage seldomly account for the effects of the CMB topography in the evolution of the lower mantle. Instead, the CMB topography is often treated as a consequence of LLVPs' formation and is not included in the boundary conditions of the models. It is possible this omission could affect the distribution of material and mixing in the lower mantle. To test this hypothesis we use CitcomS to produce a more accurate geodynamic model of the lower mantle by considering evolving CMB topography, plate velocity boundary conditions, and tracers representing accumulating subducting material. This will allow us to assess the role CMB topography has in accumulation and mixing of subducted material in the lower mantle over the past hundreds of millions of years, and simultaneously increase the accuracy of our models.

# INVESTIGATING THE ECOLOGY OF *SALTERELLA,* THE OLDEST MINERAL COLLECTOR IN THE ANIMAL KINGDOM

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Nearly all major groups of modern animals first arose and diversified in the Early Cambrian (538-509 Mya), an event we call the Cambrian Explosion. During this time, animals rapidly evolved novel traits to survive in a changing ecosystem. Multiple groups independently developed hard skeletons through growing shells (biomineralization) or building tests (agglutination). While there are many animals alive today that use either method for protection, there is no organism known to do both. The extinct Early Cambrian organism *Salterella* consists of an outer biomineralized shell with inner agglutinated layers, making it unique in the animal Kingdom. This set of features makes it difficult to place *Salterella* in a phylogenetic framework, but critical to our understanding of early animal skeleton evolution.

*Salterella* is known exclusively from the Laurentian paleocontinent. Here we describe specimens from Virginia, Nevada, northwest Canada, and Scotland. These localities were selected to represent a range of depositional environments and taphonomic modes to explore how *Salterella* lived and how it was preserved. In siliciclastic dominated environments, *Salterella* demonstrates selectivity in agglutinated grains preferring heavier grains such as Fe and Ti rich minerals. In carbonate dominated environments, *Salterella* shows incredible adaptive plasticity building its agglutinated layers completely of carbonate grains. Additionally, *Salterella* shows ontogenetic change (changes as it grew). The biomineralized and agglutinated layers have a distinct boundary near the apical end, but become increasingly interfingered toward the aperture, demonstrating a change in the way it grew its shell as it developed. These traits provide clues to how *Salterella* lived. Further understanding of the ecology of *Salterella* will help in establishing its relationship to modern animal groups and how skeletonization evolved in animals.

# NEW ESTIMATES OF VERTICAL DISPLACEMENTS AND RELATIVE SEA-LEVEL CHANGES DRIVEN BY GLACIAL ISOSTATIC ADJUSTMENT IN THE CHESAPEAKE BAY REGION

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Glacial isostatic adjustment (GIA) describes the response of the solid Earth, oceans, and gravitational field to the spatial-temporal evolution of global ice sheets during a glacial cycle. It is proposed that the Chesapeake Bay is subsiding due to the collapse of a glacial forebulge in response to the melting of the Laurentide Ice Sheet following the Last Glacial Maximum. As a result, the Chesapeake Bay is a hot spot of relative sea-level rise along the North American Atlantic Coast. We evaluate the influence of GIA on vertical land motions and relative sea-level changes in the Chesapeake Bay using ice models ICE-6G and ICE-7G with a range of Earth model structure parameters. We hypothesize that GIA is contributing to land subsidence and relative sea-level rise in the Chesapeake Bay, with a range of estimates depending on input parameters and structural differences in GIA models. We use the open-source software SELEN4.0 (a Sea lEveL EquatioN solver) to investigate the effects of GIA using a suite of radial viscosity structures and glacial retreat models. We primarily analyze the 'glacial isostatic adjustment fingerprints' of vertical displacements and relative sea level changes. Further, we evaluate the uncertainties of GIA modeling associated with input parameters and structural differences among GIA models using an ensemble approach. Vertical displacements and present-day relative sea-level change rate estimate due to GIA range from approximately -0.5 to -2.5 mm/yr and 1.0 to 2.0 mm/yr, respectively, depending on the ice sheet model used. We conclude that, overall, GIA is producing negative vertical land motions in the Chesapeake Bay, which is contributing to accelerated rates of relative sea-level rise in this region; however, there are several uncertainties that should be considered for GIA modeling. Accurate estimates of vertical displacements and relative sea-level rise carry important economic, ecological, and coastal hazard implications for the densely populated Chesapeake Bay region.

# NANOSCALE TO ECOSYSTEM SCALE STUDY OF IRON AND MANGANESE IN FRESHWATER DRINKING RESERVOIRS

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Approximately 6.8 million Virginians rely on public water, 88% of which comes from surface water sources like freshwater drinking reservoirs (USGS 2015). Surface water sources are readily available but vulnerable to anthropogenic and geogenic contamination. Iron (Fe) and manganese (Mn) are common geogenic contaminants because of their natural abundance in the sediment. Fe and Mn migrate via reductive dissolution into the bottom waters, or hypolimnion, of reservoirs during seasonal anoxia and surpass EPA secondary drinking water standards of 0.3 mg/L and 0.05 mg/L, respectively. Hypolimnetic oxygenation (HOx) systems inject oxygenated water into the hypolimnion and oxidize Fe and Mn into solids, effectively removing them from the water column. These nano- and microscale solids that largely comprise the suspended sediment are ubiquitous, yet the understudied product of HOx operations in freshwater reservoirs could greatly affect biogeochemical cycling patterns. Here, we collected suspended sediment from above and below the hypolimnion using a sedimentation trap from Falling Creek Reservoir, which has a HOx system, and Beaverdam Reservoir, which does not. We use electron microscopy and synchrotron x-ray diffraction to probe the identities and properties of the nanominerals in the suspended sediment. We also use bulk digestion methods to characterize the fluxes of Fe and Mn in each reservoir. Our results show that HOx operation increases the flux of Fe and Mn, thus creating more nanominerals. These nanominerals are aggregates of smaller, short-range ordered particles that bear resemblance to ferrihydrite. There is also evidence of crystalline detrital minerals in the suspended sediment. The identities and physicochemical characteristics of these Fe/Mn nanoparticles indicate that they are likely to remigrate into the water column after burial. Our results inform water management decisions about seasonal HOx operations and contaminant control in drinking water reservoirs.

# HYDROLOGICAL CRUSTAL LOADING IN THE LAKE MEAD REGION

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Lake Mead, the largest U.S. reservoir at the Colorado river straddling the Nevada and Arizona border, is one of the essential suppliers of fresh water to the Southwest United States. According to the U.S. drought monitor, as of the early 2000s, the whole region has experienced a strong drought still ongoing. The severe to extreme drought not only caused the lake water volume to decline to about a third of its capacity to initiate a water crisis but also negatively affected the entire region's soil and groundwater storage changes. Water deficit also reduced the water mass loading on the Earth's crust responding elastically with deformation at the surface. This can be observed from the Global Navigation Satellite System (GNSS) sites or from space via Interferometric Synthetic Aperture Radar (InSAR) technology. In this study, we investigate the vertical deformation observations at the GNSS sites and those obtained from multitemporal InSAR analysis of Sentinel-1A/B. This investigation is carried out in order to predict groundwater storage changes via their load-induced deformations. This is done through evaluating the signal strength versus uncertainties in the GNSS/InSAR observations and load models. For this purpose, we apply the effects of glacial isostatic adjustment as well as non-tidal mass loads from GNSS/InSAR observations using the global models. Furthermore, we separately estimate the expected vertical crustal deformation in the region due to changes in the amount of water stored in the lake as well as in the soil. We quantify hydrological loads and evaluate the various load models versus GNSS/InSAR observations by applying Green's functions for a spherical, layered, self-gravitating Earth, and load-Love numbers from the Preliminary Reference Earth Models (PREMs) as well as homogeneous linearly elastic half-space Earth models. Furthermore, we look into the influence of local crustal properties and evaluate the output of a range of elastic loading models using different model types and crustal properties during drought and non-drought periods. In future investigations, we would like to interpret spatially distributed deformation responses from InSAR and do additional analysis of groundwater levels necessary for the accurate prediction of changes in water masses using the deformation data. In addition, we will incorporate a thorough uncertainty analysis for each data set to determine the predictability of groundwater storage changes based on observations of vertical loading deformations from GNSS/InSAR data surrounding the lake. These approximations can provide an important insight into the dynamics of Lake Mead's interactions with local aquifers.

# Abstracts for Undergraduate Student Poster Presentations
(In alphabetical order)

# VALIDATING MELT GENERATION FROM LITHOSPHERIC MODULATED CONVECTION USING THE GEODYNAMIC MODELING CODE ASPECT

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Geodynamic modeling uses numerical methods to investigate processes in the Earth's crust, mantle, and core. Lithospheric Modulated Convection (LMC) is mantle convection driven by variations in lithospheric thickness that constrain the initial temperature. ASPECT (Advanced Solver for Problems in Earth's ConvenTion) is a finite element code that simulates problems in thermal convection to assess processes primarily in the Earth's mantle. We are testing the implementation of the new LMC approach in ASPECT for sublithospheric melt generation in magma-poor areas. We use ASPECT to solve the Stokes equations using the extended Boussinesq approximation for an incompressible fluid which incorporates the effects of adiabatic heating and frictional heating in the energy equation. Latent heating is also included in the energy equation to generate melt in the sublithospheric mantle from LMC. We use a regional model of a rigid lithosphere and an underlying sublithospheric mantle that convects via LMC. We apply the LITHO1.0 lithospheric thickness model in Uganda and the Fishwick (2010, updated) lithospheric model in Malawi as the base of our lithosphere. Our results indicate LMC generates melt in both regions for a mantle potential temperature of 1800K in Malawi and Uganda. This work suggests the ASPECT code can be used to simulate sublithospheric melt generation from LMC, which has potential applications for researchers investigating rifting, volcanism, and general tectonic processes involving sublithospheric melt.

# INVESTIGATION OF THE OCEANOGRAPHIC MUSEUM OF MONACO: IMPACTS OF CHANGING PHYSICAL CHARACTERISTICS ON MEDITERRANEAN MARINE BIODIVERSITY AND COASTAL COMMUNITIES

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The Mediterranean region has served as a cultural exchange center for millennia and its influence is global. The Physical Oceanography of the Mediterranean Sea is unique in that it is an intercontinental sea with only one point of seawater exchange to the world's oceans, the Strait of Gibraltar. The relatively low influx and export of physical properties allows the Mediterranean Sea System to be regarded as a "laboratory" for understanding physical oceanographic processes that can occur on a global scale in the world's oceans. Changing trends in the physical characteristics of the Mediterranean Sea such as increasing sea surface temperatures and increasing seawater acidity can affect marine biological processes in the Mediterranean. Efforts by scientists to quantify the biodiversity of the Mediterranean Sea estimate it contains 4% to 18% of all living marine species while only representing 0.8% of the Earth's ocean surface and 0.32% of the world ocean volume. Further understanding of the impacts of changing physical oceanography of the Mediterranean Sea on marine biodiversity and human communities who rely on these ecosystems is needed. Here we present a preliminary investigation of Mediterranean Oceanography from notes, photos, and sources gathered while visiting and studying the Oceanographic Museum of Monaco made possible by a Nyfeler Scholarship during the Fall 2022 Geosciences Study Abroad Program. The Aquariums at the museum serve as a world class source for information about Mediterranean Sea biodiversity. Information about Mediterranean marine organisms present at the Aquariums was recorded along with information about the significance of the species to human coastal economies or culture. Four species of interest were identified as either providing important ecosystem or economic services or having cultural value to coastal communities. These species were Red Coral, Dusky Groupers, European Seabass, and Neptune Grass. Our results included detailed information on the importance of these species to human communities as well as each species' susceptibility to changing Sea Surface Temperature and pH values. These species of interest appear to have differing reactions to the Mediterranean Sea Surface Temperature and pH value trends with some species being negatively impacted while others appear to be positively impacted by these changes. These results show the importance of biogeographical research of marine species to predicting impacts on coastal human communities and economies in the face of climate change.

# THE TOPOGRAPHIC TRENDS OF LARGE DOMES ON CERES WITH CRYOGENIC ORIGINS

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Ceres is a dwarf planet in the asteroid belt of our solar system. Ceres has a single recognized cryogenic volcano, Ahuna Mons. Bright streaks run from the top to the bottom of Ahuna Mons and are thought to be salt, similar to the better-known Cererian bright spots. The interpretation that these streaks result from salt or briny fluid adds to the evidence of a cryogenic origin for Ahuna Mons. Previous researchers have hypothesized that many or all of the large domes that have been discovered may be older, degraded cryogenic volcanoes. In this report, we look at the large domes of Ceres to find common trends and how they were created. Trends specifically regarding topographic features due to subsurface ice movement. When we look at these domes, we are ultimately seeing how similar they are to Ahuna Mons. Assuming the large domes were originally formed by a process similar to that of Ahuna Mons we take the topography of Ahuna Mons and use an analytic solution for the decay of the topography with time. We then interpret how the topography changed over time. If these features prove to be similar to the other large domes it could suggest an ice plume origin versus a dome created from surrounding craters.

# EFFECTS OF SOLUTION PH AND ALKALINITY ON MN PHOTO-OXIDATION RATES

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Elevated manganese (Mn) concentrations in drinking water can impact human health and cause aesthetic issues such as odor, taste, and staining. My research tested whether changes in pH and alkalinity could affect the photo-oxidation rate of Mn, which causes conversion of dissolved to solid phase Mn, a process that can result in removal of Mn from drinking water. To do this, I conducted batch experiments to test varying levels of pH and alkalinity on Mn removal rates while under constant light. I sampled experiments weekly, taking filtered aliquots and analyzing them for Mn using ICP-AES.  Results showed that Mn removal in experiments with moderate to high levels of alkalinity (10-15 mg/L and 200 mg/L $CaCO_3$) and high pH (10) occurred at significantly higher rates than experiments with little to no alkalinity and lower pH. Mn removal from solution occurred simultaneously with  the formation of small, fibrous particles. I imaged selected particles from the experiments with a Hitachi TM 3000 scanning electron microscope and measured surface elemental compositions using electron diffraction spectroscopy. Results show that the particles were mostly composed of MnOx.  Although I observed differences in Mn removal with changes in pH and alkalinity, comparison with a paired experiment conducted in the dark did not show significant effects of light on Mn removal. Thus, my results suggest that photo-oxidation may not be as important as changes in pH or alkalinity on Mn removal. My research gives insight into how different conditions in an environment can affect Mn oxidation, which gives a better understanding of Mn cycling in waters. This information could also help water resource management in cleaning contaminants in water reservoirs.

HIGH TEMPERATURES OF THE ARCHEAN CONTINENTAL CRUST: A STUDY OF THE PIKWITONEI GRANULITE DOMAIN

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The Pikwitonei Granulite Domain is a complex metamorphic terrane mainly located in the province of Manitoba, Canada that gives insight into the high temperature metamorphism the region had undergone approximately 2.7 Ga. Thin sections from samples collected in Manitoba were analyzed using an electron microprobe in order to create element maps. Most of the minerals identified were typical of high-grade metamorphism. Further analysis of the element maps has provided evidence that retrograde metamorphism took place through the edges of garnets that were partially converted into cordierite and biotite. Quantitative analysis of the samples using an electron microprobe will be performed in the near future. This will provide precise values for the temperature and pressure of the samples during metamorphism. The high-grade and retrograde metamorphism that occurred indicates that the terrane was once buried deep in the crust and then uplifted afterwards. It was likely buried to at least 20 km, however, until quantitative data is collected, it will be difficult to determine the precise depth of the terrane. The Pikwitonei Granulite Domain is an excellent example of early craton development that can provide insight into what processes took place in order to form the North American Craton.

# COATING GROWTH ON CALCITE IN ALUMINUM NITRATE SOLUTION

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Acid mine drainage (AMD) is a prevalent issue in areas where pyrite ($FeS_2$) and other metal sulfide minerals are exposed to water and oxygen through natural processes or anthropogenic activities. The oxidation and dissolution of these minerals produces sulfuric acid and releases dissolved metals to surrounding sources of water, creating toxic environments. Engineered drain channels lined with limestone are commonly used to mitigate the effects of AMD. The reaction of AMD with carbonate minerals neutralizes the acidity, which destabilizes dissolved metals and causes them to precipitate on the limestone surface. This process decreases the neutralization efficiency of the system. Understanding the impact of AMD water chemistry on the coating formation process is important for designing more effective and efficient AMD treatment systems.

This study used a mixed flow reactor approach (Palomino-Ore et al., 2019 *Applied Geochemistry*) to study the impacts of aluminum concentration on the formation of mineral coatings on calcite. Simulated AMD solutions were made at two concentrations, 0.12M and 0.24M, using aluminum nitrate ($Al(NO_3)_3 \cdot 9H_2O$). The AMD solutions were pumped into the reactor containing approximately 2 g crushed calcite (sizes 850-1000 μm) at a fixed flow rate of 1.20 mL/min and constant stirring. The effluent pH and dissolved concentrations of Ca and Al were monitored with time for each experiment. At the beginning of each experiment the solution pH and Ca concentration are higher in the effluent compared with the influent solution due to neutralization of the acid from calcite dissolution. In contrast, the Al concentration was low compared with influent due to Al precipitation. However, with time, the pH and Al concentration eventually trend towards the input solution, while the Ca concentration decreases. Characterization of the Al precipitates recovered from the calcite surfaces show that the formation of poorly crystalline aluminum hydroxide coatings act as a barrier, thereby slowing calcite dissolution and reducing the rate of neutralization. There was negligible impact of Al concentration on the calculated rates of coating formation. The rates of coating formation in the presence of nitrate are relatively slow compared to similar experiments done with aluminum sulfate, which suggests the importance of anion type on the coating formation process. The results are important for designing effective and efficient AMD treatment systems.

# CHARACTERIZATION OF NATURAL IRIDESCENT IRON OXYHYDROXIDE FROM GRAVES MOUNTAIN, GEORGIA

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Mineral-based pigments are an attractive alternative to synthetic organic dyes because they are non-toxic and resist degradation. The colors we perceive in many mineral pigments are related to bulk mineral composition and defects and impurities. Physical features such as repeating surface layers or microstructures can also produce vibrant iridescent colors through a mechanism known as structural color. These structures in metamorphic "rainbow" hematite ($Fe_2O_3$) diffract light and create the appearance of different colors that change with viewing angle. However, there are examples of other iron minerals that exhibit iridescence that are angle-independent. The objective of this research is to understand the mechanism of this particular type of iridescence in order to develop new types of mineral-based pigments.

Natural iridescent samples were obtained from the Graves Mountain mine in Lincoln County, Georgia. Often referred to as turgite, the minerals in the samples are expected to be mainly hematite and goethite ($FeO(OH)$). Although iron oxides and hydroxides are typically red to orange in color, the surfaces of these samples display a variety of vivid rainbow-like hues. We are using powder X-ray diffraction (pXRD), X-ray photoelectron spectroscopy (XPS), and scanning electron microscopy (SEM) to characterize the mineralogy, surface composition, and physical features of the samples. Powder XRD shows that the minerals scraped from the iridescent surface are a mixture of hematite and goethite. XPS shows the presence of minor aluminum content that varies for regions with different individual colors. SEM imaging shows the presence of botryoidal features with dimensions that range from the mm to the nanoscale. Our future work will attempt to integrate these characterization results to explain the mechanism of iridescence in these samples, which would open new possibilities for producing mineral-based pigment materials.

# METAL REMOVAL RATES FROM A DRINKING WATER RESERVOIR UNDERGOING OXYGENATION

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Seasonally stratified eutrophic lakes and reservoirs can develop low dissolved oxygen conditions in the bottom waters and sediment. Under these low oxygen conditions, metals, such as barium (Ba), aluminum (Al), and calcium (Ca), can be released from minerals in bottom sediment into pore water and can diffuse upward into the water column. Elevated metal concentrations can have negative impacts on drinking water quality and human health. Treatment of drinking water with elevated metals can be conducted through hypolimnetic oxygenation. The goal of oxygenation is to promote the oxidation of metals, resulting in precipitation and sedimentation of the metals from the water column, thus removing the metals from drinking water. In this study, I calculated removal rates of metals from the water column of two freshwater drinking reservoirs: one with oxygenation and one without (control). To do this, I captured suspended metal oxides from the water column using sediment traps, then filtered and digested the suspended sediment matter using microwave digestion. I then calculated suspended sediment fluxes, which reflect removal rates, or Ba, Al, and Ca. Results indicated that removal rates varied among the metals and increased during oxygenation, altering the biogeochemical cycling patterns of these metals in comparison to the control reservoir. Overall, my results suggest that oxygenation systems can enhance metal removal from freshwater drinking reservoirs, benefiting water quality and human health.

# AN INVESTIGATION SURROUNDING A SAND DEPOSIT OF THE CASCADIA SUBDUCTION ZONE.

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The Cascadia subduction zone (CSZ), located along the Pacific coast of North America, is characterized by a convergent boundary where the Juan de Fuca plate subsides beneath the North American plate. This boundary has the potential to produce great megathrust earthquakes (>8.5M) and tsunamis. Modern subduction zone earthquakes have produced devastating coastal disasters in Japan, Chile and across the Indian Ocean. The most recent earthquake occurred over 300 years ago (1700 CE), therefore, understanding the cycles of these megathrust earthquakes is essential for hazard mitigation efforts. Unfortunately, the lack of a modern event makes preparing for future hazards in the region challenging, especially with the continuing growth of coastal communities that reside in the impact zone for these tsunamis. In order to better understand this hazard, our team investigated the changes in ecology to determine past CSZ earthquake characteristics by collecting sediment samples from the Fahys Creek of the Coquille River in Southern Oregon. During our investigation, an anomalous sand layer was found, uncorrelatable to previously mapped and described tsunami deposits. Instead of a graded sand bed that overlays high marsh peat sediment, this land layer is interrupting the peat deposition. To determine what geological event caused the deposition of this anomaly, I conducted a grain size analysis. The Mastersizer 3000 was used to find the average sediment size at each depth of the sediment core. These measurements were able to be used to correlate the depth at which the sediment was delivered from. In order to characterize the ecological changes, phytoplankton biomarkers that propagate at specific aquatic conditions called diatoms were used. These diatoms collected in the samples were counted and species were identified to determine the environmental origin of the deposit. During this analysis, ratios of pennate vs centric diatoms were evaluated to determine the volume of marine diatoms that were deposited within the higher marsh environments. This data was then combined with the grain size analysis to confirm where the sediment has traveled from in the deposit, in hope to prove that this is not a tsunami deposit. Lastly, fracture ratios of the diatoms are considered to determine the amount of turbulence in the deposit. The turbidity of the deposit will give information about the energy of the depositional environment. This study is important for our team because it will allow us to better understand anomalous sand deposits in relationship with previously studied sand deposits.

# 2023 GS(art)S Submissions

*Facilitated by Amy Hagen, Erika Goldsmith, Cece Wood, and Jess DePaolis*



## Helen Burch
### *Ecosquishtems,* 2023
Gouache on paper

This piece reimagines a stratigraphic column as a continuum of paleocommunities progressing through the Early, Middle, and Late Triassic, from the beginnings of biotic recovery following the end-Permian Extinction, to the Carnian when reptiles experienced an initial boom in diversity, and finally through the complex ecosystems and ultimate destructive vulcanism that ended the period. Bright colors and an absence of definite perspective reflect the whimsy and mystery of the fossil record.

## Elizabeth Curtiss
### *Fracture Intensity Spectrum,* 2023
Mixed medium, digital art

The Fracture Intensity Spectrum is a schematic representation of fracture intensities that are collected in the field. The intensity values are used, in this instance, as a proxy to identify and bound the areal extent of brittle off-fault deformation (OFD). The data is collected in perpendicular transects along active faults in the Eastern California Shear Zone as well as in non-fault bound outcrops as a control of the background fracture intensity unrelated to active faulting. Ideally, we would see a decrease in intensity as distance from the active fault increases, and once reaching background level, can bound the OFD.
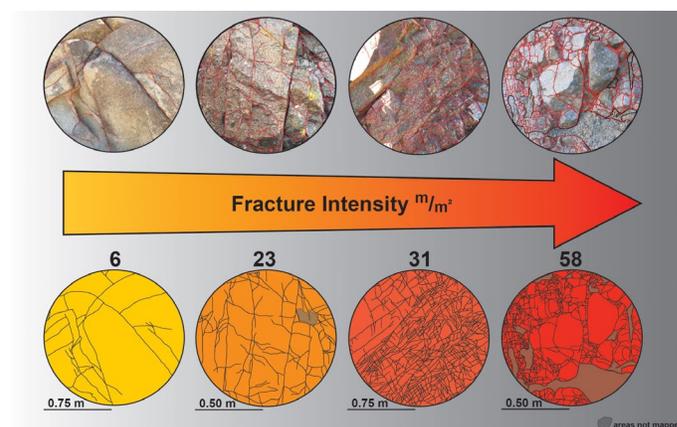
**Ella Davis**
*Walking About Loch Hourn,* 2023
Watercolor
Last summer I visited various locations for my field work in Northern Scotland including Kinloch Hourn. The Scottish Highlands are known for their overwhelming greenness which made the yellow and red ochres of the seaweed covered shore of Loch Hourn stand out between the mountains. This landscape painting looks in towards the end of the loch as we hiked back from collecting samples of the pelitic and psammitc rocks common to the southern extent of the Northern Highlands. I prefer painting watercolor landscapes because the medium allows me to better convey the motion and environment of the location.

**Jessica DePaolis**
*The Wave,* 2022
Digital Art
Inspired by the famous piece *Under the Wave off Kanagawa* by Japanese artist Hokusai, this digital art encapsulates the interdisciplinary elements of studying coastal hazards (i.e., earthquakes, tsunamis, and storms). Similar to detective work, coastal hazards research requires a lot of decoding the landscape to understand the vulnerability of a coastline. Often buried trees, abrupt changes in sediment type, and diatoms (microscopic algae with glass shells) are preserved in coastal environments and provide ecological evidence that a catastrophic event occurred. Taking these clues from the past, we can begin to understand how hazards will affect a coastline in the future.
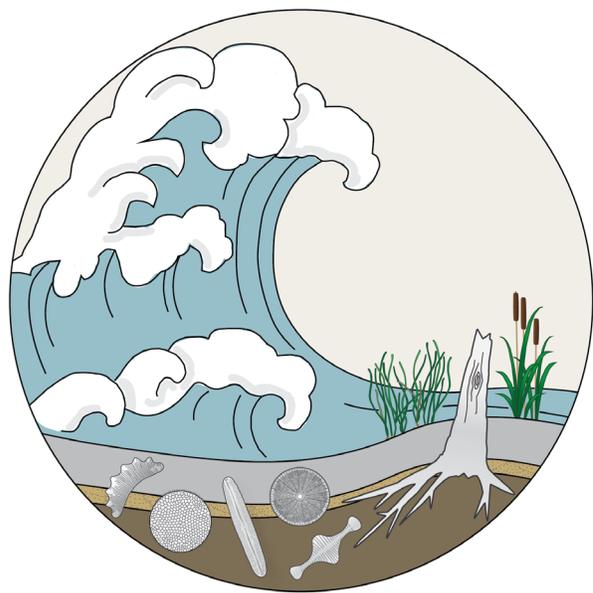
## Erika Goldsmith
### *Bones in Time,* 2023
Mixed media on paper

Modern and fossil bones can tell you so much more than you might think - they can provide a window into how the animals might have lived. Did they grow quickly? Slowly? Internally, bones preserve growth marks, just like how trees preserve tree rings, that signify about one year of growth. In this art, I wanted to share an abstract view of bone microstructure with faster growth from a younger individual displayed at the top and slower growth from an older individual at the bottom. Can you count the growth mark lines and see how old these individuals might have been?

## Alaina Helm
### *Sifnos blueschist and quartzite,* 2022
Digital image

This is a map of aluminum abundance in a blueschist and quartzite boundary rock from Sifnos, Greece. Blues and purples represent a low concentration of aluminum while yellows and oranges show areas of higher concentration. Abundance of aluminum is dependent on minerals, making different minerals and specific crystals within the rock distinguishable. You can spot garnets in red, quartz in blue, glaucophane in purple, paragonite in orange, and clinozoisite in yellow. This was made on Virginia Tech's JXA-iHP200F electron microprobe to analyze compositional trends related to fluid alteration across the sample.
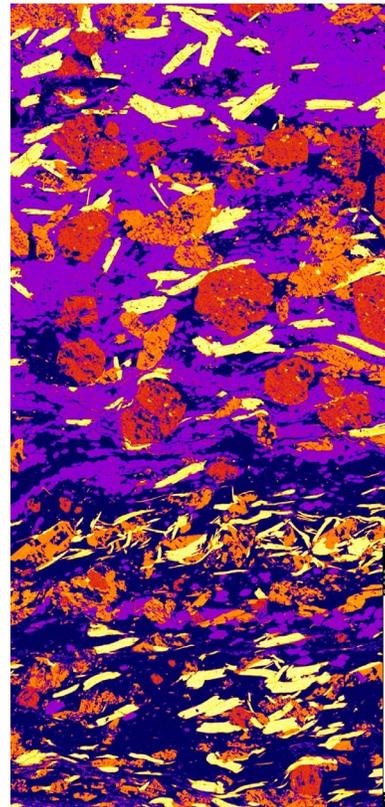
**Khanh To**
*Under the Fluffs,* 2023
Digital art
Bones, the hard parts making up internal frames of us vertebrates. We look at the bones to determine its age, its pathological history, and its biomechanical capabilities. But this internal frame cannot function without the soft tissues like muscles and nerves supporting it, acting upon it, and moving it. This digital art is a reminder that while the one component you are interested in is important in its own rights, that component is constantly interacting with other components in the system and should be considered with a larger context in mind.

**Prescott Vayda**
*Cambrian Explosion of Color,* 2023
Digital image
A regular thin section of Salterella can often be a boring monotone, but there is plenty of information hidden inside. I wanted to evoke the variety of ways that I can view the fossil. Each perspective provides different information useful for understanding how this organism lived and died.
From left to right: Plane polarized light (background), SEM backscattered electron (gray), EDS titanium spectrum (white), EDS oxygen spectrum (blue), EDS aluminum spectrum (teal), EDS silicon spectrum (green), EDS calcium spectrum (yellow), EDS iron spectrum (orange), EDS magnesium spectrum (pink), Cathodoluminescence (red). Scale bar = 1mm.
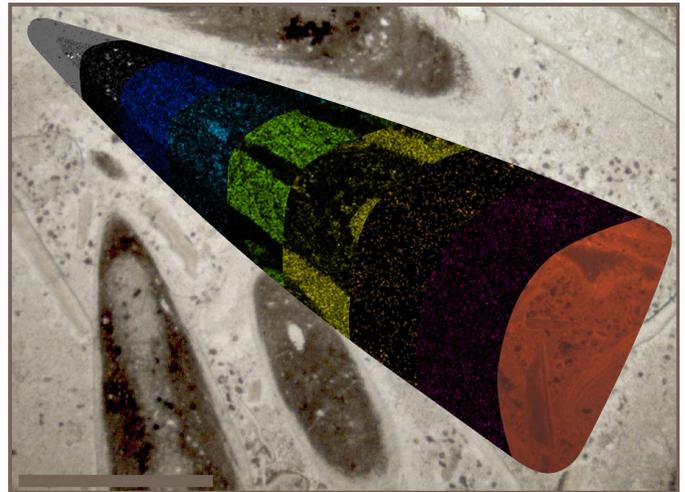




**Cassie Becker**
*Loch Linnhe,* 2022
Photograph
Photographed is a Devonian basin along the shore of Loch Linnhe. Last summer, I visited Scotland for fieldwork. I traveled to all corners of the country, but this day was the most memorable for me. I feel a sense of calmness when I remember the rolling hills, streams, salt marshes, and the abundance of sheep (not pictured). Whenever I get overwhelmed with data interpretation, I reflect on this experience, traveling to the most beautiful place I've ever seen.

**David Bunin**
*View of Mt. Hood Descending into Portland, OR,* 2022
Photograph
Mount Hood is a composite stratovolcano in the Cascades Range in the Pacific Northwest region of the United States. As the northernmost and highest peak in Oregon, it provides the iconic backdrop of Portland. Flights landing from the east into Portland International Airport descend into the Columbia River Gorge with beautiful views of Mount Hood and Mount Jefferson. Mount Hood is identified by the Cascades Volcano Observatory as having a high threat potential; any eruption would be hazardous to aircraft. This view of Mount Hood with the wing of a 737 MAX aircraft shows the connection between aviation and geosciences.





**Natalia Varela**
*Staring at the sea,* 2021
Photograph
Picture taken from the JOIDES Resolution during the International Ocean Discovery Program (IODP) Expedition 396. The sunsets in the North Atlantic gave us many moments of awe, and a daily pause from the long shifts over the two months at sea.

## Cecelia Wood
### *Dead Zone,* 2022
Photograph

Drainage from flooded, decommissioned mines have a massive impact on the surrounding ecosystem. This photograph is of a drainage upwelling site in a National Forest in central Pennsylvania. Often referred to as 'dead zones', these areas are characterized by iron deposits, acidic water, and a lack of new plant growth. Dead zones have a peculiar kind of beauty. They are desolate, yet surrounded by lush vegetation. They lack life, yet they protect downstream ecosystems from overwhelming heavy metal contamination. They are proof that life continues on, even in the most adverse circumstances.
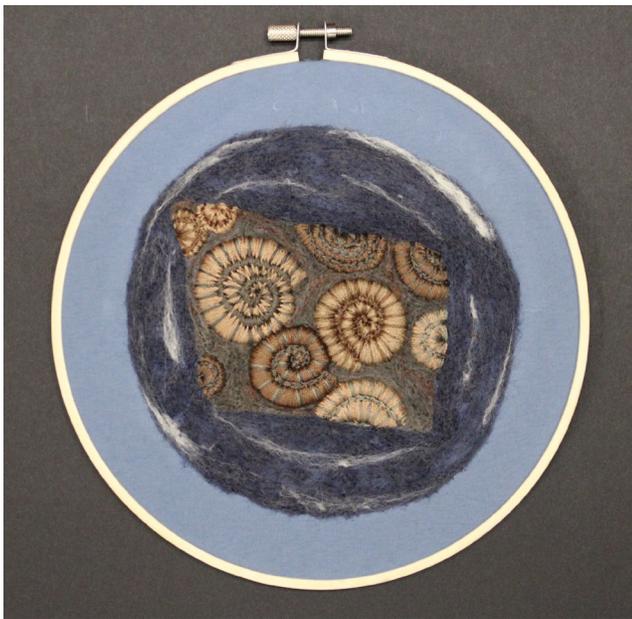




## Kayla McCabe
### *Temporary Tile,* 2023
Cotton thread, wool felt, cotton fabric, wood embroidery hoop

My work is a take on the temporal extent of human art compared to ancient life. This piece is titled "Temporary Tile" and is meant to resemble a small fossil slab collected from Alaska. The inspiration for this springs from an original fossil slab that resembled a tile akin to those found in ancient Greece or modern kitchens. Human-centric time considers thousands of years as ancient whereas geologic time can consider one million years as the blink of an eye. The materials used are cotton and wool based, therefore are temporary when considering geologic time.

**Amy Hagen**
*Portal to Alaska,* 2023
Embroidery thread on fabric
This piece allows the viewer to take a peek into a
field day in the Alaskan wilderness. Fieldwork,
especially in remote locations, allows participants to
forget the stresses of everyday life and focus on
accomplishing a scientific goal. Through creating this
piece, I hope that viewers will peer into this portal
and take a moment to escape from the stress of a busy
conference day.





**Isaac Pugh**
*Lil' Jim, the Dripanosaur,* 2023
3D Printing
Jimmy the drepanosaur has been the mascot of my
research for some time, riding on my shoulder during
presentations and bringing the joyful confusion of my
favorite research group with him. Joel Crothers, a
paleoartist friend gave him a great paint job, and I
had a blast modeling and 3D printing him, but the
time has come for a new age. The age of his alter ego,
lil' Jim the DRIPanosaur. Now, we can all glory in
the beauty of an obscure Triassic reptile, revamped to
capture the eyes of all the cool kids (or so lil' Jim told
me).

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