# How Well Can We Date and Confirm Submarine Impact Crater Candidates and Resulting Tsunami Layers?

**Background.** We have found three impact events, a crater candidate in the Caribbean, a crater candidate and impact tsunami layer in the Indian Ocean and an impact generated tsunami layer in the Hudson River. The Hudson River event has a crater candidate but it seems too small to have produced the airfall layer thickness that we observe. This may be because formation of a crater on the Atlantic margin may have triggered a large sediment slide. The events in the Indian Ocean and the Caribbean may also be the source of tsunami deposits on land. Two events, the event in the Caribbean and in the Hudson have produced Sn rich ejecta. We believe that the Sn rich ejecta imply a cometary source. Two crater candidates have analog seismic lines over them- the event in the Caribbean and in the Indian Ocean. The seismic lines show flat near surface sediment and disturbed basement. We have done much more work on the Hudson River tsunami and the impact into the Indian Ocean. For both of these events, we now have viable impact glass, impact spherules and candidates for shocked minerals. The student would continue our ongoing work on one of these three events. We need to better map the airfall layer and its thickness with distance from the crater candidate. We use calibrated XRF measurements and the LDEO XRF scanner to determine the location and thickness of the airfall and tsunami layer. We also need to see how many graded tsunami layers are present at each coring site. Those will guide us in estimating the magnitude of the event and the distance to the event. Finally, we need to produce better refined dates for each event. We know that all of the events are geologically young, probably within the last 13,000 years but we do not as yet have good age dates, particularly for the Indian Ocean and the Caribbean events.

**Work Required**: The student will spend time measuring XRF compositions of layers, sieving likely layers and determining their grain size distributions and magnetic susceptibility. In addition, the student will pick prospective shocked minerals and impact glass from sieved samples. They will then participate in SEM runs to determine the exact composition and morphology of what they have found. The student will also spend time picking organic matter and/or pelagic marine microfossils for AMS $^{14}C$ dating of the events.

**Prerequisites**: Strong interest in geology, geochemistry, geophysics and extraterrestrial impacts. High tolerance for uncertainty and intense curiosity.

**Mentors:** Dallas Abbott, dallashabbott@gmail.com, Ben Bostick, bostick@ldeo.columbia.edu

# How Has Atlantic Deep Ocean Circulation Changed in the Last 50,000 Years?

**Background:** The Earth has experienced repeated and extended episodes of global glaciation over the last two million years, the last of which reached its peak approximately 20,000 years ago. These past climate changes were associated with changes in every part of the Earth System, including ocean circulation. The water masses that make up the global deep ocean are salty, cold, and form in the high latitudes. These water masses spread throughout the oceans, driving the global thermohaline circulation. Atlantic deep ocean circulation is a critical arm of this global conveyor belt, which influences surface heat transport and ocean carbon cycling. Here, we will investigate how Atlantic deep ocean circulation has changed in the last 50,000 years, encompassing the last glacial maximum (LGM), deglaciation, and the transition into the Holocene. Scientific ocean drilling on the Iberian margin off Portugal in the Fall of 2022 recovered sediments at multiple water depths, bathed by deep waters originating from the high latitudes of the northern and southern hemispheres. These sediments are deposited at an exceptionally high rate, allowing for high-resolution, millennial-scale reconstructions of abrupt climate changes in the Atlantic.

**Analysis Required:** This project is designed to allow a student to investigate physical and geochemical evidence for changes in deep ocean circulation in the last 50,000 years. It will involve counting ice-rafted debris (IRD), as well as hands-on isotopic analysis of sedimentary constituents, such as microfossils, in deep-sea sediments from International Ocean Discovery Program (IODP) Expedition 397 drilling sites on the Iberian Margin. The selected student will work in our shared sediment laboratory and microscopy laboratory in the New Core Lab at Lamont-Doherty Earth Observatory. Training and guidance will be provided by mentors McManus and Arellano for all procedures, which will use existing equipment, including a microscope, freeze-dryer, ovens, microbalance, sieves, and beakers. Lab work will require approximately 20 hrs./wk.

**Prerequisites:** None, although knowledge of basic oceanography and climate is helpful.

**Mentors:** Apollonia Arellano: arellano@ldeo.columbia.edu

Jerry McManus: jmcmanus@ldeo.columbia.edu

# How Does Variability in Environmental Conditions Influence the Form and Function of Arctic Tundra Ecosystems?

**Background:** The Arctic is also one of the most rapidly warming regions on Earth (Ballinger et al. 2020), and thawing of large stores of permafrost carbon (C) could amplify global warming. Climate variability is also increasing, with more extreme weather events like heat waves, flooding, and storms. Arctic ecosystem responses to climate change and disturbance are variable in space and time. For example, less frequent but more intense storms might change the transport of C and nutrients on the landscape even if the mean precipitation is unaltered, and storms redirect nutrient inputs in lakes and alter lake productivity. Climate variability can have analogous effects on the movement, reproduction, and trophic interactions of wildlife species on land. We invite an undergraduate student to join the Arctic Long-term Ecological Research (Arctic LTER) research program to advance understanding of how variability in climate affects the form and function of tundra ecosystems**.**

**Analysis Required:** The student will collaborate with research mentors to identify, design and implement a hypothesis driven study to determine how variability in environmental conditions (i.e. air temperature, precipitation) affect C and nutrient cycling, vegetation form and function, and/or plant-animal interactions**.** While planning for this will be done during the Spring 2025 semester, study implementation (i.e. data collection and analyses) will take place over an 8-10 week period in (June/July/August) at Toolik Field Station, located in a remote location in Northern Alaska.

**Physical Requirements:** Applicants should be in good health, capable of rigorous outdoor activity, and prepared to live in a field camp where cooperation with others is essential, personal privacy is limited, and living accommodations are spare and simple.

**Mentors:** Natalie Boelman: nboelman@ldeo.columbia.edu, 415-793-3479
Kevin Griffin, griff@ldeo.columbia.edu, 845-365-8371,
Duncan Menge, dm2972@columbia.edu, 212-854-6889

# How Will Riverbank Erosion Hazards Respond To Climate and Land-Use Changes?

**Background**: Melting glaciers, shifting storm patterns, damming, deforestation, and other factors are disrupting the amount of water and sediment supplied to rivers around the world. It is unclear how these changes will affect the speed at which rivers erode their banks. This uncertainty poses a hazard to nearly 3 billion people worldwide who live along rivers. Recent case studies suggest rivers will erode their banks faster when supplied with more water and/or more sediment. However, it has proven difficult to test these hypotheses in nature because rivers can take years to respond to changes in their environment—by which time hazard mitigation efforts may be “too little too late”. Timely insight can be gained using laboratory stream table experiments, which effectively “speed up the clock” of river behavior to a matter of hours, and allow us to quantify the response of river flow and bank erosion under controlled conditions.

**Analysis Required**: The project will consist of conducting stream table experiments (75%) and analyzing experimental data (25%) to investigate how changes in water and sediment supply affect riverbank erosion rates. Experiments will take place in a 3-m-long, 1-m-wide stream table (Emriver EM3) at the Lamont-Doherty Earth Observatory. Experiments will involve systematically changing the river’s input water and sediment supply using pumps and feeders, and collecting photographic data over time using overhead cameras. Data analysis will involve implementing image-processing techniques to track how riverbanks erode over time (the same techniques used for satellite image analysis!). Interns will compare results across experiments to test how riverbank erosion responds to water and sediment supply; and use dimensional analysis to explore the implications for natural rivers facing climate and land-use changes.

**Prerequisites**: General physics and lab courses are required; Hydrology with interests in geohazards and environmental issues would be a plus.

**Mentors**: Austin Chadwick, achadwick@ldeo.columbia.edu

# When and Why have Earthquakes Propagated to the Seafloor at the Japan Trench?

**Background:** One of the largest earthquakes ever recorded occurred on March 11, 2011: The Tohoku-Oki Earthquake at the Japan Trench. This magnitude 9 event was characterized by uniquely large shallow slip that contributed to the generation of a tsunami that struck the northeastern coast with wave heights as high as 40 meters. This led to nearly 20,000 casualties and was a direct cause of the Fukushima Daiichi nuclear disaster. In response, IODP Expedition 343 (JFAST) set sail just 13 months later. Their goal was to drill through the fault zone to better understand the physical properties of the fault and the mechanisms that lead to shallow co-seismic slip. Despite important findings, core recovery was low and the slip surface from the 2011 event was likely not recovered. Thus, in 2024, IODP Expedition 405 (JTRACK) set sail to re-drill the plate boundary. We aim to construct a chronological record of past shallow earthquakes at the Japan Trench using clay mineralogy and radiometric dating of fault gouge. On both expeditions, one core was drilled at the trench through the plate boundary fault, and one core was drilled further east to capture incoming sediments. We have samples from both expeditions and intend to perform the same analyses on all. Prior work found evidence for heating related to earthquakes at multiple faults. Elevated temperatures during rupture can reset the geologic age of the rocks. In potassium rich fault gouge, we will measure reset K/Ar ages to investigate the timing of the most recent earthquake. Preliminary work has identified ages younger than the host-rock at the same depths where earlier work identified heating. However, these ages are complicated by the presence of both authigenic clays – those formed during faulting – and detrital clays – those Inherited from the wall rock. We will combine clay mineralogy with K/Ar analyses to extrapolate the age of the authigenic clay, the true earthquake age.

**Analyses Required:** This project will measure clay mineralogy and K/Ar ages of sediments from the JFAST cores. This work will be on the same samples analyzed previously to produce paired measurements. Lab work will involve sample preparation and clay isolation via hydrodynamic settling, clay mineralogy measurements by x-ray diffraction and Ar measurements on our noble gas mass spectrometer followed by sample digestion and K measurements on an ICP-MS. Training and guidance will be provided for all procedures. Lab work will average 30 hours/week, with the remaining time spent on data analysis, literature reviews, and lab group activities.

**Prerequisites:** An excitement for research! General earth science knowledge and chemistry lab experience is a plus but not required.

**Mentors:** Jenna Everard, jenna.everard@columbia.edu Stephen Cox, cox@ldeo.columbia.edu, Sidney Hemming, sidney@ldeo.columbia.edu

# Can We Assess the Abundance of Ice-Rafted Particles Using X-Ray Imaging and Sedimentology?

**Background:** Understanding how the Antarctic Ice Sheet evolved through past climate transitions is critical for predicting its future stability in a warming world. The Plio-Pleistocene Transition (PPT; ~2.58 Ma) is characterized by long-term global cooling and expansion of Northern Hemisphere ice sheets, with Antarctica's role in this transition not yet constrained. Marine sediments from International Ocean Discovery Program (IODP) Expedition 382 Site U1537 in the Scotia Sea's Dove Basin, provide high-resolution records of Antarctic ice sheet history. This site is in Iceberg Alley, the major pathway travelled by all icebergs calved from the Antarctic Ice Sheet. They deposit terrigenous sediments onto the sea floor termed ice-rafted debris (IRD). Because over 90% of Antarctic icebergs enter Iceberg Alley, IRD from Site U1537 has the potential to record net changes in Antarctic Ice Sheet volume. Previous work has identified an interval of low IRD flux from 2.4 – 2.1 Ma coincident with elevated diatom abundances, generally attributed to interglacial (warm) conditions at this site. Low-IRD intervals are observed at other Antarctic sites during this period, raising the possibility of unrecognized circum-Antarctic warming. However, interpretation of existing IRD records is complicated by abundant pyrite veins throughout the sediments. Because it is dense, pyrite may be misidentified as IRD in X-ray-derived counts, possibly explaining discrepancies between estimated IRD fluxes from sieving and previous estimates based on X-ray images.

**Analysis Required:** This project aims to resolve the influence of pyrite on X-ray-based IRD reconstructions from 2.4 – 2.1 Ma. The intern will isolate non-biogenic coarse fractions using wet sieving and density separation, then quantify both pyrite and IRD abundances under a microscope. The data will be compared with existing IRD records using both methods, as well as with 3D computed tomography scans documenting the distribution of pyrite veins within cores. This work will improve the reliability of IRD proxies, thus improving interpretations of Ice Sheet dynamics across the Plio-Pleistocene Transition. Lab work will average ~30 hours per week, with an initial focus on coarse fraction analysis and later on microscope work. Time outside the lab will be spent on literature review and data analysis.

**Prerequisites:** Introductory mineralogy and microscope experience are helpful but not required.

**Mentors:** Kelly Fenton-Samuels,kfenton@ldeo.columbia.edu), Sidney Hemming,sidney@ldeo.columbia.edu, Trevor Williams,trevorjwilliams@usf.edu, Claire Jasper,cjasper@ldeo.columbia.edu

# What are the Drivers of Harmful Algal Blooms in Long Island Sound?

**Background**: . The intern will interact with a multidisciplinary team of scientists, that are working towards development of novel satellite products for monitoring of harmful algal blooms, combining these with results from filed observations and laboratory experiments to test two explicit hypotheses that are key for understanding the ecological response and resilience of Long Island Sound, one of the USA's most urbanized estuary that is experiencing both natural and anthropogenic stressors from climate change and human activity. Hypothesis 1 - In Long Island Sound, the bloom forming potential and intensity of late-summer harmful algal bloom species are influenced by acidification, dissolved oxygen (DO), and nutrient conditions that develop during summer. Hypothesis 2 - Acidification and DO conditions that develop during summer can provide early indicators of late-summer to fall harmful algal blooms outbreaks that can be used for improved water quality and shellfish farm sanitation management activities in LIS. Our broad goals of this study are as follows: 1) Improve understanding of the impacts of key climate stressors –eutrophication, acidification, and hypoxia– on Long Island Sound water quality and algal bloom development and examine the drivers harmful algal blooms across a range of environmental conditions, including during extreme events. 2) Develop satellite products relevant to water quality and harmful algal blooms outbreaks, to support equitable and inclusive access to near real-time actionable information for water resource management, policy, and decision making. Products will include chlorophyll-a (Chla), colored dissolved organic matter (CDOM), suspended matter, phytoplankton pigments that allow detection of harmful algal blooms from space. 3) Incorporate satellite retrievals of LIS environmental conditions and biogeochemical state into resource management and decisions relevant to water quality and shell fisheries operations. 4) Integrate results into NOAA's Coast Watch Program and develop data products and services that are interoperable, easily accessible, and widely distributed, supporting federal, state, and local environmental justice initiatives, and CCMP priorities for inclusive management of LIS resources.

**Work Required**: This exciting project involves laboratory experiments, field data collections and data processing to understand the connections between hypoxia and acidification and harmful algal bloom outbreaks in Long Island Sound. The student will combine modelling and laboratory experiments to explain the data that has been collected.

**Mentors**: Joaquim Goes, goes@ldeo.columbia.edu, Jinghui Wu, jinghuiw@ldeo.columbia.edu

# Does the Leithsville Formation Preserve Evidence for Mechanisms of Silicification?

**Background:** The Center for the Investigation of Native and Ancient Quarries supported geological mapping that generated a chert and litho/biostratigraphy that was employed as a mapping aide for study of the Cambrian-Ordovician Kittatinny Supergroup in Sussex County, NJ. This research led to hypotheses that some, if not all, of the chert bearing horizons occurring within the Cambrian Leithsville Formation may be the result of dissolution and reprecipitation in response to tectonic loading. Previous field and lab work resulted in the creation of sawed slabs of cherts, dolomites and limestones from the Leithsville Formation. This project aims to analyze those sawed slabs to clarify any preserved evidence of dissolution and reprecipitation mechanisms, i.e. cherts replacing stylolites, cherts lining unconformities, strain visible on ooids/pisoids/oncoids, chert replacement of limestones and dolomites, etc. Field work will supplement data from the sawed slabs with additional, similar information collected at outcrops. The intern and mentor will visit the Leithsville Formation to document the precise stratigraphic position of horizons of nodular cherts and cherts replacing stromatolites, ooidal/pisoidal/oncoidal facies, as well as cherts lining unconformities and replacing limestones. Additionally, field work will photodocument and measure orientations of the tectonofabrics penetrating each chert horizon. This would include all classifications of joints, fracture cleavage, solution cleavage (stylolites), boudinage structures, and other types of lineations/foliations. Collected data from slabs and outcrop will be used to create a preliminary atlas of photographed structures detailing any dissolution/reprecipitation mechanisms.

**Analysis Required:** The project involves office/lab work at Lamont Doherty and field work in Sussex County, NJ and Orange County, NY. Office/lab work consists of analyzing sawed slabs of Leithsville Formation cherts and carbonates, plotting fabric data stereographically, and creating a photo atlas of all structures found. Field work will involve collecting similar information as in the office/lab. The field time will supplement data already analyzed from the sawed slabs and will clarify field relationships. Roughly 140 hours of office/lab work and 100 hours of field time will be required. A final report and presentation of findings is expected, consuming ~ 80 hours of time.

**Prerequisites:** Grades of A- or higher in stratigraphy, biostratigraphy, mineralogy, petrology and structural geology and experience with Adobe Illustrator. Students who have completed a geological field methods and mapping course are preferred. Knowledge of the Brunton compass, mineralogy, petrology, invertebrate paleontology, and office methods in structural geology would be helpful. This project seeks students interested in Appalachian stratigraphy and geology, and who enjoy field work.

**Mentors:** Philip C. LaPorta, Ph.D., pcl2125@columbia.edu; Margaret Brewer-LaPorta, Ph.D. mcblaporta.cinaq@gmail.com

# What Is the Rheology of a Three-Phase Magma?

**Background:** The rheology of magma exerts a strong control on the dynamics and hazards posed by volcanic eruptions. Magmas and lavas can be complex mixtures of silicate melt, suspended crystals, and gas bubbles and the rheology can evolve during emplacement as the solids crystallize, the magma degases, and the phase proportions change. Models of lava flow and magma eruptibility require improved knowledge of fluid viscosity of multi-phase systems including phase interactions over a variety of relative compositions. To provide constraints for ongoing modeling work, we will perform a series of laboratory measurements on the fluid viscosities of a three-phase analog system, with controlled ratios, particle sizes and shapes. We will compare these results to previous data collected in our lab on one- and two-phase systems.

**Analysis Required:** This project will use a benchtop cryogenic rheometer to measure the viscosity of ice+saline+gas samples over a range of temperatures, compositions and strain rates. The rheometer is controlled with software from the manufacturer and is easy to use. The time series data obtained from the experiment can be organized, sorted and plotted using excel or other data analysis software. Lab work will average 30 hrs./week with hands on activities (some of which done in a cold room), with the rest of the time focused on data analysis, literature review, etc. Intern will meet regularly with a larger team focusing on cryovolcanism and work alongside other students and postdocs studying rock and ice mechanics.

**Prerequisites:** General geoscience or materials science course work with a lab class required; Experience in a research lab would be a plus, but not required.

**Mentors:** Christine McCarthy, mccarthy@ldeo.columbia.edu, 646-761-2804; Einat Lev, einatlev@ldeo.columbia.edu

# How Did Past Ice Age Cycles Affect the Climate in the Pacific Ocean?

**Background**: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years. These past climate changes increased in magnitude during the past million years, with sea level variations of more than 120 meters and large changes in regional temperature, in association with increases and decreases in the atmospheric concentration of carbon dioxide and other greenhouse gases. Although the climate variations are very well documented in ice cores from Antarctica and in sediment cores from the Atlantic Ocean, there is less detailed information available about oceanographic and climate changes in the Pacific Ocean throughout these glacial cycles. Sediment coring and ocean drilling by ODP and IODP has recovered long sequences of deep-sea sediments from a range of locations that hold the promise for insights into the Pacific response to global climate change, including variations in the tropical El Niño – Southern Oscillation (ENSO) phenomenon, and biological productivity and deep-ocean carbon storage in the North Pacific. This project is designed to allow a student to contribute to the body of knowledge that can help answer the question of how the Pacific Ocean varied through ice age climate cycles.

**Analysis Required**: This project will involve hands-on investigation of deep-sea sediments and sedimentary constituents, including microfossils, from one or more Pacific Ocean sites, and will include, sediment processing, microscopy and isotopic analysis of microfossils. The selected student will work in our shared sediment laboratory and microscopy laboratory in the New Core Lab at Lamont-Doherty Earth Observatory. Training and guidance will be provided by the McManus group for all procedures, which will use existing equipment including microscope, freeze-dryer, ovens, microbalance, sieves, and beakers. Lab work will require approximately 20 hrs./wk.

**Prerequisites**: None, although knowledge of basic oceanography and climate is helpful.

**Mentor**: Jerry McManus: jmcmanus@ldeo.columbia.edu, 845-365-8722

# Is the Lithosphere Beneath Eastern North America Falling Apart?

**Background:** The shallow mantle beneath eastern North America is divided between a shallower, colder lithosphere and a deeper, hotter asthenosphere. The boundary between them, far from being planar, has dramatic changes in depth. Furthermore, the asthenosphere is not uniformly warm, but instead contains localized hot regions, such as the Central Appalachian Anomaly (CAA, beneath Virginia) and the Northern Appalachian Anomaly (NAA, beneath southern New England). They are hypothesized to be associated with a ~400 km wide regions of mantle upwelling and in this sense are "mini hot spots". Both seem to have affected the lithosphere. Tertiary volcanism has occurred near the CAA, and although none is known near the NAA, crustal heat flow there is high. Both regions experience frequent small earthquakes, suggesting localized stressing of the crust. Lithospheric thicknesses, mapped using seismic imaging, show large variations across the region, but whether these variations reflect the complex assembly of the continent by plate tectonic processes or its subsequent erosion by the asthenospheric upwelling is not understood. Part of the problem is that the results of different seismic imaging techniques cannot fully be reconciled, possibly because each is sensitive to different aspects of Earth structure. Consequently, one's intuition of what, say, eroding lithosphere should look like in these images might be incorrect. Our approach will be to use state-of-the-art seismic wave modeling code to calculate exact synthetic seismograms for a suite of plausible Earth models, including those with upwelling asthenosphere and eroding lithosphere, and then to create seismic images based on them using several commonly-used imaging methods. Because they correspond to known Earth structure, and are not influenced by observational noise, they will enable much more sophisticated interpretation of real-Earth images.

**Analysis Required**: The project is computer-based. It presumes a willingness to spend several hours each day in front of a computer screen, looking at model results. The intern will learn to use the SpecFEM seismic wave modeling code to compute synthetic seismograms and to apply previously-written Python-based data analysis code to build images from them.

**Prerequisites**: The intern should be willing to learn a little geophysics. Some prior exposure to general earth science, and especially to plate tectonics, and to the Python scientific programming environment would be helpful but is not required.

**Mentors**: Bill Menke, menke@ldeo.columbia.edu

Andrew Lloyd, andrewl@ldeo.columbia.edu

# Why and When Do Dikes Become Sills in Extensional Tectonic Settings?

**Background**: Magma-filled fractures, known as *dikes*, are the primary pathways by which magma moves through the Earth's crust toward volcanoes. Under certain conditions, dikes can reorient into horizontal, thin, laterally extensive intrusions called *sill*s. Sills are thought to store a large fraction of magma within the crust and play an important role in controlling where and when eruptions occur. In neutral and compressional tectonic settings—such as hot spots and subduction zones—the conditions that favor the transition from dikes to sills are relatively well understood. In contrast, the mechanisms that lead to sill formation in *extensional* tectonic environments, such as continental rifts and mid-ocean ridges, remain poorly tested. This knowledge gap persists despite abundant evidence for sills in geophysical imaging and the geological record in these settings. One leading hypothesis suggests that when a dike opens, it locally alters the surrounding stress field in a way that may promote sill formation. Testing this hypothesis is particularly timely given the recent renewed eruptive activity on the Reykjanes Peninsula after centuries of quiescence.

**Project Description:** In this project, we will conduct laboratory analog experiments in the Fluid Mechanics Laboratory at Lamont-Doherty Earth Observatory to investigate whether, and under what conditions, pre-existing dikes promote sill formation in extensional tectonic settings. The experiments use a transparent tank filled with gelatin, which serves as an analog for the Earth's elastic crust. Water is injected into the gelatin to simulate magma, producing fluid-filled fractures that closely resemble natural dikes and sills. Extensional tectonic conditions will be created by removing supporting plexiglass plates, allowing the gelatin to deform. A series of experiments will explore how crustal structure—such as layering, variations in material strength (represented by different gelatin concentrations), and the presence of pre-existing dikes or cracks—influences whether newly injected dikes transition into sills. The experiments will be recorded using multiple digital video cameras to capture fracture growth from different perspectives. The experimental results will be compared with previous analog studies and with numerical models currently under development. The student will gain hands-on experience with laboratory experiments, data collection, and scientific interpretation, while contributing to an open research question in volcanology with direct relevance to active volcanic systems.

**Desired skills**: Structural geology or intro physics (mechanics) would be beneficial, but not necessary. Coding experience in any language is a plus.

**Benefits for the student:** The student will gain experience in designing and conducting experiments, in data collection, experiment documentation, and lab notebook best practices, image analysis, and the visualization and interpretation of novel scientific data. The student will also collaborate in designing instructional materials to pair with videos of these analog experiments for Earth Science educators.

**Mentors**: Kate Scholz, kscholz@ldeo.columbia.edu. Einat Lev, einatlev@ldeo.columbia.edu

# How Well Can We Track Melt Formation in the Earth's Mantle?

**Background:** Volcanic eruptions are omnipresent geohazards with unpredictable and often catastrophic consequences for human life and habitat. Although active volcanoes are monitored, much more research is needed to improve forecasts. Such forecasts integrate a myriad of information, including an understanding of how volcanoes work in their entirety, from melt formation deep in the Earth's mantle to melt ascent and eruption on the Earth's surface. Melt formation processes in the Earth's mantle are especially difficult to infer because the regions of the Earth's mantle where melts form are inaccessible. Therefore, we rely on indirect observations obtained from volcanic rocks. While much research has been conducted on the bulk composition of volcanic rocks, it is recognized that this information is incomplete, because volcanic rocks are commonly mixtures of multiple melt batches that formed in the mantle and were mixed before the melt erupted and solidified into volcanic rock. However, information on the original melt batches can be preserved in the form of magmatic crystals such as olivines and pyroxenes that crystallize before the melt batches mix. Analytical advances now allow more detailed compositional information from individual crystals, which in turn enables us to track the mantle origin of individual melt batches in greater detail than is possible from bulk rock.

**Analysis Required**: This project will focus on pyroxene crystals from various volcanoes in arc settings (Mexico, Kermadec, and New Zealand). Lab work includes separating pyroxenes from two New Zealand samples, mounting their pyroxenes and performing elemental mapping of individual crystals by microbeam methods. The new data will be integrated with existing (yet unevaluated) data of pyroxenes from other samples. The first half of the project focuses on lab work, with the rest of the time being dedicated to computer-based data analysis, literature review, and preparing the presentations. The average workload is about 30 hrs. per week.

**Prerequisites**: General Earth Science and interest in the study of volcanoes and volcanic rocks; ability to perform work with a binocular microscope; knowledge of Excel.

**Mentor**: Susanne M Straub, smstraub@ldeo.columbia.edu, 845-365-8464

# What Is the Composition of the Bulk Silicate Earth?

**Background**: A fundamental geophysics question has been debated for over 60 years: What is the composition of the bulk silicate Earth, especially within the deep, enigmatic lower mantle (660 to 2,900 km depth). Our research uniquely integrates Mineral Physics, Seismology, and Geodynamics to link atomic-scale material properties with global-scale Earth dynamics. As interns, you will be at the forefront of combining quantum physics simulations with large-scale data analysis to build a predictive theory of our planet. Our primary goal is to translate 3D seismic tomographic images of the lower mantle into better mineralogical and thermal models. Solving the mystery of the Earth's deep composition has profound implications: (1) Earth's evolution: It will elucidate how the early Earth evolved from a magma ocean, created by the Moon-forming Great Impact, into a differentiated, layered planet. (2) The geomagnetic field: Understanding the lower mantle is vital to constraining the composition and properties of the Earth's core, which drives the geomagnetic field and (3) technological advancement: This project is developing new cyberinfrastructure and data/software tools that will become a community asset, making complex geophysics research accessible to a wider international community.

**Work Required**: Our work has 3 themes: (1) Ab Initio Mineral Physics: We use cutting-edge quantum simulations to predict the thermodynamic and thermoelastic properties (like density and seismic wave speeds) of complex mineral assemblages-including key phases like bridgmanite, ferropericlase, and post-perovskite—at the extreme pressures and temperatures of the deep Earth (up to ~6,500 K and 3.6 Mbar). This includes modeling quantum phenomena which profoundly impact seismic signatures. (2) Data and Machine Learning Tools: We are building a publicly available database of these properties. We then apply advanced Bayesian statistics and Machine Learning techniques to rapidly convert observed seismic wave speeds into 3D maps of rock composition and temperature. (3) Geodynamic Validation: The thermal/ mineralogical models are tested dynamically using geodynamic simulation codes. We check them by generating density distributions consistent with the geoid and plate tectonics. Interns will benefit by (1) Contributing to the development and maintenance of the mineral properties database. (2) Applying machine learning and Bayesian inversion methods to complex datasets. (3) Visualizing and analyzing 3D tomographic structures of the lower mantle, including features like subducting plates and large low velocity provinces and (4) Learning how to link quantum mechanics to planetary-scale phenomena.

**Mentors:** Renata Wentzcovitch,rmw2150@columbia.edu, Göran Ekström,ekstrom@ldeo.columbia.edu, Jacqueline Austermann, jackya@ldeo.columbia.edu, Kui Ren, kr2002@columbia.edu

# Can In-Situ Measurements and Models Inform the Coupling Between Forest Carbon and Water Dynamics?

**Background:** Forest productivity, health, and resilience are highly influenced by terrestrial carbon and water cycles. The connection between these two cycles in Northeast forests remains uncertain, and clearer evidence is needed to support effective management decisions. The Lamont Sanctuary Forest (LSF) experimental site on Columbia's Lamont campus now includes a one-hectare plot that supports student participation in research and education. Baseline measurements and modeling of soil moisture, soil health, and forest and soil carbon stocks since 2024 provide an initial record of the factors that control carbon and water dynamics at the site. In this project, we propose leveraging two novel and automated *in-situ* monitoring systems that quantify soil water retention and carbon fluxes. This expansion will allow a more complete assessment of changes in water and carbon processes and the extent to which these processes respond together. The results will clarify key mechanistic links within the forest system and will guide the development of future management strategies that support the improvement of multiple ecosystem services. Furthermore, this project will pair in-situ measurements with satellite and drone imagery and will use GIS-based environmental data layers to support a data-driven and AI-assisted analysis of water and carbon dynamics through space and time. This will be an important step towards a long-term experimental site on campus, while strengthening student participation and advancing education and research related to forest carbon dynamics, water regulation, and ecosystem processes.

**Analysis Required:** This project will use both grid-based and model-based monitoring at the LSF experimental site. The student will gain hands-on experience with sample collection and with operation of a HyProp-based laboratory system that produces soil moisture release curves, as well as operation of an automated carbon flux measurement system. The student will also build skills in sensor data processing, model-based spatiotemporal data analysis, and collaboration with Lamont scientists involved in related research. Field and laboratory tasks will average 10 hours per week. The remaining time will focus on data processing, literature synthesis, image analysis, model calibration and validation, and preparation of manuscripts and reports.

**Prerequisites:** A strong interest in addressing environmental challenges through field, lab, and model-based research is required. General chemistry and laboratory courses or prior experience handling soil samples would be a plus.

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