Can We Develop Better Markers for Extraterrestrial Materials and/or Distal Ash Layers?

Background: In pre-modern sediments, a high Ni content or a high magnetic susceptibility can be a marker for impact ejecta. High susceptibility can also be a marker for volcanic ash. However, the definitive markers for impact are high Ir and the presence of shocked minerals. Both of the latter techniques are too technical and time consuming for a summer intern project. In the ocean basins, there are only two crater candidates that are sufficiently large and young to show up in gravity gradient data derived from satellite altimetry. One is located north of Australia and the second is located between Australia and New Zealand. We plan to measure along core magnetic susceptibility on marine cores taken near the second crater candidate and then to sample the core and measure more accurate susceptibilities on boxed samples. We will then use an XRF to assess the overall composition of the layer and surrounding sediments. If the layer contains high Ni and low Ba compared to surrounding layers, it would be a good candidate for an impact ejecta layer. If the layer has high Ti, high Ba and typical Ni values it is more likely a volcanic ash layer derived from the Tonga-Kermadec arc. At this location, ash layers from the Tonga-Kermadec arc can only come from extremely large volcanic eruptions so whatever we find will be interesting. Once we have measured the XRF composition and the magnetic susceptibility of the samples, we will sieve them and select candidates for volcanic ash/impact ejecta using a picking microscope. We will also pick carbonate microfossils for ^{14}C dating of the layers.

Worked Required: The student will measure the magnetic susceptibility and XRF composition of samples and will sieve the most promising samples. Once samples are sieved, the student will look at the samples with an optical microscope and pick prospective impact ejecta/ volcanic ash. We will ground truth these samples with a scanning electron microscope that can both image and analyze the grains. If these samples look promising, the student will pick material for thin sections and for ^{14}C dating.

Pre-requisites: A strong interest in earth science and adequate computer and microscope skills. Competence in plotting and manipulating data with excel is required. Competence with MatLab would be useful but is not essential. Student should be able to use a microscope several hours a day.

Mentors:
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Dr. Dallas Abbott: dallashabbott@gmail.com, (845) 365-8664

How Did Large Marine Volcanic Eruptions During the Holocene Influence Ocean Productivity?

Background: The abundance of marine life is constrained by the availability of nutrients needed for photosynthetic life to grow. Although iron is abundant on earth, it is highly insoluble. As a result, the availability of iron limits the rate of primary production (net photosynthesis) in nearly half of the world's oceans. As such, even transient additions of iron, for example from dust, potentially can stimulate life, and as a result, affect climate by removing carbon dioxide from the atmosphere. Iron is also abundant in volcanic ash. In this project, we will examine the connection between recent (Holocene) eruptions and marine productivity in nearby ocean waters. To do so, we will examine volcanic ash layers preserved in five LDEO cores from tropical latitudes (30°N to 30°S). All of these ash layers were detected by the core describers after the cores were taken and all are within the top meter of the core. This makes it likely that the ash layers are Holocene in age. We analyzed one such core last summer and found rare black, Mn-bearing foraminiferal tests within two different ash layers and exclusively white foraminiferal tests outside the ash layers. We attribute the black foraminiferal tests to increased biological productivity in a region where the sea water has a very low Fe content and where biological productivity is iron limited. As a result of the increased productivity, local ocean waters became temporarily anoxic or less oxic, allowing longer transport and subsequent precipitation of Mn derived from submarine sources.

Work Required: The student will analyze samples within, above and below volcanic ash layers using an XRF and a magnetic susceptibility meter. After sieving the sample and saving the less than 38 micrometer size-fraction, the student will pick marine microfossils for dating the ash layer and ash shards for chemical and optical analyses on the SEM and later on a microprobe. The student will also pick mineralized material from inside and outside of both white and black foraminiferal tests so its chemical composition and oxidation state can be evaluated using a synchrotron.

Pre-requisites: A strong interest in earth science and adequate computer and microscope skills. Competence in plotting and manipulating data with excel is required. Competence with MatLab would be useful but is not essential. Student should be able to use a microscope several hours a day.

Mentors:
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Ben Bostick: bostick@ldeo.columbia.edu , (845) 365-8659

Why Is the Ice on Falljökull Glacier in Iceland Dark?

Background: Global mean sea level is rising significantly and will continue to do so in the coming centuries. Ice melting from Greenland, Antarctica and other bodies of ice, like glaciers on Iceland, is responsible for the majority of sea level rise. However, exactly how much the sea level will rise is still unclear because we lack complete understanding of the physical processes that control ice melting. A key aspect of this is surface albedo, which dictates how much incoming solar radiation is absorbed by the surface and how much is reflected back into space. In the case of ice, the absorbed solar radiation leads to melting of the ice and ultimately, sea level rise. The feedbacks and non-linear relationships between ice albedo and the climate and meteorology are very complex and we do not fully understand them. Moreover, ice is often covered by light-absorbing impurities, such as dust, volcanic ash, black carbon, and algae, which drastically lower the albedo. Unfortunately, the climate models that we use to predict sea level rise are not able to accurately capture the spatiotemporal variability of ice albedo, which may lead to inaccurate or uncertain sea level rise predictions. It is therefore very important that we understand the sources, transport, and behavior of these impurities so that we can accurately model ice albedo variability on large ice bodies, such as glacier in Iceland.

Work Required: This project involves analysis of field data collected on and around the glacier Falljökull in Iceland in the summer of 2022. The data consists of in situ albedo measurements, drone imagery, and samples of ice, water, sediment, and volcanic ash. Satellite data (MODIS, Sentinel, Landsat, etc.) and climate model output can be collected for extended analysis if time permits. The analysis is aimed at figuring out why the ice on Falljökull glacier in Iceland is so dark and where the impurities are coming from. Our hypothesis is that it either comes from dust deposition from the moraines and/or mountains surrounding the glacier, or from ash deposition from eruptions of nearby volcanoes.

Prerequisites: Some experience with coding (Python/Matlab/etc.) is required.

Mentors:
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Can We Measure the Geochemistry of Barnacles in the Hudson River to Learn About the Environment?

Background: Barnacles are universally found in intertidal environments. These sessile organisms are actually crustaceans, protecting themselves by generating hard calcium carbonate plates. As a carbonate organism, the geochemical composition of these shell plates can reflect the composition of the water in which they grew, providing insight into aspects of climate and water quality. Barnacles can easily be collected with low costs associated with field work. However, analysis of their skeletons is not incredibly common in the literature. By exploring different laboratory methods, we can determine what geochemical markers can be converted into valuable environmental monitors. We will collect barnacles from the Hudson River and measure the stable isotopic and/or metal composition of the organism's plates. This work will provide much needed insight into methods development as we explore the capabilities of these organisms to teach us about their environment. Ultimately, once we understand the capabilities of modern barnacles, we can begin to explore the fossil record.

Work Required: Work will include 1-2 days of field work to collect barnacles in the Hudson River. Retrieved samples will have to be removed from their substrate, cleaned, and pulverized in advance of analysis. Geochemical analysis types will vary based on amount of samples collected in the field. Analysis of the metal composition of the plates may include bulk assessment of barnacles using X-Ray Fluorescence or single barnacle analysis on an inductively-coupled plasma optical emission spectrophotometer or mass spectrometer. Stable isotope analysis would involve an isotope ratio mass spectrometer. Work will be split between Barnard College and LDEO

Prerequisites: No pre-requisites are required but some college level course work in chemistry and biology is desirable.

Mentor:
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What Drives Geochemical Variability in Terrigenous Sediments at IODP Site U1479?

Background: Terrigenous (land-derived) sediments are brought to the deep sea by various transport mechanisms, including icebergs, winds, and ocean currents. The geochemical characteristics of those sediments can provide clues to their provenance (continental source), and thereby allow us to reconstruct the pathways that transported them. One of the major goals of IODP Expedition 361 was to reconstruct changes in the Agulhas Current system, in part, by using terrigenous sediment provenance. Transport mechanisms can be grain-size specific and can cause sorting which can alter the composition compared to its source. To minimize this effect, we performed our measurements on only the clay sized grains, <2 μm in diameter. In spite of this, we see some correlations between our geochemical data and grain size data. The goal of this project is to explore the effect of grain size on geochemistry within the small, <2 μm clay fraction.

Work Required: We have taken a subset of samples from IODP Site U1479 and separated the <2 μm clays into five smaller grain size fractions (1.4-2 μm, 0.8-1.4 μm, 0.5-0.8 μm, 0.2-0.5 μm, and <0.2 μm). The student intern will obtain Argon isotope ratios for all these samples and other geochemical measurements on a subset of those.

Pre-requisites: The project will involve chemical digestions and chemical separation techniques, so some experience in a chemistry laboratory is preferred.

Mentor:

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The Enigmatic Physiology of the *Noctiluca Scintillans* – How Does It Thrive in a Rapidly Changing Sea?

Background: Over the last decade and half, the Arabian Sea ecosystem has undergone a dramatic shift. Diatoms the ubiquitous, unicellular, siliceous photosynthetic organisms that thrive in the nutrient-rich waters of the winter monsoon have been replaced by an unusual mixotrophic dinoflagellate *Noctiluca scintillans* (Noctiluca) (Fig. 1). Since their first appearance in 2000, Noctiluca blooms have become more intense and widespread. Our central thesis is that the growth of Noctiluca is being facilitated by the expansion of the 'dead zone' in the Arabian Sea and in previous studies, we have shown that Noctiluca can photosynthesize at higher rates and thrive under hypoxic (low oxygen) conditions in comparison to diatoms. However, oxygen depletion in seawater caused by excessive organic material inputs into the ocean, also produces excessive CO2 and acidic ocean conditions due to simultaneous heterotrophic degradation of organic material by microbes. There is very little known as to how Noctiluca is able to survive and thrive under these dual stressors. This study will use a laboratory grown strain to examine Noctiluca's enigmatic physiology under hypoxic and ocean acidification conditions. The need for this information is becoming even more urgent, as Noctiluca blooms are becoming more widespread and intense and are disrupting the delicate balance of the Arabian Sea ecosystem, causing declines in biodiversity and damage to local fisheries and the societal well-being of coastal communities in the region.

Work Required: This project will utilize laboratory experiments and cultures of Noctiluca to investigate how this species maximizes its photosynthesis under hypoxic conditions and high CO2 concentrations and the potential effects of those conditions on photosynthesis, respiration and growth. Anticipated tasks for a research assistant will include: culture maintenance and manipulation, planning of growth rate and grazing experiments, and utilization of different instruments and techniques including dissolved oxygen sensors and titration, microscopic imaging, static and fast rate repetition fluorometry. Additionally, the assistant will be exposed to the statistical analyses of results from such replicate experimental treatments.

Pre-requisites: We seek students with a background in biology, with interests in issues related with the environment, environmental justice and societal well-being. Many of the techniques specific to the project will be taught prior to commencement of the experiments. However, a basic set of analytical lab skills (e.g. keeping a sterile environment, precise measurement of liquids and solids, general lab safety) is required. A basic understanding of cellular biology (e.g. cell structure, processes of photosynthesis, respiration, etc.) is also an asset but not necessary. Ability to understand the implications of these blooms in the context of climate change and society.

Mentors:
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How Are Rising Ocean Temperatures and Ocean Acidification Shaping Marine Phytoplankton Communities Along the U.S. East Coast?

Background: This study forms an important component of NOAA's Ocean Acidification Program, which seeks to expand the understanding of ocean acidification (OA) through interdisciplinary partnerships with academia and thus prepare society to respond to changing ocean conditions and resources. OA is occurring because our oceans are absorbing carbon dioxide from the atmosphere, leading to lower pH, greater acidity and a fundamental change in ocean chemistry globally. Lamont Doherty Earth Observatory (LDEO) has been tasked with understanding the response of critical marine phytoplankton to co-occurring multi-stressors conditions (low pH, high temperature, low oxygen, low nutrient, etc.) and to assess their adaptive capacity to OA. The results of the study will inform the potential response of phytoplankton primary productivity, ecosystem structure, and biogeochemical cycling of the future oceans. The Goes Lab has been conducting laboratory studies and participating in cruises dedicated to NOAA’s East Coast Ocean Acidification (ECOA) program to understand how phytoplankton groups differ in their response to the OA gradient along the coast of New England and the mid-Atlantic Bight and how this is shaping phytoplankton community structure, size spectra and the photosynthetic efficiency of phytoplankton.

Work Required: In the laboratory, the student will conduct OA experiments that expose lab grown phytoplankton cultures to various degrees of OA that simulate pre-industrial, current and future scenarios. During the course of the experiments, the student will estimate phytoplankton growth and photosynthetic rates using state of the art instrumentation. Results from these experiments will then be used to assess the resilience/vulnerability of various groups of phytoplankton. The second aspect of this internship is the analysis and interpretation of high spatial and temporal resolution data that we have collected during the entire east Coast. In addition to photosynthetic rates we have differentiated predominant phytoplankton functional groups using laser-stimulated fluorescence and optical microscopy. In tandem, our colleagues have measured pH, alkalinity, dissolved inorganic carbon, oxygen and hydrographic data that allow the exploration of links of the coastal phytoplankton community structure and production to OA gradients along the U.S. East Coast and provide a better understanding of how OA in conjunction with other multi-stressors will impact ecologically and/or economically important marine species. The student will build a wide range of skills in the laboratory, as well as in data analysis and statistics as well as employ satellite data to study coastal processes and phytoplankton productivity. The student will also analyze phytoplankton taxonomic data using a highly advanced plankton imager and using the large ECOA datasets to infer how phytoplankton community and associated productivity are changing along the East coast gradient in OA.

Pre-requisites: We are looking for a student with a strong background and interest in environmental sciences, who has some quantitative skills, but more importantly who is enthused by interdisciplinary sciences and wants to address the big environmental problems that threaten the food security and economy of east coast communities. Experience in field data collection methods, programming or GIS data analysis preferred, but not required.

Mentors:
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What is the Role of Climate Variability in Controlling Arctic Ecosystem Structure and Function?

Background: The Arctic is rapidly warming. Some responses to this warming involve acceleration of processes common to other ecosystems around the world (e.g., shifts in plant species), whereas others are unique to the Arctic but with global consequences for society (e.g., carbon loss from permafrost thaw). The objectives of the Arctic Long-Term Ecological Research (ARC-LTER) project for 2023-2029 are to determine how and how fast trends in climate change and especially climate variability are changing arctic ecosystem structure and function. These objectives will be met through continued long-term monitoring of changes in undisturbed and disturbed ecosystems along the terrestrial to aquatic continuum in the vicinity of Toolik Lake, Alaska. In addition, we will measure the recovery of these ecosystems from natural or imposed disturbances, maintain existing long-term experiments, and initiate new experimental manipulations and observational studies to achieve the objectives. Based on the data generated, carbon and nutrient budgets and measures of species composition and abundance will be compiled for major components of the arctic landscape. Through a combination of data analysis and modeling we will assess how climate change and climate variability will affect biogeochemistry and community dynamics of ecosystems, and determine how ecosystem responses will propagate across the landscape.

Work Required: This project will be field based, and interns will spend approximately 10 weeks on site at the Arctic LTER, at the Toolik Field Station in northern Alaska (https://www.uaf.edu/toolik/). This is a very remote location and requires semi-strenuous outdoor work under a variety of weather conditions. Students will be trained in the required analytical techniques. Projects can be related to terrestrial ecosystem ecology (studies of arctic flora, fauna and biogeochemistry), aquatic ecosystem ecology (studies of streams, lakes and the land water interface) and the related environmental variability (or temperature, precipitation or sunlight). Numerous specific project ideas can be discussed with interested applicants.

Prerequisites: Basic biology and ecology courses are required. Experience with field work would be a plus.

Mentor:
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What Do Deep-Sea Sediments From the South Atlantic Ocean Tell Us About Dust and Climate Over Millions of Years?

Background: Sediments that end up on the deep-sea floor of the South Atlantic Ocean come from the surrounding continents of South America and Africa. The continental-derived fraction of marine sediments gets to the South Atlantic Ocean mainly by wind, with perhaps a secondary process by being carried along in ocean currents. This project will use sediments in marine geologic records from the South Atlantic Ocean to understand better how dust moves around and how climate and environments change over millions of years on the surrounding continents. The time focus includes the last 5 to 10 million years or so, incorporating the Late Cenozoic Ice Age and warmer Pliocene and Miocene Epochs. Moreover, the analyses may improve insight into tectonic-climate history of surrounding continents as the Andes developed and climates changed, especially across Africa. The student will analyze the geochemical composition of sediments that have come from the land areas surrounding the South Atlantic, which may also allow us to define better air and ocean circulation.

Work Required: The student will focus on new marine cores recently obtained in 2022 from IODP Expedition 390, west of the mid-ocean rift in the deep part of the Subtropical South Atlantic Ocean. The student will analyze ~20 sediment samples and their geochemical compositions from, tentatively, Sites U1556 and U1557. The new analyses will allow us to test the hypothesis that the dust comes from both South America and South America, depending on whether (former) climates were warm or cold and the associated winds. Efforts include sieving and weighing, and then processing samples in ultraclean labs in the Geochemistry Building. Possible analyses include Sr-Nd-Pb-K/Ar isotopes and major and trace element analyses, on a mass spectrometer (ICP-MS) and an inductively coupled plasma optical emissions spectrometer (ICP-OES), respectively. Lab work will average ~30 hours per week, with the rest of the time dedicated to literature review, data analysis and discussion of the results, and preparation of results for presentation in both oral and written formats.

Prerequisites: Laboratory experience, even from just classes, is preferred. We want a student who is interested in how the continents provide sediments to the deep sea and how the oceans, climate, and dust have changed in the geologic past.

Mentors:
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What is the Earthquake Hazard and Fault Displacement Along the Magma Poor Portions of the East African Rift?

Background: One of the fundamental problems in divergent plate tectonics is how strain is accommodated in young rift basins that develop in magma-poor, thick, cold continental crust. Active continental rift basins define evolving divergent plate boundaries where continental break-up may eventually occur, leading to the formation of new oceanic crust. Strain in these basins is manifested through the establishment of large rift-bounding normal faults (border faults). Continued weakening and accrual of slip on the faults allows continued thinning of the continental crust. The segmentation and propagation patterns of active rift border faults provide insight into controls on the expression of rift zones, syn-rift depo-centers, and the long-term basin evolution. More importantly, the spatial variation of strain accommodation patterns along border faults may highlight potential sections of displacement deficit where future surface-rupturing, dangerous earthquakes may occur. The proposed project will assess the along-fault distribution of displacement along a prominent active border fault in the magma-poor branch of the East African System. More specifically, the project will focus on the Thyolo border fault of the Shire Rift Zone in southern Malawi, where previous studies have highlighted the presence of an active fault scarp with prominent topographic expression [1]. This fault represents a new zone of strain localization in the Shire Rift Zone [2].

Work Required: The project will utilize a new, 15 m resolution, Digital Elevation Model to delineate surface traces of normal faults in the Shire Rift. In southern Malawi subsurface data is sparse. Measurements of scarp height along the trend of the border fault will provide data on the sub-aerial component of fault throw. Fault throw is the vertical offset of a normal fault at any location along the fault. Measurements of scarp height will be made at 1 km intervals along the 90 km-long fault system using ArcMap software. The subsurface extent of fault throw will be estimated from a ~60 m resolution model of depth-to-magnetic basement generated from aeromagnetic datasets. The estimated basement depth will be automatically extracted at a 1 km interval at the same locations as measurements of scarp height, using Geosoft Oasis Montaj software. The datasets generated by the exercises will be analyzed to delineate the short- and long-term slip distributions along the fault system.

Prerequisites: The student should have familiarity with ArcGIS and have taken a course in structural geology. Some previous experience with computer programming and commercial software packages is desirable but not essential. As a result of their work, the student will estimate trends of throw maxima and minima along the fault system which will highlight the segmentation zones along the Thyolo Fault and the patterns of recent surface-breaking earthquake ruptures. The results will also provide an understanding of the long-term evolution of the border fault system in the evolving Shire Rift Zone. In addition, it will reveal zones of slip deficit along the fault, thereby providing insight into earthquake hazards in the region.

Mentor: Folarin Kolawole: fola@ldeo.columbia.edu, (332) 330-4658.

[1] Wedmore, L.N. et al., 2020. Structural inheritance and border fault reactivation during active early-stage rifting along the Thyolo fault, Malawi. Journal of Structural Geology, 139, p.104097.

[2] Kolawole, F. et al., 2022. Strain localization and migration during the pulsed lateral propagation of the Shire Rift Zone, East Africa. Tectonophysics, 839, p.229499.

What are the Geological Controls on Pre-Contact Quarries in the Southern Appalachians?

Background: Investigations by National Forest Service (NFS) archaeologists, working in Pisgah National Forest, have discovered what they believe are pre-contact bedrock quarries at high elevations within the Blue Ridge Mountains. NFS archaeologists have contracted CINAQ (The Center for the Investigation of Native and Ancient Quarries, a NYS 501.c3 research institution) to confirm the presence of said quarries and their distribution across the landscape. Additionally, CINAQ's expertise was requested in helping NFS, and the Eastern Band of Cherokee Indians, in understanding the geological, engineering and cultural considerations that impacted quarry development and usage. CINAQ is working with NFS, the US Geological Survey, and the Eastern Band of Cherokee, to provide this information. This study is the first of several that may be supported by a multi-year Memorandum of Agreement between NFS and CINAQ. Additional funding may be available through CINAQ as the project develops.

Work Required: This project will require field work in Pisgah National Forest to collect petrologic and petrofabric data from the host rocks of several pre-contact quarries. Additionally, field work will include limited archaeological excavation of tailings piles associated with the quarries. Office/lab work will consist of plotting petrofabric data on stereonet and statistics programs to discern population clusters. Slab and microscope thin section analyses will be conducted. Petrofabric data clusters will be compared with strain recorded on quarry tailings and associated archaeological findings. A final report and presentation of findings is expected. Total hours are estimated to be approximately 400 distributed through field and laboratory work, as well as write up.
Field work would commence in Spring of 2023, and continue through the Autumn, when foliage would be diminished and visibility enhanced. Student field participation would be expected during the summer months. Laboratory analysis and write up would occur during non-field time periods, such as weekends during school semesters. This project could serve as a Senior Thesis; however, accessing this work through NSF REU might be possible, as the Federal Government supports collaboration across federal agencies.

Pre-requisites: Grades of A- or higher in stratigraphy, biostratigraphy, mineralogy, petrology and structural geology. Students who would have completed a geological field methods and mapping course would be preferred, but it is not a requirement. Hand-sample petrology and rock mechanics background would be helpful. This project would be ideal for students interested in Appalachian tectonic stratigraphy and structural geology.

Mentors:
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Did Icebergs and their Influence on Deep Ocean Circulation Cause the Most Dramatic Climate Changes of the Last Ice Age?

Background: The last ice age was punctuated by repeated abrupt climate changes that involved dramatic cooling of the northern hemisphere at times when much of southern hemisphere was warming. These climate shifts occurred at times of episodes of catastrophic iceberg discharge from the vast Laurentide ice sheet that covered much of North America, and the melting icebergs may have reduced northward heat transport by weakening the large-scale Atlantic meridional overturning circulation (AMOC). Although computer simulations consistently suggest it is possible, and this mechanism is widely favored as a potential explanation for these otherwise puzzling climate oscillations, some studies have argued that the bipolar temperature changes actually happened first, thus causing iceberg outbursts into the glacial ocean. A study site that is positioned near the boundary of the subtropical gyre and the subpolar North Atlantic holds great promise to contribute to resolving this puzzle. Paired measurements of two proxies for deep ocean circulation will be compared to proxy evidence for sea-surface temperature change and ice-drift in the central Atlantic. The selected intern will have the opportunity to generate a paleoclimate record for the last ice age that can be combined with existing evidence to complete a record of variations in regional oceanographic climate conditions that can be directly compared to deep ocean proxies in the same sediment core. This in turn may help determine whether icebergs and melting ice initiated the climate changes, or were instead released subsequently as glaciers grew in response to the abrupt northern cooling. What is needed is a sequence of evidence in the same sediments that can unequivocally clarify the roles of icebergs, glacial meltwater, ocean circulation and sea-surface temperature (SST) change. Simultaneous investigation of proxies for all of these processes in sediments from the selected study site may provide such insights.

Work Required: This project will require a student to process samples taken from the sediment core, identify and quantify ice-rafted debris, determine the relative abundance of polar foraminifera species, and possibly select and prepare specimens for isotopic analysis. They will then apply visual and simple time-series analyses to assess the sequence of climate events. Training will be provided for all procedures. Lab work will require ~20 hrs/wk.

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

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.

Work Required: 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. It will involve hands-on investigation of deep-sea sediments and sedimentary constituents including microfossils from one or more Pacific Ocean sites, selected in consultation with mentors Pallone, Weinstein, and McManus. The student will work in our shared sediment and microscopy laboratories in the New Core Lab at LDEO. Training and guidance will be provided for all procedures, which will use existing equipment including microscope, freeze-dryer, ovens, microbalance, sieves and beakers. Lab work will require 20 hrs/wk.

Pre-requisites: None.

Mentors:
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Can Precariously-Perched Rocks Constrain the Maximum Post-Glacial Shaking from Earthquakes in New York?

Background: Although the occurrence rate of large earthquakes in the New York City is low, seismic risk is moderately high, due to the large population and fragile infrastructure. One earthquake of magnitude 5 has occurred in New York City (in 1884) and larger earthquakes have occurred in geologically similar region nearby, such as in New Hampshire (about magnitude 6, 1638) and Massachusetts (about magnitude 6, 1755), but little is known about them because of their antiquity. A key issue is the rate that any point on the Earth' surface experiences earthquake accelerations large enough to cause damage to structures. We will address this question by examining the stability of standing stones and precariously-perched rocks. The use of such stones and rocks to constrain maximum ground accelerations was pioneered by Brune and is well-established as a paleo-seismic tool. Brune's original technique assessed the stability of the stones by mechanically shaking them. However, the technique that we will use is completely hands-off. It uses use photography and advanced image-processing techniques to create 3D renderings of the stones, which can then be subject to computer-based stability analysis. Cosmogenic dating, carried out by other researchers, constrains the ages of rocks and stones deposited by Ice Age glaciers and enables the calculation of accurate rates.

Work Required: The intern(s), accompanied by the mentor, will perform about 20 days of field work in Harriman State Park to identify, characterize and photograph the rocks and stones. The intern will then use publicly-available rendering software to produce 3D models of the stones, and to subject them to static stability analysis using a Python-based analysis code.

Pre-requisites: The intern needs to be willing to learn a little seismology. As time will be split between fieldwork and computer analysis, the intern will need to be willing to invest significant time doing both. Some prior exposure to the physics of vibrations and waves and to data analysis would be helpful, but is not required.

Mentor:
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Did Dustiness in the South Pacific Increase Over the Mid-Pleistocene Transition (~1.25 to 0.7 Million years ago)?

Background: Our community's understanding of Earth's long-term climate evolution predominantly comes from Northern Hemisphere climate records. Given the central role of the Southern Ocean in the global climate system and its proximity to the Antarctic Ice Sheet, the Southern Hemisphere data gap severely inhibits our ability to understand global changes in ocean-atmosphere-ice sheet dynamics and carbon cycling during major climatic transitions. Records from the South Pacific are especially valuable to improve our understanding of these processes, because the Pacific contains by far the largest surface area and volume fraction of the Southern Ocean and therefore holds the largest capacity for carbon storage in the deep ocean. New sediment cores from the Subantarctic Pacific, recovered during the recent International Ocean Discovery Program (IODP) Expedition 383, provide us with the unique opportunity to fill this gap in Southern Hemisphere paleoclimate data.

The student's project will be nested in a larger multi-institutional effort to generate high-resolution climate proxy time series over the past 2 million years using the new materials recovered during Expedition 383. These long records will explore changes in climate/carbon dynamics at the ocean surface (dust input, nutrient utilization, and export production) and at depth (water mass structure and circulation). This specific intern project aims to reconstruct the dust input to the South Pacific at site U1541, one of the Expedition383 sites in the central Subantarctic South Pacific. The Southern Ocean is a region where the scarcity of iron limits biological production, i.e. even if there is plenty of macro nutrients (Nitrogen and phosphorus) available, phytoplankton cannot grow due to a lack of the micronutrient iron. Dust is a key vector for iron input. Reconstructing dust input is crucial for evaluating whether or not iron fertilization has occurred in the past and whether or not iron fertilization has played a role in regulating atmospheric CO2 and driving climate changes during the Mid-Pleistocene Transition (MPT).

Work Required: The project will analyze sediment samples for helium isotopes. The intern will be trained by the PI and the lab manager. The intern will learn to leach the carbonate from the samples (as the carbonate fraction does not contain any helium) and will learn to analyze the leached samples for their helium isotope signature on a mass spectrometer. Lab work will account for about half the intern's time, with the remainder of the time dedicated to reading relevant literature, data analysis, and discussion of the results with the advisor and the research group, and presenting the results.

Pre-Requisites: No specific prerequisites. Interest in climate change -future, present, and past - would be great.

Mentors:

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What Are the Differences in Sediment Grain Size and Contaminant Distribution in Long Island Sound?

Background: Detailed knowledge of sediment dynamic and related distribution of habitats and contaminated sediments in estuaries is essential for successful managing these systems. The Long Island Sound Mapping Project is a collaboration between different universities from Connecticut, New York State (including Columbia, Stony Brook, Queens College) as well as NOAA with the goal to provide a detailed benthic habitat analysis of the Long Island Sound. In the summer 2023 our group will collect sediment grabs samples in the Western and Central Long Island Sound. As part of this project, we will analyze these samples for grain size. In addition, we plan to look into the variation of metals and other contaminants using measurements with an X-ray florescence (XRF) scanner. The results can be compared with data from a pilot study and work in Eastern Long Island Sound. Of specific interest are differences in grain size distribution and contaminants that can provide important insights on different sediment sources and how sediments are transported in the Long Island Sound system.

Work Required: Under supervision of the advisors the student would participate in collecting sediment grab samples in Long Island Sound (depending on schedule), analyzing selected sediment samples and field descriptions, integrating the results, and comparing those with existing data from other part of the Long Island Sound. Data analysis and integration will be done using Excel and GIS software.

Prerequisites: Confidence in working with Excel and potentially ArcGIS is preferred but not required.

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How Did the Mediterranean Outflow Water Vary With Past Climate?

Background: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years. These past climate changes were associated with changes in every part of the Earth System, including ocean circulation. In the modern ocean, the Mediterranean Sea serves as an evaporating basin that takes in seawater at the surface and injects highly saline waters back into the Atlantic Ocean at depth. This Mediterranean outflow water (MOW) thus contributes to the salinity contrast between the Atlantic and Pacific that preferentially allows for the production of deep water in the North Atlantic. Recent drilling on the Iberian margin has recovered a rapidly accumulating sediment sequence underlying the MOW that has the potential to allow high-resolution reconstruction of variations in the strength of the outflow and its relationship to past climate changes.

Work Required: This project is designed to allow a student to investigate physical and geochemical evidence for changes in the strength of the MOW throughout the last large ice-age climate cycle. It will involve hands-on investigation of grain-size distributions and isotopic analysis of sedimentary constituents including microfossils in deep-sea sediments from an IODP Expedition 397 drilling site 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 Pallone and McManus for all procedures, which will use existing equipment including microscope, freeze-dryer, ovens, microbalance, sieves, beakers and automated grain-size analyzer. Lab work will require approximately 20 hrs/wk.

Pre-requisites: None.

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How Did the Deep Ocean Circulation Change Across the Mid-Pleistocene Transition (MPT)?

Background: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years. These past climate changes were associated with changes in every part of the Earth System, including ocean circulation. Within the last million years, Earth's climate underwent a fundamental shift toward longer and more pronounced ice age cycles. Two leading candidates for driving this transition are ice-sheet bedrock interactions, and changes in the North Atlantic's deep ocean circulation. Recent drilling on the Iberian margin off Portugal has recovered sediments at multiple water depths bathed by deep waters originating from the northern and southern hemispheres. These sediments have the potential to allow reconstruction of variations in these waters that may provide insights on the deep ocean influence on the MPT.

Work Required: This project is designed to allow a student to investigate physical and geochemical evidence for changes in the strength of the deep ocean circulation at multiple water depths across the MPT. It will involve hands-on investigation of grain-size distributions and isotopic analysis of sedimentary constituents including microfossils in deep-sea sediments from an IODP Expedition 397 drilling site 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 Pallone for all procedures, which will use existing equipment including microscope, freeze-dryer, ovens, microbalance, sieves, beakers and automated grain-size analyzer. Lab work will require approximately 20 hrs/wk.

Pre-requisites: None, although knowledge of basic oceanography and climate is helpful.

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What is the Earthquake History of the Jamaica Passage?

Background: The northern part of the Caribbean Plate is a primarily strike-slip boundary with a component of compression. Recent earthquakes along this boundary include the devastating 2010 and 2021 earthquakes in Haiti. To the west, Jamaica was also hit by major earthquakes in 1907 and the 1692 earthquake that destroyed Port Royal, site of the Pirates of the Caribbean movies. During an NSF funded RAPID cruise of the R/V Pelican in January 2022, we collected seismic images of the sediments and sediment cores along the Jamaica Passage between these two islands. The seismic data records the deformation of the sediments along the Enriquillo-Plantain Garden Fault (EPGF), preserved in the several basins that lie along this plate boundary fault. The cores record distinct deposits from numerous earthquakes over the last several thousand years that affected the region.

Work Required: The summer intern work on the paleoseismology of the EPGF. The intern will help load the processed seismic data into The Kingdom Suite interpretation software, and participate in analyzing the stratigraphy and correlating it to the cores. The results will help us better understand the tectonics of the region and its earthquake history, and to assess the hazard for future events.

Pre-requisites: None.

Mentors:
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How Will Restored Oyster Reefs Grow in a Changing Climate?

Background: As climate change accelerates, accurate predictions of biological responses to climate and anthropogenic disturbances are critical to mitigate likely damage to the biosphere. However, our ability to predict responses of foundation species and their supported ecosystems to multiple emerging stressors is severely constrained by models mostly drawn from controlled experiments.
Organisms producing calcified skeletons are predicted to face the greatest challenges under rapidly changing environments. The eastern oyster Crassostrea virginica is a calcifying ecosystem engineer producing intertidal reefs in the Northwest Atlantic. Once a dominant structural and ecological component of many estuaries, eastern oyster reefs have declined dramatically because of climate and human impacts during the last two centuries. Because C. virginica reefs provide key ecosystem goods and services, enhance biodiversity, improve water quality, and protect shorelines and coastal communities from storms and sea levels rise, they are subject to extensive conservation and restoration programs (i.e., the Billion Oyster Project in NYC).

Calcareous shells perform vital functions for oysters and create reef habitat supporting marine communities. Although climate alterations are known to impact oyster survival, their consequences on the oysters' ability to produce their shells and, therefore, accrete reefs in restored locations remains a major research gap. A spatial assessment of mechanisms shaping oyster calcification in real-world ecosystems are scarce but essential for building the theoretical framework necessary to anticipate the scope of biological responses in these key ecosystem engineers.

Work Required: The project will characterize and model spatial patterns of oyster shell structure, calcification and organic composition at different locations in the Hudson River Estuary system. This work will analyze shells from restored reefs of C. virginica populations collected from different locations in the Hudson River, East Rivers, Upper and Lower Bays. Laboratory work includes oyster shell samples cleaning, collection of shell morphology and density data, sample preparation (grinding and polishing) for compositional analyses (at Lamont-Doherty Earth Observatory), and thermal gravimetric analysis (carried out at the Columbia Nano Initiative shared labs) for shell organics characterization. Laboratory work will average 25hrs. /wk., with the rest of the time being focused on datasets organization, data analysis, and literature review. The student would also have the possibility to partecipate to a summer sampling and monitoring field activity in collaboration with the Billion Oyster Project.

Prerequisites: Background in environmental/biological sciences; the candidate should feel comfortable commuting to the Lamont-Doherty Earth Observatory for most of laboratory work and occasionally to the CU Morningside campus (CNI) for use of different analytical facilities; the candidate should be well-organized with excellent time management ability.

Mentor:
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How Can We Identify the Geology Beneath the Greenland Ice Sheet?

Background: The geology beneath ice sheets exerts an important influence on ice flow by controlling the distribution of heat and water at the base of the ice. Knowledge of the geology beneath the ice is therefore an important boundary condition in ice sheet models. Direct knowledge of subglacial geology is extremely limited, with just a few boreholes through the ice and inferred continuation of limited rock exposures from ice sheet margins. Additional information on the subglacial geology can be gathered from geophysical data (gravity, magnetic, and radar measurements) measured from aircraft flown above the ice sheet. Recent work has used these data to determine the locations of major geological boundaries as well as local features such as ancient lake beds and impact craters. Many outstanding questions exist about the nature of these boundaries and the location of other features, particularly in areas where the ice sheet is vulnerable to future change.

Work Required: This project will use existing geophysical datasets (gravity, magnetics, radar, and sonar) to classify coastal and subglacial geological environments, using coastal exposures as ground truth. From these we will select specific targets and develop models of the sub-ice sheet geology beneath parts of the Greenland Ice Sheet. We will also use ground-based instruments to conduct surveys over geological targets in the local Lamont area in order to explore signatures of known geological features and compare them with regional gravity surveys.

Pre-Requisites: Introductory geology courses are required, with physics desirable.

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Will Machine-Learning Approaches Improve Antarctic Sea Ice Seasonal Predictability?

Background: Sea ice in the polar oceans is an active component of the global climate system and amplifies climate change in polar regions. With its large seasonal and interannual variability, Antarctic sea ice significantly affects surface energy balances in the atmosphere and ocean by changing surface albedo, salt injection, and insolation between the air-sea interface. Therefore, long-range forecasts of Antarctic sea ice are very much in demand, not only because of the potential importance of sea ice in the global climate but also for the practical purpose of exploring the Antarctic continent. Our recent study examines Antarctic sea ice seasonal predictability with a linear Markov model. This statistical mode was built on a multi-variate space of sea ice concentration, and atmospheric and sea surface temperatures, which captures spatial patterns of co-variability among the atmosphere, ocean, and sea ice. The temporal evaluation of sea ice is predicted through a linear Markov process. This model's advantages include its ability to maintain spatial coherence of sea ice variability and its focus on predictable signals by removing unpredictable noise. The disadvantage of the model is that it only captures linear variability in the polar climate system. Here we propose a novel approach to explore the contribution of nonlinearity in the climate system to sea ice predictability by using machine-learning tools to predict the temporal evaluation of Antarctic sea ice in the multi-variate polar climate system. The method maximumly retains the benefit of the linear Markov model and explore potentially added benefit from machine-learning techniques.

Work Required: This study is built upon the model that was developed the last summer. We will replace the linear Markov process with one or a few machine-learning tools to reconstruct the seasonal prediction model. The linear Markov model was developed with 43 years (1979-2021) of satellite and reanalysis data, which is relatively short for machine-learning applications. We will use a historical run (150+ years) from a CMIP6 coupled climate to train the machines and apply the transfer-training technique to extend the time series of observational data. The student is expected to learn the existing code of the linear Markov model, acquire CMIP6 historical runs (locally available), select machine-learning tools and reconstruct a machine-learning-based sea ice forecast model under the supervision of mentors.

Pre-Requisites: The student should be familiar with computer programming, and knowledge of Python is preferred.

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