How Do Historical Flooding Events at the Mouth of the Hudson River Relate to Ages of Open Ocean Fossils in Hudson River Sediments?

Background: We identified layers containing multiple modern pelagic foraminifera in six Hudson River cores taken many kilometers from the mouth of the Hudson River. From the Pb contents of the sediments, we know that some pelagic fossil-rich layers formed over 100 years ago, before the common use of ballast tanks in commercial shipping. Some of these layers are also characterized by high Sr contents. Because Sr is greatly enriched in seawater compared to river water, the Sr enrichment might come from marine sediments being forced into the Hudson during long-lived, relative sea level highs at the mouth of the river. The history of flooding at the mouth of the Hudson shows possible correlations with Sr and Pb highs in a previously studied core taken off Yonkers, NY. We will examine a second core taken off Manhattan Island. This core contains at least seven layers bearing tens of pelagic foraminifera but the composition of the bulk sediment in and around the layers has not yet been characterized. We seek to determine if these seven fossil bearing layers also manifest Sr and/or Pb highs.

Analysis Required: The intern will help to sample and process samples for measurements of Sr, Pb, Zn, Cu and other metals on one Hudson River core using X-Ray Fluorescence and Plasma Mass Spectrometry, depending on their overall concentrations. The student will also sieve samples from Sr rich and Sr poor regions of the core to look for further pelagic foraminifera. We will characterize the largest and best-preserved pelagic foraminifera isotopically to determine the conditions under which they grew. We will also image and analyze interesting particles with visible light and scanning electron microscopes potential cosmic spherules. The latter may provide stratigraphic markers derived from times of intense meteor showers prior to 1900.

Prerequisites: Intense interest in geology and environmental events. One prior course in either chemistry or physical geology. Some experience with light microscopes is desirable but is not required.

Mentors: Dallas Abbott (dallashabbott@gmail.com), Reinhard Kozdon (rkozdon@ldeo.columbia.edu) and Ben Bostick (bostick@ldeo.columbia.edu)

Can We Use South African Clay to Learn the History of the Agulhas Leakage?

Background: The global meridional overturning circulation describes a network of surface ocean currents, areas of deep-water formation, deep ocean currents, and upwelling regions that make up the arteries of Earth's climate system. The strength of these currents regulates the amount of CO_2 stored in the deep ocean versus in the atmosphere. Surface currents regulating regional climate, control the transport of heat to high-latitudes. Variability in the strength of ocean turnover has been connected to the most impressive variability in Earth's climate history, both modulating the intensity of the ice age cycles and provoking abrupt climate change during the last deglaciation.

South of Africa's Cape of Good Hope is a critical choke-point in the global meridional overturning circulation, restricting passage of water between the Indian Ocean and the Atlantic Ocean. A strong western boundary current, the Agulhas Current, flows southward along South Africa's eastern margin. At Africa's southern tip, some of this water can escape into the Indian Ocean in huge eddies (~1 Sverdrup, or 3x the discharge of all the rivers in the world), called Agulhas Rings. This process, called the Agulhas Leakage, is poorly understood.

We aim to constrain the strength of the Agulhas Current and its Leakage across multiple ice age cycles during the middle Pleistocene, a time when the pace of cycles in the Earth's climate was changing dramatically, and Earth's climate was becoming increasingly severe.

Analysis Required: The sediment samples will come from coring at IODP Site U1479 in the Cape Basin. For this project, we will be working in tandem with another group focusing on deep water at the same site. We will use the terrigenous (continentally-derived) fraction of the sample, while the other lab group works on the foraminifera. We will do experiments with instruments on Lamont's campus with the goal of determining: 1) the distribution of grain sizes in each sample, and 2) the clay mineral species present in each sample. Lab work will average 30 hrs. /wk., with the rest of the time being focused on data analysis, literature review, and group meetings etc.

Prerequisites: Introductory geology, general chemistry and lab. Having a climate-systems-like class would be very useful for the discussions.

Mentors: Daniel Babin, babin@ldeo.columbia.edu, Sophie Hines, shines@ldeo.columbia.edu, Allison Franzese, franzese@ldeo.columbia.edu, Sidney Hemming, sidney@ldeo.columbia.edu

Can We Use Historical Events like Meteor Showers and Environmental Pollution as Stratigraphic Markers in the Hudson?

Background: The Hudson River has a long history of Pb pollution due to burning of hydrocarbon fuels and local incineration. Pb pollution is dangerous to human health. Anthropogenic burning can produce layers with a higher content of low melting point metals like Pb. We have identified layers in the pre-modern (~pre 1890) portion of one Hudson River core that appear to contain relatively high concentrations of cosmic spherules. From previous Cs dating, we were able to relate these spherule rich layers to known historical meteor showers. Other magnetic spherules are terrestrial and might represent residues from historical forest fires. In this study, we seek to replicate the above results in a second Hudson River core with some previous Cs dating. If successful, our techniques will be very useful for dating Hudson River cores with high deposition rates as well as for characterizing the local history of anthropogenic pollution.

Analysis Required: The intern will help to sample and process samples for measurements of metals and magnetic susceptibility on a Hudson River core taken near Peekskill New York. The student will also sieve selected samples for characterization of their grain size distribution. The student will help to select interesting particles using a visible light microscope, which will be followed up with imaging and analysis on a scanning electron microscope. The latter are necessary to distinguish magnetic spherules derived from industrial pollution, meteor showers and forest fires,

Prerequisites: Intense interest in geology and environmental events. One prior course in either environmental science or physical geology. Some experience with light microscopes is desirable but is not required.

Mentors: Karin Block (kblock@ccny.cuny.edu), Dallas Abbott (dallashabbott@gmail.com) and Ben Bostick (bostick@ldeo.columbia.edu)

How Do the Chemical Affinities and Speciation of Arsenic in Soil and Sediment Affect Its Concentration in Water?

Background: Arsenic is a common groundwater contaminant that affects the water quality of more than 150 million people throughout the world. Groundwater arsenic is most often derived from natural sources in soils and sediments. Arsenic concentrations are controlled by chemical reactions between solids and solution, and depend on the chemical composition and speciation of the arsenic. Tests performed during the installation of water wells, made primarily to ensure well safety, provide only an incomplete picture of the chemistry controlling water quality, because they only measure what is in the aqueous phase. Our research group characterizes the solid phase as well, through chemical, mineralogical, microbiological and physical measurements, and link that information to the aqueous phase to improve our understanding of the chemistry that affects water quality.

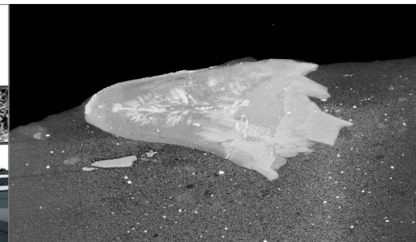
Analysis Required: This project will involve developing data analysis tools to leverage our ever-expanding datasets of solid-phase mineralogical data with our new database of the global distribution of arsenic in groundwater. Among the most important types of data to be analyzed will be spectroscopic data collected at synchrotrons by several research groups. These specialized facilities can accurately determine the chemical form of dilute elements in soils, rocks, and even water. Much of the research (at least 20 hours/week) will be conducted in the R programming platform. Lab work may include mineralogical characterization using X-ray, FTIR spectroscopy, diffraction and other methods.

Prerequisites: General chemistry, an interest in Earth Sciences and lab courses are required; experience in R Studio or excel would be ideal.

Mentors: Benjamín Bostick, bostick@ldeo.columbia.edu, 845-365-8659.

What Can Fossil Lake Sediments Tell Us About Past Climate and Environments?


Scanning electron microscope (SEM) for high-resolution imaging


CT-scan of a fossilized tooth from northwest China lake sediment


Rutgers core repository stores sediments from all over the world

Background: This project focuses on fossil lake sediments from the eastern and western US and northeastern and northwestern China, comprising some of the most famous fossil deposits in the world, including those that produce feathered dinosaurs, as well as mammals, fish, insects, and plants. These lakes formed during the Mesozoic, a time period that spanned from 66 million to 250 million years ago, during which the areas were in different latitudes than now because of continental drift. The US deposits were tropical, while those of China were temperate to arctic. Atmospheric CO_2 was much higher than present, more like what we will see in the future by 2100 to 2400.

Project description: How do lake sediment properties, particularly grains and fossils transported by ice or algae, and microfossil assemblages deposited at different latitudes, inform our understanding of climate under high CO_2 conditions on Earth or ancient environments or Mars?

The student will quantitatively characterize and visually describe lake sediments and fossils. They will disaggregate the samples to examine sediment grains and look for fossils, use high-resolution microscopes to image grains and fossils (charcoal and plants, fish scales, invertebrate fossils, teeth, etc.), and perform automated grain size analysis to measure the distributions of sediment size that reflect physical processes that deposited the sediments. The student will also use techniques such as X-Ray Fluorescence and X-Ray Diffraction to characterize the chemical composition of samples, like those on the Mars Rover *Curiosity*.

We will take a one-day field trip in NY State to observe a modern lake to collect sediments and microbes for lab analysis. Another one-day field trip will visit local outcrops in NJ and look at fossil lake deposits in person. By the end of the summer, the student will have gained skills in lake sediment lab work, fieldwork, and data analysis.

Prerequisites: No prerequisites. All are welcome; we will teach you what you need to know and can adjust the project based on your interests.

Mentors: Clara Chang, cchang@ldeo.columbia.edu; Paul Olsen, polsen@ldeo.columbia.edu; Sean Kinney, kinney@ldeo.columbia.edu.

What Do Ground and Airborne Measurements of Carbon Dioxide Tell Us About Greenhouse Gas Emissions Within New York City?

Background and Project Description: Carbon dioxide (CO_2) and methane (CH_4) are important greenhouse gases. CO_2 has increased dramatically in recent years. CO_2 is emitted from human-related combustion sources such as cars and power stations, as well as being taken up and emitted by natural sources such as trees and vegetation. Methane is emitted from different sources such as leaky natural gas lines, landfills and sewers, as well as natural emissions from wetlands. The New York Metro Area is the third largest urban source of CO_2 in the world and the largest in the US. Within New York City, our estimates of CO_2 and CH_4 emission are calculated from inventories maintained by various state and federal agencies. However, recent studies have shown that inventory methods consistently underestimate CH_4 emissions and that fossil fuels are likely responsible for a large portion of the underestimate. Likewise, the uncertainty related to CO_2 inventories is not well defined.

We are developing an urban network of gas sampling sites in order to calculate the total amount of CO_2 and CH_4 emitted within New York City. This method involves measurements of CO_2 and CH4 in the atmosphere around the city at various locations. We are coordinating these ground-based measurements with a series of flights around New York and other cities on the east coast corridor. The student may have the opportunity to work on the airborne instruments and data if they are interested.

Anticipated tasks: The undergraduate intern will use an existing dataset of re-analysis wind fields in a Lagrangian particle dispersion model to determine the surface influence of air reaching potential sampling locations in the urban network. This involves learning to use already developed tools and applying them to the specific problem. The intern will work with our team to visit sampling locations for calibration of instruments around the city and work with the airborne team for the New York flight series.

Skills required: As this project is part of a larger team project, strong communication skills are required. Coding experience in Python, R or MatLab and experience working with different file formats (e.g. NetDCF4, arl, etc.) are an advantage but not essential. Experience with laser-based instruments is also an advantage but not required. Some fieldwork may require long hours on occasion but much of the work will be lab based in between the fieldwork trips.

Research Mentors: Roisin Commane: r.commane@columbia.edu, (845) 365-8571
Arlene Fiore: amfiore@ldeo.columbia.edu, (845) 365- 8580

How Hot Has Greenland Been During the Last 10,000 Years?

Background: The Arctic is warming faster than any other location on Earth. The Greenland Ice Sheet and local glaciers are melting rapidly, and ecosystems are undergoing dramatic changes. Ten to five thousand years ago, rapid warming also occurred in Greenland, but unlike today, the warming was due to natural changes in the amount of summer sunlight received in the Arctic. In the small town of Kulusuk, in southwestern Greenland, a glacier sits next to a large freshwater lake. A sediment core from this lake gives a record of the material that settled onto the lake floor over the past 10,000 years. We used this sediment core to document the changes in the size of the glacier over this time. We now know that the glacier completely melted away between 8,000 and 5,000 years ago, during a time known as the Holocene Thermal Maximum. During the past 5,000 years, the glacier grew back in fits and starts, alternating between periods of growth and stability. The goal of this research is to determine how the summer temperatures at the glacier changed during the past 10,000 years. To do this, we will use an exciting organic geochemical tool known as the alkenone paleothermometer. Alkenones are fat molecules produced by algae that grew in the lake each summer. When they grow at colder temperatures, the algae make more polyunsaturated fats (more like vegetable oil and less like animal fat). We will measure the degree of polyunsaturation of the alkenones in the sediment core to determine when and by how much the temperature of the lake water has varied during the past 10,000 years. We hypothesize that the changes in glacier size were related to the summer temperature in Kulusuk. During this project the intern will determine the temperature history of southwestern Greenland (the first record of its kind from the region) and what the relationship is between summer temperature and the size of the Kulusuk glacier.

Analysis required: The lab work will take place primarily in the Organic Geochemistry lab at LDEO and will consist of isolating lipid molecules from a lake sediment core from Greenland and purifying them for analysis on a Gas Chromatograph – Flame Ionization Detector (GC-FID). The intern will learn a series of laboratory skills and wet chemistry procedures for purification of lipid molecules, and will learn how to operate a GC-FID and will reduce the resulting data to generate a valuable new temperature record for southwestern Greenland that spans the past 10,000 years.

Prerequisites: None required.

Mentors: William D'Andrea: dandrea@ldeo.columbia.edu;
Helen Habicht: mhabicht@ldeo.columbia.edu

What Is the Current Rate of Frontal Retreat of the Greenland Ice Sheet?

Background: The Greenland Ice Sheet has been losing mass over the last few decades. Recent estimates using the mass budget method combining observations of ice velocity and climate models indicate that the Greenland Ice Sheet is losing mass almost six times faster over the last decade compared to the 1980s, with an average mass loss increase of 80 Gt/yr per decade. Studies indicate that both the dynamic and surface mass balance (surface melt) components contribute significantly to the mass loss. A major current effort in glaciology is understanding the flow of ice from ice sheets into the ocean so that we may more accurately predict their future contribution to sea levels.

Most major outlet glaciers of the Greenland Ice Sheet are experiencing thinning and ice-front retreat. Prominent calving glaciers like Jakobshavn Isbreae, in Southwest Greenland, have recorded significant retreat in the last decade. However, around the last year, this large glacier has slowed down and has thickened slightly. This is likely a dynamic effect because the overall surface melt has not decreased in the last few years.

Analysis required: In this project, the student will map the calving fronts of major Greenland outlet glaciers during the recent decade using Landsat imagery (2010-2019/20) using GIS software such as ARC GIS and create a time series of the retreat of the calving fronts. Using this time series, the student will calculate whether the calving fronts are continuing to retreat or slowing down, and delineate important dynamic patterns of how Greenland Ice Sheet is responding to increased warming in the recent years. The student will also use velocity maps from InSAR and regional climate model simulated surface melt to correlate with the observed change of the glacier calving front.

Datasets to be used: Landsat Imagery, Greenland ice velocity, Climate model output from RACMO or MAR regional climate models.

Prerequisites desired: Familiarity with GIS techniques such as ARC GIS, MATLAB/Python

Mentor: Indrani Das, MGG, indrani@ldeo.columbia.edu, 845-365-8334

What Are the Effects of Deoxygenation and Increasing Atmospheric CO_2 on *Noctiluca scintillans?*

Background: Global oceanic dissolved oxygen has decreased by ~2% and sites affected by low oxygen conditions are increasing. Consequences of deoxygenation include habitat compression, reduction in habitat suitability, species migration and reduction in abundance and species diversity. The most dramatic change is in the Arabian Sea. It has one of the most intense oxygen minimum zones in the world. Here, in a dramatic shift in biodiversity, the unusual mixotrophic dinoflagellate *Noctiluca scintillans* (Fig. 1), has replaced diatoms. The latter are an important food source for fish. Our fieldwork showed that the green endosymbionts, *Pedinomonas noctilucae*, that *Noctiluca* harbors within its cell, photosynthesized at higher rates under low oxygen conditions than diatoms indicating that *Noctiluca* blooms are facilitated by intrusion of low oxygen waters from the Arabian Seas 'dead zone'. We are currently the only laboratory able to culture *Noctiluca* and we have some important experimental results. We found that *Noctiluca* cells proliferate when exposed to both high CO_2 and hypoxia, quite different from their photosynthetic endosymbionts. *Noctiluca* decreased significantly in high CO_2 + hypoxia, but also released their endosymbionts, which surprisingly, thrived as free-living populations. This behavior is unusual. Regions where *Noctiluca* proliferates are also regions where deoxygenation is intensifying. As a mixotroph, *Noctiluca* uses its dual modes of nutrition, both eating and photosynthesis. However, another way that *Noctiluca* could grow in lean times is by expelling and then eating its endosymbionts. We seek to understand this additional mode of survival.

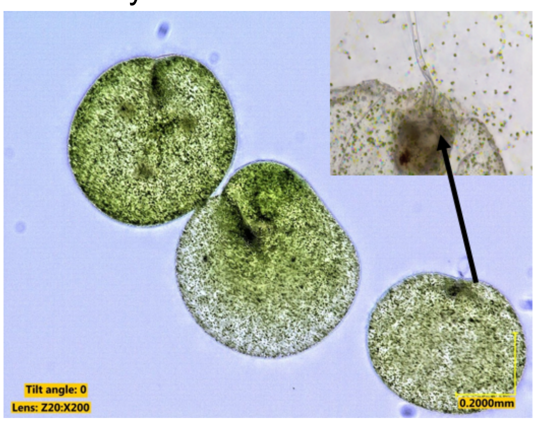


Fig 1: *Noctiluca* cells grown in high CO_2 and hypoxic conditions contain many green endosymbionts. Magnified section shows *Noctiluca* ejecting its endosymbionts.

Experimental Plan: This project will use *Noctiluca* cultures to conduct controlled incubation experiments that investigate the combined impact of low oxygen and high CO_2 on the ability of *Noctiluca scintillans* to survive and grow to bloom proportions through expelling its endosymbionts and then eating them to recover from unfavorable conditions. Such a mechanism has not been observed in other symbiotic systems. The results could not only help us to understand how this unusual organism will fare in a changing world but also illuminate the complexities of symbiotic systems.

Mentors: Dr. Joaquim Goes (jig@ldeo.columbia.edu), Dr. Helga do Rosario Gomes (helga@ldeo.columbia.edu), Kali McKee (kmckee@ldeo.columbia.edu)

Pre-requisite for Students: Background in biology, strong laboratory skills and experience and a willingness to commit time and effort to the experiment above all else.

How Did Deep Ocean Circulation Change Across the Mid-Pleistocene Transition and How Is It Related to Changes in the Agulhas Current System?

Background: The Agulhas Current is the largest western boundary current in the world's ocean, transporting 70 million cubic meters per second of water along the southeastern margin of Africa. The Agulhas Current is formed by several current sources that come together along the margin of Africa, and it is fully constituted at the northern end of the Natal Valley off Durban South Africa. At its retroflection, ~20% of the current "leaks" into the Atlantic Ocean and carries heat and salt to the northern North Atlantic and aids in the formation of deep water in that region. Deep water formation in the North Atlantic has a strong impact on global climate, particularly glacial-interglacial cycles that have dominated Earth's climate over the past million years. For this summer we are particularly interested in the mid-Pleistocene transition—a time period where the cyclicity of glacial cycles and ice sheet volumes changed from 40 kyr period to 100 kyr period. IODP Expedition 361 drilled six sites near the African margin to understand the greater Agulhas Current system and its impact on regional and global climate over the last 5 million years. Site U1479 is located off the coast of Cape Town, South Africa and monitors remnants of the deep water mass formed in the North Atlantic, known as NADW (North Atlantic Deep Water).

Analysis required: This project will require sieving ~50 sediment samples from site U1479 and preparing them for neodymium isotope analysis. Neodymium isotope chemistry is performed in the trace metal chemistry lab via ion exchange chromatography. For this project, the intern will learn how to perform clean chemistry and will prepare samples for measurement on the MC-ICP-MS instrument.

Prerequisites: some knowledge of lab wet chemistry and an interest in paleoceanography.

Mentors: Sophie Hines (shines@ldeo.columbia.edu, 845-365-8401) (plus Sidney Hemming, Ian Hall, and Expedition 361 Scientists)

Tracking the Last Moments Before Explosive Volcanic Eruptions: What Can Water in Quartz Tell Us?

Background: Even with advances in monitoring techniques, some volcanoes still erupt without warning, as seen in the recent, fatal eruption of White Island in New Zealand. This suggests that the processes responsible for providing the final trigger for the eruption could occur just moments before the explosion, but exactly how much time remains an open question.
A new way to track the timescales of eruptions comes from measuring profiles of water in crystals ejected by volcanoes. These crystals, often including quartz, form in magma chambers below volcanoes, then might sit for tens, thousands or even hundreds of thousands of years before eruption. During this time, the intense heat and pressure force small amounts of water, in the form of hydrogen, into the quartz. During, or just before the eruption, when the pressure is finally released, this hydrogen tries to escape the crystals, leaving lower water concentrations at the crystal edges than in their cores. Because we now know how fast hydrogen moves in crystals, we can start to work out, based on the concentration difference between the rim and core of the quartz, how long the eruption process took.
This is a new and emerging field – the speed of hydrogen movement in quartz has only just been fully measured during 2019. This project therefore provides a unique opportunity to be one of the first people to ever determine volcanic eruption rates from water profiles in quartz, which has the potential to be an important tool in the future.

Analyses required: This project will involve preparation and analysis of quartz (and possibly feldspar) samples from the Bishop Tuff, a >2000 km^2 volcanic deposit in the western USA formed some 767 k.y. ago. These crystals will then be analyzed by Fourier Transform Infrared (FTIR) spectroscopy to measure their water contents. Lab work will be ~20 hours per week, with the rest of the time spent on literature review, data processing and analysis.

Prerequisites: None required, although some knowledge of chemistry / mineralogy / physics / programming would be useful.

Mentors: Mike Jollands, jollands@ldeo.columbia.edu, 845-365-8649
Terry Plank, tplank@ldeo.columbia.edu, 845-365-8410

How Have Water Quality Indicators in the Hudson River Estuary Changed Over the Last 50 Years?

Background: The signature Federal environmental law in the USA, the Clean Water Act, was first authorized roughly 50 years ago. Prior to that time, the Hudson River Estuary was notorious for numerous, widespread water quality problems that affected human and ecosystem health. Fifty years of management actions related to the Clean Water Act should have improved conditions. On the other hand, increases in human population and economic activity in the region, coupled with ongoing habitat destruction, species invasions, and climate change, have the potential to push water quality indicators in the opposite direction. While the consensus is that conditions in the Hudson River estuary are much improved over the last 50 years, that conclusion is largely based on data from the waters around New York city. Data for other portions of the Hudson River estuary are readily available, but have not been collated and summarized in ways that would allow one to discern decadal scale trends and interactions between variables. Identifying decadal trends in water quality indicators in the Hudson River estuary are critical for understanding past changes, as well as for predicting future water quality conditions under different management scenarios.

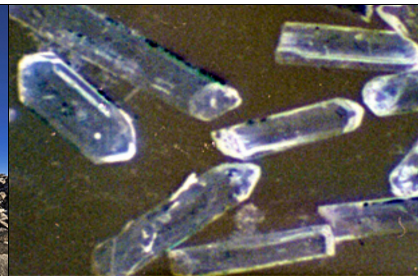
Analyses Required: The intern related to this project will work in the Juhl Aquatic Ecology lab at Lamont Doherty Earth Observatory. This project is primarily focused on assembling, summarizing, and analyzing existing data sets from on-line or published resources. Some limited opportunities for field work measuring water quality indicators is possible, and will be encouraged to help the student understand where the data originate, but the bulk of the intern’s time will be working with existing data.

Prerequisites: Familiarity with Excel, or other data management software, is a critical skill for this project.

Mentor: Andrew Juhl, andyjuhl@ldeo.columbia.edu

Did One of Earth's Largest Bolide Impacts Cause an Extinction Event 215.5 Million Years Ago?


Outcrops at Devil's Playground, Petrified Forest National Park, AZ


Microscopic Zircon Crystals from Petrified Forest National Park, AZ


Inductive Coupled Plazma - Mass Spectrometer

Background: About 215.5 million years ago, during the dawn of the age of dinosaurs, an asteroid slammed into northern Quebec, Canada producing the 100 km diameter Manicouagan crater. Unlike the larger and more famous impact 66 million years ago that wiped out the non-bird dinosaurs, this event has been said to have little or no effect on life. However, there is a major biological turnover-event called the Adamanian-Revueltian (A-R) boundary in fossil-rich continental strata of the of the western US that might be the right age, but available dates are too far from the boundary to know one way or another. Fortunately, there are abundant, datable zircons from ashes from that interval that can test whether or not the A-R boundary coincides with the impact.

Analyses Required: The goal is to test: 1) whether the A-R boundary the same age (within error) of the Manicouagan impact; and 2) are the zircons in the mudstone primarily from airfall ash or are they reworked from older sediment. To those ends, this project will sort zircons and other volcanic minerals from previously prepared heavy mineral residues from mudstones and sandstones collected from the Chinle Formation from Devil's Playground in Petrified Forest National Park, AZ, characterize the sediments they are from, and participate in dating them using Laser Ablation - Inductively Coupled Plasma - Mass Spectrometry) LA-ICP-MS at the LaserChron facility in Tucson, AZ. Lab work at Columbia/Lamont will consist of performing automated grain size analysis to measure the distributions of sediment size of the sediments, sorting the mineral assemblages, quantifying their volcanic components, and imaging them. It is anticipated that lab work will take an average 25 hours a week, with the rest of the time being focused on data analysis, literature review, etc. We also plan to arrange a field trip collect additional samples while in AZ at Petrified Forest and visit Rutgers University in New Jersey where samples will be recovered a core recovered from Petrified Forest that spans the boundary. There will be an additional local field trip to Triassic-Jurassic lake deposits.

Prerequisites: General geology and lab courses are a plus as in an interest in paleontology and stratigraphy.

Mentors: Sean Kinney, kinney@ldeo.columbia.edu; Paul Olsen, polsen@ldeo.columbia.edu; Clara Chang, cchang@ldeo.columbia.edu.

How Does Hematite Form and Can It Be Used as a Paleoclimate Proxy?

Background: Iron oxides are ubiquitous minerals found in a variety of environmental settings. The pigmentary phase of hematite ("pigmentite") is very common within soils; however, its origins are hotly debated because of the difficulties with directly observing the natural precipitation of iron oxides. One leading hypothesis suggests that pigmentite is derived from a series of iron oxide precursors and that the amount of pigmentite within a soil is proportional to the precursor maghemite, which is strongly magnetic. Geological records provide opportunities to test this hypothesis. Marine cores housed at Lamont-Doherty preserve sedimentary records of wind-transported dust that contains the iron oxide particles of soils that formed under the African monsoon. The geologic core repository of Rutgers University has a large collection of Triassic "red beds" that contain ample concentrations of pigmentite formed under the monsoon of Pangaea. Study of these cores will not only help answer questions surrounding the origins and formation of the pigmentite, but also help to refine proxy records of monsoonal climate change.

Analyses required: Data collection mostly will involve two lab methods. One method is visible light diffuse reflectance spectroscopy. Pigmentary hematite has characteristic color properties that can be used to assess the concentration of the mineral within sediment/soils. The other is traditional rock magnetism. The project will collect data from two cores. The first is Lamont marine core V30-40. This core is famous for its sedimentary composition of wind-blown detritus from West Africa that provides a record of precessional climate change for the Quaternary monsoon. Study of this core will involve (1) assessing the concentration and identity of iron oxides, and (2) assessing correlations between the already established precession record and the concentrations/identities. The second core is the Late Triassic Rutgers core no. 1 that preserves the exemplar Van Houten Cycle, which records a full set of lake-playa sedimentary facies divisions. The water depth changes are due the sensitivity of monsoonal rainfall to insolation changes, forced by orbital precession. Study of this core will focus on the purple and red color changes, as well as the hematite concentrations, associated with the sedimentary facies divisions of the climate cycle.

Prerequisites: a strong curiosity about the environment and willingness to learn how to operate technical instruments.

Mentor: Christopher J Lepre, PhD (lepre@ldeo.columbia.edu)

What Controls the Rains Down in Africa?

Background: Climate and environmental change played a large role in the evolution of our human ancestors. It has been shown that extreme fluctuations between aridity and lush, humid intervals pressured hominins to become more resilient and adaptable to a range of environments. However, little is known about African climate prior to the formation of expansive grasslands ~10 million years ago, despite this environment potentially playing a large role in the climate that drives these extreme fluctuations. Major changes in conditions in Africa, such as the change in ecosystem land cover, may have had a large effect on the region's sensitivity to climate. To answer these questions, we will examine plant wax biomarkers preserved off the West coast of Africa in a marine core dating back to the Oligocene, prior to major land surface shifts. We are able to quantitatively reconstruct monsoon strength by looking at isotopes, chain lengths, and distributions of the wax compounds in order to analyze changes in mean, variance, and cyclicity of rainfall through time. This will be the first study of high-resolution rainfall change in Africa prior to the onset of C_4 grassland expansion 10 million years ago and we will use these data to contextualize the environmental history of our earliest ancestors.

Analyses Required: The project will analyze leaf wax biomarkers from marine core sediment off the West coast of Africa, ODP Leg 159 Site 959. Lab work is comprised of a series of 'dirty' steps including grinding sediment in preparation for biomarker extraction, and a series of 'clean' wet chemistry steps to isolate the plant waxes needed to answer our research questions. Solvent extraction, column chemistry, and compound analyses will be performed in Lamont's Organic Geochemistry Lab to prepare for high-precision isotope measurements on a Gas-Chromatograph (GC) Isotope Ratio Mass Spectrometer (IRMS). Following lab work and sample processing, time will be spent analyzing the isotope and compound distribution data in excel and potentially MATLAB, and review of the literature will occur throughout the summer to prepare for understanding the meaning and context of a novel dataset.

Prerequisites: General chemistry and lab courses are suggested; Organic chemistry with interests in paleoclimatology and human evolution are a plus.

Mentors: Rachel Lupien, rlupien@ldeo.columbia.edu, 845-365-8369; Kevin Uno, kevinuno@ldeo.columbia.edu, 845-365-8308

Did the Last Ice Age Begin Simultaneously in the Northern and Southern Hemispheres?

Background: Over the last few million years, the Earth has experienced a series of glaciations that have become increasingly severe. These repeated ice ages are widely believed to be paced, if not entirely caused, by periodic changes in the seasonal distribution of sunlight due to astronomically driven variations in the tilt and orientation of the Earth's rotation axis, as well as the shape of Earth's orbit. A favored formulation of these dramatic climate shifts by Milutin Milankovitch is that they are the planetary response to the amount of summer sunlight received at high northern latitudes. Each ice age eventually affected the entire Earth, yet the seasonal insolation is largely of opposite sign in the northern and southern hemispheres.

During the last glacial interval, vast ice sheets grew on North America, while glaciers also advanced from the Andes on South America. This project is designed to explore the timing of climate change and growth of ice at the beginning of the last ice age in each hemisphere, taking advantage of the record of iceberg discharge in high-quality deep-sea sediment cores recovered from the North Atlantic and South Pacific Oceans. Parallel stable isotope, microfossil and sedimentological evidence will be used to align the two locations in time and allow an evaluation of the phasing of hemispheric changes relative to each other as well as the astronomically driven insolation variations.

Analysis Required: This project will require a student to process samples taken from two sediment cores, identify and quantify ice-rafted debris, determine the relative abundance of polar foraminifera species, and to select and prepare benthic and planktic specimens for isotopic analysis. They will then apply visual and simple time-series analyses to assess the sequence of climate events with respect to each location and to the changes predicted by Milankovitch's formulation of the orbital theory of the ice ages. Training / guidance will be provided for all procedures. Lab work will require 20 hrs./wk.

Prerequisites: None, although knowledge of basic climatology and oceanography are helpful.

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

Is a Mini-Hotspot Lurking Beneath Florida?

Background: The mantle beneath western North America has long been understood to contain upwelling regions that are hot enough to melt and cause volcanism. The Yellowstone super-volcano, which is atop a long-lived mantle plume, is one such volcanic area, but many smaller volcanic fields, such as those near the Colorado Plateau, are associated with smaller-scale mantle upwelling (or “mini-hotspots”) of less certain origin. Only more recently recognized are that mini-hotspots also occur in the mantle beneath eastern North America, with the two beneath Virginia and southern New England being especially prominent. But what about Florida? Although it and the nearby Bahama Banks are covered by thick blankets of sedimentary rock, samples of basement rocks recovered from deep boreholes indicate extensive volcanism about 100 million years ago, during the Mesozoic Era. Might the deep heat that caused this volcanism persist to the present day? Might a mini-hotspot occur beneath Florida, too? In this project, we will use seismological tools applied to the very high-quality seismic data collected by the EarthScope Transportable Array to characterize the asthenosphere (the convecting layer of the upper mantle) beneath Florida, seeking to understand its temperature and flow pattern.

Analysis Required: The intern will be involved in analyzing and interpreting seismic data.

Prerequisites: The intern needs to be willing to learn a little seismology and to spend a long time staring at wiggly lines. Some prior exposure to the physics of vibrations and waves and to data analysis would be helpful.

Mentor: Bill Menke (menke@ldeo.columbia.edu, http://www.ldeo.columbia.edu/users/menke/, 845-304-5381)

Can Artificial Neural Networks Solve Dynamical Seismological Problems?

Background: So far, successful applications of artificial neural networks to seismological problems mostly have been in the area of pattern recognition, such as detecting earthquake signals in noisy seismograms and discriminating between different kinds of seismic sources. Such applications are "no-brainers", in the sense that neural nets already have been successfully applied to commercial pattern recognition problems, such as facial recognition and handwriting decoding. However, their application to dynamical problems is less well-developed. (I use the word 'dynamical' to mean problems with parameters that fluctuate in time and space and that obey an underlying set of physical laws). In this project, we will select several simple – but dynamical - seismological problems, develop and train neural nets to solve them, and access the accuracy and reliability of the results. The very large 'EarthScope' database provides a potentially-useful training dataset.

Analysis Required: The intern will be involved in designing and testing neural networks that solve simple and well-posed seismological data analysis problems.

Prerequisites: This is a technically-demanding project that requires learning a little about seismology and artificial intelligence and spending a lot of time programming in MatLab and/or Python software environments. Prior coursework in mathematical physics and some experience in coding is a must.

Mentor: Bill Menke (menke@ldeo.columbia.edu, http://www.ldeo.columbia.edu/users/menke/, 845-304-5381)

Can We Use GPS Reflectometry to Measure Tides and Sea Levels Both at Piermont Pier and in Greenland Fjords?

Background: As ice melts and oceans warm around the world, sea level is rising in many places, but falling in others. Reliable predictions of how this will continue are crucial for meeting sustainable development goals, developing natural hazard response plans, and managing coastal infrastructure. A key component for efforts to reduce uncertainty in sea level change is expanding the global network of tide gauges to better observe the spatial pattern of sea level change.

In support of an NSF-funded, LDEO-GINR (Greenland Institute of Natural Resources) collaborative proposal, four coastal observation suites will be deployed to communities around Greenland in 2020 and 2021. Each location has different bedrock uplift rates, benthic habitats, and infrastructure concerns. In addition to bottom pressure recorders installed in Greenland, the LDEO team is investigating the use of less expensive global navigations satellite system (GNSS) receivers for both bedrock uplift rates and for relative water level determination through a novel reflectometry technique (GNSS-R). This technique exploits multipath data (i.e. both the direct and surface-reflected satellite signals) to precisely measure how the height of the antenna above the sea surface changes over time due to tides and sea-level rise.

The summer intern will work closely with the team to develop a GNSS-R capable setup through the installation, testing, and analysis of a GNSS receiver at the LDEO Field Research Station (FRS) in Piermont. This site benefits from the colocation of a Hudson River Ecological Observing Station (HRECOS) which includes real-time tide and meteorological observations for inter-comparison and ground truthing of the GNSS-R. The internship will build from external collaborator's successful deployment of robust and inexpensive GNSS receivers in the field at multiple sites in Canada and Greenland. These collaborators have developed Python and MatLab processing software, minimizing new code development, allowing this project to focus on data analysis and interpretation.

Analysis Required: This project will combine instrument installation, basic electronics (e.g., Raspberry Pi), minor software development, and data analysis (e.g., basic statistics). Field work includes instrument setup and build, initial installation of the GNSS system at Piermont Pier FRS, and total station levelling. Field work will average 10 hrs./wk., with the rest of the time being focused on data analysis, literature review, etc.

Prerequisites: At least one introductory Earth Science course. Some calculus and interest in Python programming and statistics would also be useful.

Mentor: David Porter, dporter@ldeo.columbia.edu, 845-365-8183

What Plant is That? Using Organic Geochemistry to Identify Plants and Ecosystems.

Background: Geoscientists rely on studies of modern ecosystems as models or analogs for ecosystems in the past. For this project, we will explore the organic geochemistry of modern trees, shrubs, and grasses from the Sahel and the Sahara Desert to improve our ability to identify plant types in the geologic past. By identifying plant types in the past, we can begin to accurately and quantitatively reconstruct past ecosystems and in doing so, we can explore the vegetation structure (i.e., habitats) of our hominin ancestors and more broadly, the possible effects of ecosystem changes on human evolution.

This project will focus on using molecular fingerprints, or biomarker profiles, of modern African plants to address the question "What plant is that?". We will extract plant biomarkers (i.e., leaf waxes and secondary compounds) from modern plants from Niger. Biomarkers will be separated and purified in preparation for analysis using gas-chromatography mass spectrometry. Once analyzed, the biomarkers will be identified and quantified to yield biomarker profiles. We will then explore how the biomarker profiles from modern plants can be used to identify plants in the geologic record.

Analysis Required: This project will involve solvent extraction of biomarkers from plants followed by column chromatography to separate and purify compounds. Lab work will require 20 to 40 hours per week.

Prerequisites: None, although knowledge of organic chemistry and programming in R is a plus.

Mentors: Kevin Uno, kevinuno@ldeo.columbia.edu, 845-365-8308; Helen Habicht, mhabicht@ldeo.columbia.edu, 845-365-8189

What Is the History of Microplastic Contamination in New York City?

Background: Our pilot research demonstrated that plastic, including microplastics, are widely distributed in New York City area waters, including Newtown Creek and Flushing Bay. This past summer, through the analysis of plastic additives in sediment cores collected from a lake in Central Park, we found that the increasing proportion of plastics in the younger parts of the core was consistent with increases in global plastic production. In order to define the history of the type of plastic entering the environment through atmospheric delivery, we seek to determine plastic polymer types (e.g., polyethylene) in these samples using advanced pyrolysis Gas Chromatography/Mass Spectrometry.

Analysis Required: Lab work includes isolating microplastics from other sinking particles, characterizing microplastics using several optical approaches, and identifying them using advanced pyrolysis Gas Chromatography/Mass Spectrometry. Lab work will require average 30 hours per week, with the rest of the time being focused on data analysis and literature review. We also plan to arrange a field trip to an urban lake in New York City to collect more sediment cores.

Prerequisites: General chemistry and lab courses are required. Organic chemistry with interests in biological and environmental issues would be a plus.

Mentors: Beizhan Yan, yanbz@ldeo.columbia.edu, 845-365-8448
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