Did a Meteorite Impact Precede the Last Rapid Global Warming Event, the PETM?

Background: The Paleocene-Eocene Thermal Maximum (PETM) was a sudden global warming event that coincided with the Paleocene-Eocene boundary ~55 million years ago. It is a unique interval in geologic history, and understanding what occurred is important because it may be analogous to what is happening today. Over its short ~200,000 year duration, 35-50% of benthic foraminifera (sediment surface plankton species) became extinct. It is characterized in the marine record by large and rapid changes in marine benthic oxygen and carbon isotope ratios, and the change in the oxygen isotopes corresponds to a ~5-8°C warming. The sediments deposited along the mid-Atlantic margin during the PETM are unique compared to those deposited before and afterward. In particular, the Marlboro Clay, a unusually thick clay layer extending from New Jersey to North Carolina often marking the beginning of the PETM, has unique mineralogy and chemical compositions that may hold clues to the cause of this unusual period in the climate history. Moreover, recently microtektites (ejecta from a meteorite impact) were identified in sediments that coincide in time with the base of the Marlboro Clay. This project would like to address two important questions: 1) is the Marlboro derived from the same sources as the overlying and underlying sediments, in which case its unique composition reflects intense chemical weathering as a consequence of PETM climate, or does it have a different source, which would mean that the PETM had broad and unique impacts on erosion and sedimentation patterns in Eastern North America; and 2) is the Marlboro Clay deposited because of a meteorite impact, and can we see the signature of the impactor in its composition (e.g., Ir anomaly)?

Analysis Required: The project involves preparation and analyses of samples from ODP Leg 174 AX drill cores, where microtektites have been identified at the onset of the PETM, and samples of the Marlboro Clay. The samples require leaching and size fraction separations (4 weeks) followed by dissolution in the ultraclean chemistry lab and analyses of major and trace element concentrations by ICP-MS (1.5 week). K-Ar analyses will constrain the average age of the sediments (2 days). If time permits, an aliquot of the solutions will be processed for column chemistry to purify Nd, Sr, Pb, and their isotope ratios will be analyzed at Lamont.

Mentors: Merry (Yue) Cai (cai@ldeo.columbia.edu), Steven L. Goldstein (steveg@ldeo.columbia.edu) and Wallace Broecker (broecker@ldeo.columbia.edu)

What is the Impact of Vegetation on Air Pollution?

Background: Ozone in the troposphere is an air pollutant and potent greenhouse gas. An important sink of ozone occurs when the gas is removed by vegetation at the Earth's surface. We call this vegetation sink "ozone dry deposition". Despite the relevance of the ozone depositional sink for understanding the causes of ozone pollution, dry deposition is often overlooked in regional and global modeling and observational analyses. Ozone dry deposition can occur when the gas diffuses into plant stomata, the small pores on leaves used for gas exchange, or through other, poorly understood, pathways. Stomatal uptake of ozone is injurious to plants, and can interrupt global carbon and water cycling. Major research questions on this topic include how does the ozone vegetation sink change with meteorology and vegetation cover, and how does this impact regional-to-global ozone air quality? Our work with an undergraduate intern would address these broader research questions by advancing the understanding of day-to-day variability in ozone dry deposition and the contribution of variability in this sink to high vs. low pollution days across the Environmental Protection Agency (EPA) pollution-monitoring network.

Analysis Required: The undergraduate intern will use an existing dataset from the EPA Clean Air Status and Trends Network (CASTNet) of modeled ozone dry deposition and measured ground-level ozone concentrations and meteorology. Specifically, the intern will examine day-to-day changes in the ozone dry depositional sink and ozone pollution across the eastern United States and identify relationships with synoptic-scale meteorology.

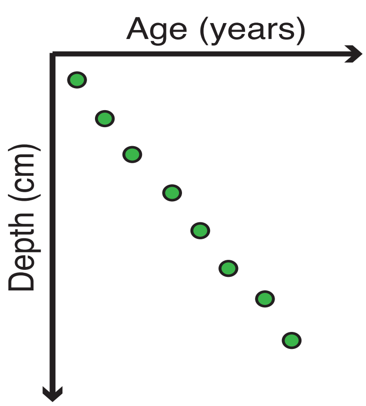
Prerequisites: Coding experience in Python, MATLAB, IDL, or R is an advantage. The minimum required skills are comfort and experience with basic data analysis and statistical techniques in Excel. Communication skills are highly valued for thoroughly documenting codes and disseminating scientific findings.

Mentors: Olivia Clifton (oclifton@ldeo.columbia.edu) and Arlene Fiore (amfiore@ldeo.columbia.edu)

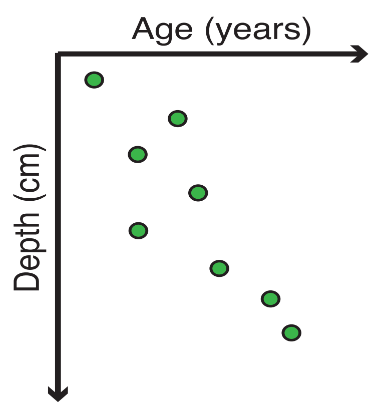
How Reliable is Radiocarbon Dating?

Background: Radiocarbon (^{14}C) dating has long been held as the "gold standard" for dating marine sediment. Radiocarbon is generally measured on planktic foraminifera, and ideally the ages all fall along a straight line as determined by the sedimentation rate. But radiocarbon dating seldom behaves ideally! In fact, sometimes two different foraminifera species will give completely different ages on the same sediment sample. This offset could happen for two reasons: 1) vital effects in the incorporation of radiocarbon into different foraminifera species 2) sedimentary effects, like bioturbation or dissolution, which influence different foraminifera species to different degrees. Which species is going to be the most reliable at recording the age of the sediment? Picking the right foraminifera is critical to developing accurate age models, the basis upon which all paleoclimate records are built. In this project, the student will measure radiocarbon ages in multiple foraminifera species of different size fractions in order to determine the best candidate for accurate age reconstruction and to assess the mechanisms that may fractionate the ages between different species.

IDEAL SCENARIO



ACTUAL SCENARIO



Analysis Required: This project will require picking of foraminifera from different species and size fractions. Lab work will require ~20hrs/week. If time allows, we may take a field trip to the National Ocean Sciences AMS facility (NOSAMS) at Woods Hole Oceanographic Institute to learn how radiocarbon measurements are made.

Prerequisites: None, although previous experience in picking foraminifera is a plus.

Mentors: Kassandra Costa (kcosta@ldeo.columbia.edu) and Jerry McManus (jmcmanus@ldeo.columbia.edu)

Cleaner Air for China in a Warmer World?

Background: How will air quality over China respond to changes in climate and air pollutant emissions in the next two decades? This project is centered within a larger collaborative project assessing future air pollution in China, including under climate change, and the resulting impacts on mortality in China. The ongoing air pollution crisis in China has focused attention on the massive public health burden associated with exposure to smog, composed primarily of particulate matter and ozone. As of 2013, measurements from ground-based networks observing ozone and particulate matter in several Chinese cities are publicly available, and we may acquire additional measurements via scientific collaborators in China. Estimates of ambient air pollution are available from new satellite-based approaches. Together, these datasets offer a novel opportunity to evaluate a chemistry-climate model that is used to project future changes in air pollution. We are currently simulating multiple emissions scenarios for air quality under climate change in the 2030s, considering different possibilities for air quality policies around the globe and within China. This project will assess strengths and weaknesses of the model's ability to capture the processes shaping future air quality in China. Evaluation of the model may also involve observed relationships (i.e., between ozone and particulate matter, and between each of these pollutants and meteorology).

Analysis Required: This project involves analyzing measurements of ozone and particulate matter made in ambient air over China and a satellite fusion product for ground-level fine particulate matter and evaluating existing present-day simulations from a global chemistry-climate model. This model is used to project future changes in air quality in response to different climate and air pollution policy choices. Depending on progress, observed meteorological fields might also be used to identify real-world relationships between air pollution and meteorology over China that can be used to evaluate the modeled relationships between air pollution and meteorology. At least one future model scenario for climate and air pollution over China will be examined.

Prerequisites: Some familiarity with a programming language (C, Fortran or python) and/or with a statistical analysis and graphical software package (IDL, ncl or MatLab) is desirable. Prior experience working in a Linux/Unix environment is a strong plus, as is experience analyzing 4D gridded model output. Communication skills are highly valued for thoroughly documenting any new analysis and visualization codes developed as well as the scientific findings.

Mentors: Arlene Fiore (amfiore@ldeo.columbia.edu) and Dan Westervelt (danielmw@ldeo.columbia.edu)

Is There Evidence of Co-Variation between Rainfall and Sediment Provenance with Human Evolution in Southern Africa?

Background: Southern Africa spans a significant range of climatic and vegetation zones from the low-latitude tropical regime that is primarily under the influence of the Intertropical Convergence Zone (ITCZ) and Congo Air Boundary (CAB) to the high southern latitudes that are influenced by the northern extensions of the circum-Antarctic westerly wind belt. Southern Africa contains the cradle of human kind, and contains many but spotty records of occupation and innovation. It appears that the timescales of human evolution are connected to precipitation variability, but the regional variability is quite large and requires many records. Studies of the paleoceanographic and terrestrial records from the Limpopo cone may help to put together these timescales to test the hypothesis of cause and effect. Presently, the southernmost extent of the seasonal migrations of the ITCZ and CAB is situated north of the Limpopo Catchment during austral summer (December, January, and February [DJF]), but there is emerging evidence from marine sediment cores for significant variations in rainfall in the Limpopo and other catchments to the south of it. We seek to understand how the terrigenous sediment derived from these catchments may have changed during times of different rainfall, and we will be studying a core that has already been studied for organic geochemical evidence for vegetation variability. This work will complement the concurrent study by other interns and senior scientists of sediments collected during 2016 by IODP Expedition 361 along the path of the Agulhas Current, to follow its history over the past few million years. We expect all of the interns to work together. There will be energetic group discussions at LDEO and with our international collaborators during the internship and beyond.

Analysis Required: This project will require sediment preparation and 40Ar* and geochemical analysis (major and trace elements and perhaps radiogenic isotopes) of samples from a core that was taken near the Limpopo River. Lab work will require 20 hrs./week. Some interaction with high school interns likely.

Prerequisites: None, although some coursework or background in geology, paleoclimate or isotope geochemistry is a plus.

Mentors: Sidney Hemming (sidney@ldeo.columbia.edu), Allison Franzese (afranzese@hostos.cuny.edu), Steve Goldstein (steveg@ldeo.columbia.edu) and Merry Cai (merrycai@gmail.com)

How and When Will This Lava Dome Collapse?

Background: Lava domes are formed when the erupting lava is too viscous to flow freely, yet there is not enough gas to create an explosion. In recent years, lava domes collapses and the resulting pyroclastic flows caused great damages at Unzen, Japan (1991), Merapi, Indonesia (1994), Soufriere Hills Volcano, Montserrat (1997), which caused over 100 deaths, and currently at Sinabung, Indonesia. In order to provide prediction tools for dome hazards, it is important to understand what controls the stability of lava domes. The mechanical stability of a dome depends on many factors, both internal, including the distribution of vesicularity, temperature, and crystallinity, and external, such as the underlying topography and slope. In addition, domes are inherently three-dimensional and often asymmetric. However, most models of lava dome evolution assume relatively simple fluids, a flat bed, and/or a two-dimensional dome.

Fig. 1: Evolution of the dome at Sinabung in dome-flow between 16 and 20 January 2014 (Photos by Fabrice Digonnet)

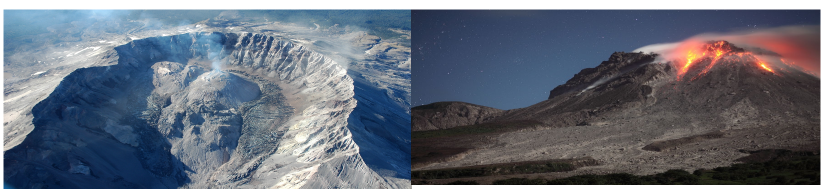


Fig. 2. Left: Lava dome within Mount St. Helen’s crater, September 2006 (Photo by Willie Scott, USGS). Right: Soufriere Hills volcano lava dome in Montserrat, 2010 (Photo from Volcania.com)

Analysis Required: We will address questions regarding dome evolution and stability using analogue fluid experiments in the lab. The student will prepare mixtures of syrup/wax, gas bubbles and crystals at different rations, and characterize their viscosity using a viscometer. Next, the student will create domes by “erupting” the mixtures through conduits onto varying topographic models (caldera, hill slope, etc.) The student will document the evolution of the domes using an array of cameras and will create 3D reconstructions of the dome surface to capture pre- and post-collapse structures. We will then compare modeled domes with natural collapse cases.

Prerequisites: Experience using Matlab is a plus. Laboratory experience also a plus.

Mentor: Einat Lev (einatlev@ldeo.columbia.edu)

Will RNA Tell Us "Who" Is Active in Bangladesh Groundwater?

Background: In Bangladesh geogenic arsenic is naturally released from the sediment to the groundwater in shallow aquifers. This arsenic has been consumed by tens of millions of people causing a public health crisis. The release of arsenic is naturally occurring and is mediated by microorganisms. Laboratory experiments and analysis of DNA from aquifers indicates that Fe reduction coupled to oxidation of organic matter. However isotope data and some of the DNA sequences indicate there may be other important processes occurring. Since DNA is of all microbes not just the active microbes, the results may be biased and we may be missing important processes. Fortunately RNA is only expressed in active microbes. We developed methods to collect and extract RNA from the groundwater and we are currently using high throughput methods to sequence the RNA. The goal of the work will be to analyze samples from arsenic impacted regions to better understand the active microbial populations. You will be involved in all aspects of the sample preparation and analysis.

Fig. 1: Sample collection for RNA in Bangladesh from a well next to a community well. The pump controllers are under the box and the filter is hidden behind the small plants.

Analysis Required: The project will require you to us geochemical and biological methods in the lab. We will teach you all the methods you need, you just need to be willing to learn.

Prerequisites: None. But chemistry and biology labs are a plus along with experience with Excel.

Mentor: Brian J. Mailloux (bmaillou@barnard.edu)

What Is the Relationship between Infant Mortality and the Environment?

Background: The infant mortality rate (IMR) for a region or country (defined as the number of children who die before their first birthday for every 1,000 live births) is of interest to a wide user community in interdisciplinary studies of health, development, sustainability, and environment. Subnational IMR estimates derived from vital statistics and other sources are frequently used as a proxy for indicators such as poverty and wellbeing since alternative measures, such as gross domestic product or population living on less than one U.S. dollar per day, are unavailable at sub-national levels for many countries.

We are in the process of developing the second version of SEDAC's Global Subnational Infant Mortality Rates data set, which compiles IMR data for 248 countries and territories, 153 of which include subnational units, benchmarked to the year 2014. This data will be integrated with demographic, environmental, and other spatial data to analyze the relationships between infant mortality rates with biophysical variables (i.e. biomes, soil quality, drought and malaria prevalence, and water availability) and geographical factors (i.e. low elevation coastal zones, slope, proximity to urban areas, and distance to roads). Do the world's poor live under geographic and biophysical conditions that are significantly different than other populations? What do those conditions look like?

Analysis Required: This project will require data processing, mapping and spatial analysis using ArcGIS. Lab work will require a minimum of 20 hrs./wk.

Prerequisites: Some experience with GIS software (ArcGIS, others); academic interest in sustainability, health, poverty, the environment, and/or demographics.

Mentors: Dara Mendeloff (dmendelo@ciesin.columbia.edu) and Sandra Baptista (sbaptist@ciesin.columbia.edu)

What is the Effect of Sediment Type on Contaminant Distribution in Eastern 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 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 2017 our group will collect subbottom (seismic) data, sediment grabs and core samples in the Eastern Long Island Sound. As part of the project we will analyze these samples for grain size and physical properties. In addition we plan to look into the variation of organic matter, metals and other contaminants using measurements with an X-ray florescence (XRF) scanner. The results can be compared with data from a pilot study are in central Long Island Sound. Of specific interest are the differences in the distribution of contaminants that result from the differences in grain size and bottom morphology of these two areas.

Analysis Required: The student would participate in analyzing selected sediment samples and/or acoustic data in the lab, e.g. using the XRF scanner, 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.

Mentors: Frank Nitsche **(**fnitsche@ldeo.columbia.edu) and Tim Kenna, (tkenna@ldeo.columbia.edu)

A Chance of Rain: Can Fossil Leaves Tell Us about Precipitation 23 million Years Ago?

Background: The fossil record holds a wealth of information on past climate. Fossil plants in particular can provide us with information on past temperatures, rainfall and even soil nutrient status and atmospheric CO_2. Plants are immobile and can't hide from the elements, therefore, their only choice is: adapt. In this project, we're investigating a series of 23 million year old fossil leaves from New Zealand that span a period associated with a large scale melting episode in Antarctica. As you might expect, the leaves reveal that the earth was warmer than it is today. Significantly, the leaves suggest a sharp increase in CO_2 at that time, which implies that an increase in atmospheric CO2 was involved in the Antarctic melting at the time. However, lake sediments derived from the same site suggest that rainfall was higher during the same period as well. If this is true then that could have strong implications for how we predict changes in rainfall patterns in response to future climate change. We suspect that changes in rainfall are recorded in the isotope chemistry of the fossil leaves. Plants become less water conservative when water abounds: leaves transpire more and keep their stomata open longer. We can use isotopes of carbon, hydrogen and oxygen bound in leaf material to determine how much transpiration was taking place. This, together with the physical features of the leaves, provides a detailed perspective on rainfall variation 23 million years ago. We will require fossil leaves to be isolated from sediment samples and analysis of H, O and C isotopes from fossil leaves.

Analysis required: The lab work will consist of physically separating fossil leaves from sediment and preparing them for analyses (separation, cleaning, homogenizing and weighing). The leaf samples will then be analyzed on an Elemental Analyzer coupled to an isotope ratio mass spectrometer (EA-IRMS).

Prerequisites: None required.

Mentors: Tammo Reichgelt (tammor@ldeo.columbia.edu) and William D'Andrea (dandrea@ldeo.columbia.edu)