Are you shopping for a Junior or Senior Project???

Shopping for Prehistoric Ideas?  OR  Life on Other Planets or the Solar System

Perhaps Field Work !  OR  Life in the Oceans
NOTES

1. Projects suggested by the faculty members and research staff are listed here. Contact these researchers for further information.

2. In many cases topics suggested are general areas of research. Discussion will be needed to decide on a specific problem and the scope of the project, particularly those which have both Junior Paper and Senior Thesis potential.

3. Feel free to discuss ideas of your own with any faculty member, even those not listed (who had no ideas or did not meet the deadline).

CODES IN LEFT-HAND MARGIN

JP = suitable for Junior Independent Work.
ST = suitable for Senior Thesis research.
JP or ST = could be scaled for either Junior Independent Work or Senior Thesis Research.
My research involves understanding the structure, composition, and evolution of planets through experimental study of minerals at high pressures and temperatures. Other interests include: mineralogy, high-pressure physics and chemistry, and planetary science. Potential projects are available in any of these areas. Some examples are:

**JP or ST 1. Mineralogy and composition of Earth’s lower mantle**
The Earth’s lower mantle is volumetrically the largest region of the planet. The composition of the lower mantle can be determined by comparing sound velocities in mantle minerals to seismic data for the Earth. In the last few years, a lively controversy has arisen regarding the mineralogy of the lower mantle as a result of conflicting experimental and theoretical studies of mineral sound velocities at high pressures and temperatures. In this project, you will construct a mineralogical model for the lower mantle and identify the physical properties that are the key to understanding the differences between existing models.

**JP 2. Data-driven materials discovery using a mineral thermoelastic database**
There is a growing recognition of the need for reliable, state-of-the-art databases in the geosciences. Compilations of thermodynamic and mechanical properties of minerals have wide applications to mineralogy, geosciences and materials science. We have constructed a database of mineral single-crystal elastic properties comprising the results of nearly 500 measurements on more than 200 different compositions. In this project, you will use this compilation to explore data-driven materials discovery. Possible projects include: 1) refinement of thermoelastic properties through synthesis of elasticity and compression data; 2) evaluation of systematic approaches to understand compositional and structural variations in the mechanical properties of minerals.
Requirement: Linear algebra.

**JP or ST 3. How do minerals respond to meteorite impacts?**
Meteorite impact events are important processes that shape the evolution of planets. In addition, the dynamic loading of rocks and minerals that occurs during impact events produces unique deformation features and characteristic phases that constrain impact conditions. There are two different projects available in this area. In the first, you will develop a (relatively simple) computer code to identify the high-pressure phases formed during high-velocity impact events. In the second, you will use an existing computer code to model how the strength of minerals affects their response to dynamic loading of the type that occurs in high-velocity impact events.
**JP or ST 4. Sterling Hill/Franklin mineral deposits**
The mineral deposits are Sterling Hill and Franklin NJ are among the most unique worldwide for their mineralogical diversity and unusual properties. There are a number of possible research projects here that involve descriptive and analytical work on specific mineral groups found at Franklin to better understand their geochemistry and paragenesis. Systems of interest include both major phases as well as post-mining and secondary weathering minerals.

**ST 5. Computational studies of mineral structures**
Over the last few decades, the development of new sophisticated theories together with advances in computer power have revolutionized our ability to calculate the properties of minerals from theory without any experimental input whatsoever. In this project, you will learn how to use one of these programs to determine the effects of pressure on simple fluoride or oxide minerals. The goals will be to determine how pressure affects the crystal structure and equation of state (pressure-volume relationship) of these minerals. The results have application to understanding the deep interior of the Earth.
JP 1. **What drove Earth’s largest δ¹³C excursion?**

The largest perturbation to the carbon cycle in Earth history, as measured by the stable carbon isotopic composition (δ¹³C) of marine carbonate rocks, occurred in the Ediacaran Period (635–542 Ma). Known colloquially as the 'Shuram' excursion, workers have long noted its tantalizing, broad concordance with the rise of abundant macro-scale fossils in the rock record, variously interpreted as animals, giant protists, macro-algae and lichen known as the 'Ediacaran Biota.' Thus, the Shuram excursion has been interpreted by many in the context of a dramatically changing redox state of the Ediacaran oceans - e.g., a result of methane cycling in a low O₂ atmosphere, the final destruction of a large pool of dissolved organic carbon (DOC), and the step-wise oxygenation of the Ediacaran oceans that paved the way for the radiation of animal life.

The Shuram excursion is so large, however, that many wonder whether such a dramatic carbon cycle perturbation is even possible. Therefore, several diagenetic hypotheses have been proposed to explain it alternatively, contending that the signal is caused instead by post-depositional alteration of carbonate rocks. This JP project will be a part of a multi-proxy, field-based study of the Wonoka Formation of South Australia, an Ediacaran-aged carbonate and siliclastic succession which hosts the excursion, to test the various explanatory models. Specifically, the project will be to develop strontium isotope data (⁸⁷Sr/⁸⁶Sr) from the Wonoka Formation. The ⁸⁷Sr/⁸⁶Sr of the ocean is influenced by two major, isotopically distinct sources - continental weathering and hydrothermal input from mid-ocean ridges - and has changed over the course of Earth history with changes in global tectonics and paleogeography. As the isotopic composition of Sr changes much more slowly than carbon, a stratigraphic record of ⁸⁷Sr/⁸⁶Sr will be helpful in discriminating between oceanographic and diagenetic processes that could be driving the Shuram excursion. Discerning which style of model is correct - is it a record of ancient global carbon cycling or of secondary diagenetic processes? - is vitally important to our understanding of the co-evolution of animal life and the surface environment.

JP or ST 2. **Modern analogues for snowball Earth cap dolostone?**

Learn how to measure a recently developed proxy (magnesium isotope ratios) in recent and ancient dolomites to gain insight into the mechanisms of dolomite formation. Explore implications for the interpretation of snowball Earth cap carbonates. Are recent dolomites an appropriate analogue for snowball Earth cap dolostones? How does the origin of the cap dolostone affect our understanding of the aftermath of a snowball Earth?

JP or ST 3. **Investigating Earth’s CO₂ thermostat**

Learn about the role of silicate weathering in the global carbon cycle on million year timescales. Carry out experiments in the lab reacting seawater with basalt at
low temperatures. Quantify rates of alteration using mass spectrometry and
explore implications for the role of seafloor weathering in Earth’s CO₂ thermostat.
How does seafloor weathering affect planetary habitability?

**JP or ST 4. Records of ancient seawater chemistry from deep-sea pore fluids**
Learn how fluid in the pores of deep sea sediments retain a memory of past ocean
chemistry and how we access these records using geochemical measurements and
numerical models. Develop and upgrade a database of global pore fluid profiles
to identify pristine records. Make state-of-the-art geochemical measurements of
the pore fluid and sediment to reconstruct seawater chemistry. Explore
implications for our understanding of the global carbon cycle and climate over the
last 10-20 million years.
My interests are centered around discovering and interpreting the structure of the deep Earth and the interiors of other planets. Both high frequency body wave seismology and low frequency normal mode seismology can be used to image Earth's mantle, the outer core and the inner core. Though nearly all of our seismic data has been collected on the Earth, planetary seismology is a growing field where insights from mineral physics and planetary dynamics can be combined with seismological modeling.

Possible projects include:

**JP (or ST) 1. Arctic seismology – a core science study.** This project will investigate the seismic structure of Earth's core as observed from the Canadian High Arctic. Historical data from a site in the Queen Elizabeth Islands will be investigated to image the core's velocity structure using earthquakes from the South Atlantic. This site is a candidate for re-occupation in a future seismic deployment (and may therefore lead to field work in the future) and this project will ascertain whether such a deployment might improve our understanding of Deep Earth structure.

Similar seismic field site BRHR, on Banks Island, Northwest Territories. Photo courtesy Dr A Schaeffer, U. Ottawa

**JP or ST 2. Princeton's seismic environment.** The department has housed a digital seismometer in Guyot Hall since 2016, re-occupying the location of an older, paper-based instrument. A second seismometer and accelerometer will be installed in a nearby quieter location. This JP or ST may include deployment of the new instrument; it will involve analyzing the data gathered from Princeton's instruments to better understand what seismology can reveal about seismic signals recorded in Central New Jersey.

**JP or ST 3. Seismically imaging New Jersey's lithosphere.** The Earthscope project (http://earthscope.org) installed several seismic stations in New Jersey in 2013, and this project will use the receiver function technique to examine the seismic structure of the crust and upper mantle in the Princeton region.

**JP or ST 4. A topic in Deep Earth Observational Seismology, or Planetary Seismology which particularly interests you**

These are very brief outlines. If you would like to discuss potential ideas for either JP or ST projects, please get in touch.
Near the end of the Cretaceous 66 m.y. ago the volcanic eruptions known as Deccan Traps of India and a large asteroid impact culminated in one of the Big Five mass extinctions in Earth’s history, which will be investigated here. Similar volcanic eruptions known as the Siberian Traps 251 m.y. ago culminated in the Permian-Triassic mass extinction, the Central Atlantic Magmatic Province (CAMP) 181 m.y. ago is closely linked to the Triassic-Jurassic mass extinction, and volcanism is also linked to the Devonian and Ordovician mass extinctions (350 and 450 m.y. ago) although less well known. Thus all five mass extinctions are closely associated with volcanism, but a large impact is known only from the latest Cretaceous.
Mercury is a toxic byproduct of large igneous province volcanism and globally distributed by wind. Mercury fallout accumulates as Hg anomalies in marine and terrestrial sediments where it marks high-stress biotic environments. It is also a potential new age marker that can be used in correlating terrestrial and marine environments. Major Hg anomalies have been identified in association with large igneous province volcanism at all five major mass extinctions during the Phanerozoic, which establishes flood basalt volcanism as major contributor, if not cause, of mass extinctions. This project explores several aspects of mercury fallout in terrestrial sections from USA and Canada that originated from Deccan volcanism in India, including:

1) Measure Hg anomalies in sediments as indicator of the magnitude, frequency and intensity of volcanic eruptions.
2) Identify high-stress environments and climate change associated with volcanism,
3) Examine whether the gradual decline and extinction of dinosaurs was related to the global effects of Deccan volcanism and related climate change.
4) Evaluate age control of terrestrial sequences based on Hg stratigraphy correlated with marine sequences linked to Deccan volcanism,
5) Measure Hg levels in dinosaur teeth and bones as measure of toxicity that may have hastened their demise.

Each of these aspects is suitable for a JP or ST project with the latter combining a larger and more involved study. Projects include fieldwork, different types of lab analyses, literature research, comparison and integration of new results with known studies for a comprehensive evaluation and interpretation of new results.

Advisors include Gerta Keller, Blair Schoene, Satish Myneni, Thierry Adatte

**Project 1, Hg anomaly record:** This project will measure Hg concentrations in terrestrial sediments of the late Maastrichtian to establish the Hg signature of paleomag chron 29r that spans the last 250,000 years before the mass extinction 66 m.y. ago. This will be the first terrestrial Hg record for this interval. Suitable for JP and/or ST. **Project Advisors:** Keller, Schoene, Adatte

**Project 2, high-stress environments and climate change:** This project will assess the nature and magnitude of environmental changes in terrestrial sediments leading to high-stress conditions for life and plants as a result of Deccan volcanism and related climate changes. Lab work involves stable isotope study of climate change. Results will be compared with the marine record. Suitable for JP and/or ST. **Project Advisors:** Keller, Schoene, Adatte

**Project 3, Demise of Dinosaurs:** Dinosaurs declined in diversity and abundance through the late Maastrichtian. Could this decline be related to climatic and environmental changes as a result of Deccan volcanism? This study examines the long-term dinosaur record to evaluate whether their decline and eventual demise was a result of volcanism induced climate change. Suitable as JP Project or combined with Project 2(b) as ST Project. **Project Advisors:** Keller, Schoene, Myneni, Adatte
Project 4, Age control based on Hg anomalies: This project will evaluate the age of terrestrial sections based on correlation with the marine Hg stratigraphy record that is available. Suitable for JP and/or ST. Project Advisor: Keller, Schoene, Adatte

Project 5, Mercury in Dinosaur teeth and bones: Mercury is a toxic element potentially detrimental to life as it gets incorporated in organisms threatening survival. This project involves measuring Hg concentrations in teeth and bones of dinosaurs and/or other vertebrates that lived during the high-stress time induced by Deccan volcanism over the last 250,000 years of the Maastrichtian preceding the mass extinction. This project parallels the Hg analysis in sediments (Project 1 outlined above). Suitable for JP and ST. Project Advisors: Myneni and Keller

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I am a field geologist studying Earth history and the limits of global change. My current work involves using sedimentary and volcanic rocks to extract information about Earth’s ancient magnetic field and the relative motion of continents, perturbations to the global carbon cycle, and the coevolution of life and climate change.

**JP or ST 1. Geography and climate during the Late Paleozoic Ice Age**

Pre-Mesozoic paleogeographies are constructed by using paleomagnetic data to constrain the latitude and orientation of individual continents. During the Carboniferous, large forests finally began to cover the land, Pangaeian mountain belts formed, and big perturbations to the carbon cycle were recorded in the ocean. At the same time, the Gondwana supercontinent moved over the south pole and was variably covered in ice sheets (see image below). This glacial interval is known as the Late Paleozoic Ice Age (LPIA) and is the most recent analogue to the glacial-interglacial cycles that characterize the most recent 3 million years.

Does the paleogeography of ice sheets determined from the geological record really match the paleomagnetic record of latitudes for drifting Gondwanaland? Do geographic extents of ancient ice sheets really match the tropical sedimentary record of sea level (and thus ice volume) changes? With what amplitude and frequency did the LPIA glaciers wax and wane—did they respond to the same astronomical forcings that the modern ice sheets do?

JP or ST projects can tackle these questions through either (1) reanalysis of paleomagnetic and glacio-geologic data to tackle the questions of paleogeography, or (2) study of the geochemistry of carbonate and phosphate fossils from tropical sedimentary rocks to test current interpretations of sea level change. This project could lead to senior thesis field work in Utah and Nevada.
Most records of Pleistocene climate change (i.e., the last few million years of ice ages and interglacials) come from drill cores, either through polar ice sheets or deep sea sediment. Very few continuous records of climate change have been retrieved from land in the tropics, despite the fact that the tropics are very important for driving global change. In this JP or ST, you will glue together a large stalactite from Northern Ethiopia. Next, you will slice, grind, photograph, count annual layers, drill, and initiate a suite of geochemical measurements. With this data, you will tell a story of how climate was different between glacial and interglacial periods in East Africa. You may even determine whether the drought of the past forty years that has had such a large impact on humans is unique, or if similar droughts occurred earlier in Earth history.
JP or ST  3.  **3D digital reconstruction of embedded objects in rocks**

Using new technology housed in the Princeton Grinder Lab (http://giri.princeton.edu/), the student can choose a subject of interest and investigate it with the Grinding, Imaging and Reconstruction Instrument (GIRI). For example, the student could examine an ancient fossil, modern bones or teeth, 3D sedimentary bedforms like stromatolites or ripples, or petroleum reservoir rocks and targets for carbon sequestration like oolites and sandstones. The idea is to study an object or the interior of an object of geoscientific that is not readily modeled by simplying photographing or scanning the surface. The project involves image analysis and 3D modeling using languages like Matlab, Python and Java, and software such as Avizo, Envi and Imagine.
PROFESSOR MOREL IS ON SABBATICAL THIS ACADEMIC YEAR 2017-2018

Opportunities for research on the interaction of chemicals with microorganisms.

JP or ST 1. Specific research projects include measurements of various metal-binding ligands in algae when exposed to metal pollution. Laboratory studies would include the study of biochemical responses of marine or freshwater phytoplankton to individual metals such as cadmium, copper, lead, mercury, and zinc. Field studies might involve measurements of these biological markers of metal stress in Lake Carnegie.

JP or ST 2. Will increasing carbon dioxide concentrations in the atmosphere promote increased productivity in marine ecosystems? Projects related to an ongoing study of the interaction between trace metal availability and carbon utilization and limitation in marine phytoplankton are also available.

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Research webpages: http://geoweb.princeton.edu/research/geochemistry

Water is essential for the origin and survival of life on our planet and perhaps plays a pivotal role on the existence of life on other planetary bodies as well. In several different forms, water mediates the physical and chemical interactions between various components of the Earth’s surface environment, which includes mineral oxides, biota and their byproducts, and the atmosphere. One of the challenges in environmental sciences is to gain a better understanding of interactions between these different components in nature, and to use it to predict a variety of biogeochemical processes such as elemental cycling, biological chemistry of elements, and the fate and transport of contaminants in the environment. This area of research is gaining importance, and researchers from different disciplines began conducting studies to explore these interactions in greater detail. I am interested in exploring one of these fundamental interactions, which include the evaluation of the chemical state of water in different geologic media and how this modifies the biogeochemical behavior of different inorganic and organic moieties in the natural systems. I am also interested in evaluating the chemical state(s) of important geochemical species to develop predictive patterns for explaining their macroscale behavior

All of my projects are related to environmental chemistry, and the research focus is on the macroscale and molecular level observations of various biogeochemical reactions. Background in chemistry is useful for these projects. For senior thesis, these projects involve experimental work with microscopy and spectroscopy tools in my laboratory, Princeton Materials Institute, and those available at the X-ray synchrotrons (such as National Synchrotron Light Source, Brookhaven, NY; Advanced Light Source, Berkeley, CA), and theoretical studies for chemical speciation and spectral analysis. Details of these research projects and results from
senior theses submitted by my group members can be obtained from my research group web pages. Some of the available topics for senior thesis and summer research are as follows:

**JP or ST  1.** Naturally formed halocarbons (halogen containing organic molecules) in the environment. Focus: Characterization; evaluation of biogeochemical parameters that influence the formation of halocarbons and their behavior in the environment; role of halocarbons in C- and other elemental cycles. Research includes field trips for water, soil and sediment sampling in Pine Barrens (NJ) and the nearby estuarine environments, detailed analysis either in our laboratory or in the campus. The following picture shows one of our field sites in Pine Barrens, NJ.

![Pine Barrens, NJ](image)

**JP or ST  2.** Chemistry of naturally occurring organic compounds in the environment. Chemistry; molecular structure; reactions with minerals in soils and sediments, and their role in interfacial reactions in the natural systems.

**JP or ST  3.** Environmental chemistry of contaminants. Biogeochemistry of selected contaminant metals in soil, sediment and aquatic systems, and their biological accumulation.

**JP or ST  4.** CO₂ reactions with geologic media. The focus is on the influence of elevated atmospheric- and soil/sediment-CO₂ on mineral weathering and carbon storage in terrestrial systems, water quality, and biogeochemistry. This study involves prediction of mineral-fluid equilibria from thermodynamic speciation, and conduct laboratory investigations to verify these predictions for reactions at different time scales (direct laboratory experiments for reactions at short time scales, and observations from mineral weathering for long time scales). Field sampling is necessary at the Mammoth Mountain (CA).
Microbiology and Biogeochemistry of Arsenic, the Arctic, the Antarctic, the Deep Subsurface and of Mars

JP or ST 1. Metagenomic/metaproteomic analysis of dinosaur bones. For the past 10 years paleontologists have reported isolation of soft tissue of purported dinosaur collagen from 65-195 million year old dinosaur bones providing a record of their DNA. These reports have been challenged since most proteins do not survive over a million years under normal conditions. Alternatively, it has been hypothesized that the soft tissue recovered after bone demineralization might be derived from microbial biofilms in the fossilized bones. To address this alternative hypothesis from perspective of microbiology, three metagenomes were constructed from DNA extracted from an excavated Centrosaurus rib and its adjacent mudstone collected from the Dinosaur Provincial Park, Canada. The JP would involve reviewing the controversial topic in literature and learning fundamental bioinformatic tools to analyze large sets of metagenomic sequences. Specifically, the JP would focus on comparing the microbial community composition associated bone and mudstone and recover the dominant draft genomes from the metagenomes. A ST would involve further annotation of the binned genomes and construction of database for future metaproteomics studies. Eventually, the ST would shed light on why the fossilized dinosaur bone could serve as an ecological niche for certain microbes to proliferate and whether the previously reported collagen proteins are in fact bacterial peptides.

Centrosaurus bone excavated from Cretaceous mudstone outcrop.

JP 2. Stable Isotope Signatures of Biomarkers in the Martian Atmosphere. The recent detection of atmospheric CH₄ in the Martian atmosphere by the Curiosity rover suggests that subsurface gases are actively being released and consumed. Such gases may be biomarkers for subsurface life. A previous ST has demonstrated the ability of the permafrost methanogen Methanosarcina soligelidi to produce CH₄ under Martian atmospheric pressure conditions. A JP would involve using Cavity Ring Down Spectroscopy (CRDS) to monitor the stable isotope composition of CH₄ produced in low pressure M. soligelidi incubation experiments to elucidate possible effects of low pressure on kinetic isotope effects in CH₄ production. The student will also utilize Ion Chromatography Mass Spectroscopy (ICMS) to monitor acetate depletion as a possible carbon source in methanogenesis under Martian conditions.
JP 3 or ST 2. **Arsenic and Pipelines.** Arsenic is the most important contaminant in the ground water of New Jersey. Most of the wells that have arsenic concentrations exceeding the maximum permissible limit (5 ppb) exist in the Piedmont of New Jersey where the aquifers reside in arsenic rich Triassic sediment. Arsenic transport from this sediment into the groundwater is governed by microbial activity. Dozens of natural gas and light oil transmission pipelines are being built throughout the eastern USA because of the rapid production of hydraulic-fracturing produced oil and gas in Pennsylvania. These pipelines will operate a Impressed Current Cathodic Protection systems to prevent corrosion. Cathodic shields produce H₂ gas, while decreasing the O₂ and increase the pH around the pipelines while reducing corrosion. These conditions could stimulate the growth of

*NASA cartoon of hypothetical Martian CH₄ seeps into the atmosphere.*

*Alex Byrnes and Keeley Welsh collecting well water samples for analyses.*

*Galvanic microcosms using DC current electrodes, soil and water.*
anaerobic bacteria that mobilize arsenic. Will the operation of the gas pipelines increase arsenic contamination in the groundwater near the pipelines? Two projects are available for JP or ST projects. One involves collecting well water samples near a 60+-year-old existing natural gas pipelines and performing geochemical, isotopic and DNA analyses. The goal is to determine whether CH₄ leakage and cathodic currents from these old gas pipelines have impacted the biogeochemical cycling of Fe, S and arsenic in drinking water today. The second involves reproducing the cathodic shield in the lab using galvanic microcosm experiments with soil and groundwater and measuring the arsenic, gas chemistry and DNA over time.

**JP 4 or ST 3. Is the Arctic a Methane (CH₄) Sink?** Global climate models project the strongest future warming in the Northern Hemisphere to occur at high latitudes with some models predicting a 4-8°C warming over these regions by the end of this century. As a consequence, thawing permafrost and the resulting microbial decomposition of previously frozen organic C are believed to lead to the production of CH₄ at rates that will make it a source (net emission into atmosphere), and thus a significant potential positive feedback to global warming. Yet certain types of permafrost soils consume atmospheric CH₄. Could the latter offset the former? What geochemical conditions would stimulate this CH₄ sink? A JP would determine the effect of nutrients (Cu, NO₂⁻, NO₃⁻, NH₄⁺, acetate, sulfate, etc.) on CH₄ oxidation rates at atmospheric concentration. A senior thesis would expand the project to include molecular analyses of the incubated soils such as gene quantification and amplicon sequencing to characterize the methanotrophic communities.

**ST 4. Who is oxidizing all the Earth’s atmospheric CH₄?** Some uncultivated species belonging to the aerobic CH₄ oxidizing bacteria are capable of oxidizing the CH₄ in the Earth’s atmosphere at very high rates. These species, known as the high-affinity methanotrophs (HAM), are responsible for the uptake of atmospheric CH₄ in soils and rocks globally yet their phylogenetic identity remains a mystery because they have never been isolated in pure cultures. We recently obtained the draft genomes of the two main genotypes of high-affinity methanotrophs, namely Upland Soil Cluster (USC) alpha and USC gamma. The senior thesis project would make use of these two near-complete genomes and screen published soil metagenomes from all over the world in order to delineate the spatial distribution of HAM, to deduce the environmental features supporting HAM, and to construct site-specific HAM genomes to understand their evolution.

**JP or ST 5. The Impact of Carbon Cycling in Arctic Permafrost on Global Warming.** Global climate models predict a 4-8°C warming in the Arctic by the end of this century. As a consequence, thawing permafrost and the resulting microbial decomposition of previously frozen organic C is one of the most significant potential feedbacks from terrestrial ecosystems to the atmosphere. To study this process intact permafrost cores were collected from the Canadian High Arctic and subjected to long-term thawing experiments. The cores have been analyzed using
metagenomics during the thawing experiment while measuring the flux of CH₄ and CO₂. A JP project would involve studying the metabolic properties of a draft genome of a nitrogen-cycling Thaumarchaeota. A senior thesis would involve analyses of existing metagenomic data sets with the goal of obtaining draft genomes of other bacteria and determining their role in the cycling of carbon and nitrogen during permafrost warming.

**JP or ST 6. Carbon cycling in Antarctic cryosols.**
The soils in McMurdo Dry Valleys in Antarctica are poor in organic carbon. Cyanobacterial mats developed in glaciological lakes and streams, when dried, become organic inputs to the open soil. It is therefore hypothesized that the oligotrophic nature of valley floor selects for autotrophs. Among microorganisms in Antarctic terrestrial ecosystem, photoautotrophic Cyanobacteria are relatively well-studied. Organic compounds are also generated by chemoautotrophs and methanotrophs via carbon fixation and atmospheric CH₄ oxidation. However, the relative contributions of chemoautotrophy and methanotrophy to the organic carbon pool in dry valley soils remained undetermined. Research projects that elucidate the carbon cycling pathways in the Taylor Dry Valley and the ice-free areas near Princess Elizabeth Station are available to juniors and seniors. For example, using the metagenomic datasets to decipher relative abundance of marker genes in photosynthesis, carbon fixation and CH₄ oxidation, conducting microcosm experiments using stable-isotope-labelled substrates (¹³CO₂, ¹³CO₃²⁻ and ¹³CH₄) to compare the rates of photosynthetic autotrophy vs. chemoautotrophy vs. CH₄ oxidation.

**JP or ST 7. Microbial Dark Matter in the Deep Crustal Biosphere.** One of the most exciting scientific endeavors of the past 30 years has been the exploration of the subsurface biosphere. Based on the many marine and few continental sites being studied, the subsurface biosphere has been estimated to harbor a large fraction of the...
the Earth’s undefined prokaryotic biomass, so called microbial dark matter. Broad and compelling research questions continue to drive this field, including:

1. What fuels the deep biosphere?
2. How does the interplay between biology and geology shape the lithosphere?
3. What are subsurface genomes telling us about microbial dark matter?
4. How does life evolve in the subsurface?
5. Did today’s surface biosphere originate underground?
6. Is there life as we don't know it in the deep subsurface?

This project will focus on questions 3, 4 and 5 by analyzing metagenomic sequences collected from deep fractures in South Africa. The JP or senior thesis would involve using binning approaches to recruit sequences into draft genomes to determine the physiological properties of the microbial dark matter, to perform phylogenetic analyses of various genes with the genomes and to compare the single cell genomes to these draft genomes from the same sample. A senior thesis would compare the genomes of the same species collected from different locations to determine how the species evolved over time in the subsurface. The student will also be able to travel to South Africa for fieldwork at several kilometers beneath the Earth’s surface where scientists are drilling into an active fault zone.

**JP 8. Cultivation of spore-forming microbes from ancient permafrost.** A large variety of microorganisms have been detected in ancient permafrost by using culture-independent techniques such as next generation sequencing. However, the adaption and survival mechanisms of ancient microorganisms in subzero temperature environments over a wide geological time scale remain underexplored. Enrichment and isolation of such cold-adapted microorganisms would facilitate the understanding of the physiology of microbes and their roles in biogeochemical cycling in ancient permafrost sediment. JP projects would aim to review latest cultivation techniques and come up with experimental designs to
cultivate spore-forming microorganisms from Siberian permafrost sediment up to several million years old. Ultimately, pure cultures of the dominant microbial lineages would be isolated for further genetic and physiological studies.

**JP 9.** **Geochemistry of ancient permafrost from Siberia.** The global climate change could have a strong influence on carbon cycling in permafrost. Understanding the geochemistry of permafrost is critical to infer and predict the metabolic activity of microorganisms and their response to global warming. Perennially frozen sediment of various geological ages up to ~3 million years will be the focus of this JP project. A JP would apply ion chromatography to measure various anions (sulfate, nitrate and nitrate, etc.) and short chain fatty acids (formate, acetate and propionate) in the leachate from the ancient permafrost sediments. Additionally, the JP would involve analyzing the total organic carbon (TOC) and total organic nitrogen (TON) in the permafrost sediment by using Picarro measurement and TOC/TON analyzer. The determination of geochemical properties in permafrost sediment of a wide range of geological ages would further constrain the metabolic capability of the microbial lineages detected in the 3-million years old permafrost sediment from Siberia.

**ST 8.** **Applying FISH-TAMB to Select Bacteria for Specific Functions.**
Small subunit of ribosomal RNA gene has been a dominant target gene for biodiversity assessment. Yet many important ecological processes are performed by microorganisms that have not been isolated in pure cultures, whose phylogenetic identities are unknown and who comprise a small fraction of the total community. Fluorescent in situ Hybridization of Transcript-Annealing Molecular Beacons (FISH-TAMB) is a novel molecular technique that labels living cells based upon their specific function, not their phylogenetic identity. A senior thesis would entail training a student in the FISH-TAMB methodology, determining its detection limit, and optimizing a fluorescence-activated cell sorting (FACS) protocol to isolate novel microorganisms involved in anaerobic CH₄ cycling in deep fracture water from South Africa. If target cells are successfully separated from the microbial community, they can be selected for single cell genome sequencing and genome annotation.
Methane-metabolizing cells labeled by FISH-TAMB (in red). (A) A pure culture of the methanogen M. barkeri. (B) – (E) Cells from South African fracture fluid.

**JP10. Stable Isotope Geochemistry of Anaerobic CH₄ Oxidation in Deep Subseafloor Sediments.** The anaerobic oxidation of methane (AOM) is an important sink in the global CH₄ budget, consuming an estimated 80% of CH₄ arising from marine sediments. However, the contribution of the high-temperature deep biosphere to AOM is largely underexplored. A JP would involve using Cavity Ring Down Spectroscopy (CRDS) technology to measure the stable isotopic composition of dissolved inorganic carbon (DIC) collected from deep subseafloor sediments in the Nankai Trough off Muroto, Japan. The student will also utilize Ion Chromatography Mass Spectrometry (IC-MS) to monitor the depletion of electron acceptors coupled to the anaerobic oxidation of CH₄ in microcosm incubations. The goal of the JP is to improve our understanding of the contributions of various modes of AOM in the deep sub-marine biosphere.

**ST 9. Functional Biogeography of the Deep Crustal Biosphere.** Surface microbial communities, like those associated with hot springs, exhibit geographic distribution patterns. The study of such patterns, called biogeography, has mostly been based on the phylogenetic identity of these microorganisms. With next-generation sequencing technologies, functional gene features are recovered in an unprecedented volume in metagenomic and metatranscriptomic data. This enables the exploration of the functional biogeography of microorganisms, which can be more directly related to environmental conditions than can phylogeny. A ST project would be to apply dimensional reduction methods (e.g., non-negative matrix factorization) to compare and contrast the biogeographic patterns of the genetic potential in multiple subsurface water samples using the existing metagenomic data. Another potential project would be to apply a similar approach to a parallel set of metatranscriptomic data to investigate what biogeographic patterns may appear in expressed genetic profiles.
PROFESSOR OPPENHEIMER IS ON SABBATICIAL THIS ACADEMIC YEAR 2017-2018

JP or ST 1. Sea Level Rise: risk assessment, risk perception, and public policy
This project involves projection of sea level rise and storm surge characteristics under high uncertainty, assessing how individuals are likely to respond to changing risk using an agent-based model and survey data, and developing effective policy responses.

JP or ST 2. Correlation Structure of Extreme Events
Few studies examine the correlation of climate variables in the context of future warming. Yet spatial and temporal correlation bears implications for the effectiveness of public policy responses. In this project, we are exploring correlations between extreme events (e.g., heat waves) in the climate record and in output of model ensembles in order to understand the resulting challenges they pose to adaptation, if any.
My research involves understanding how climate and ocean circulation influence marine biogeochemistry and ecosystems, and how these changes can in turn impact the climate itself.

JP or ST 1. Fate of oceanic oxygen minimum zones

Global warming reduces the amount of oxygen in the ocean and is expected to increase the volume of tropical oxygen minimum zones (OMZ), where O2 levels are already low and unsuitable for most organisms (fish etc). Yet the fate of OMZs in the Pacific and Indian Oceans is still unknown because the changes associated with warming are obscured by natural variations. This project makes use of ocean model results to assess natural variations and warming induced changes in oxygen minimum zones.

JP or ST 2. Ocean eddies, filaments and carbon pump

The ocean biological pump removes carbon from the atmosphere and exports it to the deep sea. We know that the biological production at the surface is shaped by small-scale ocean circulation structures, like the eddies and filaments shown on the satellite image below. The impact of these structures on the export of carbon to the deep ocean, however, is still uncertain. This study involves analyzing very high resolution ocean model results to assess the impact of these structures on the biological carbon pump.

[Satellite image showing a bloom of phytoplankton shaped by small-scale eddies and filaments in the Indian Ocean (image from NASA Ocean Color).]
JP or ST 1. Earthquake catalogs include many features, including mainshocks, foreshocks, aftershocks, and swarms. These can potentially teach us, for example, about how the properties of the crust vary in space, where faults are “creeping” or “locked”, and how to refine earthquake forecasts (i.e., using foreshocks). But first one must be able to recognize which earthquake belongs in which category, given that catalogs consists only of a string of numbers (earthquake origin time; location; magnitude). Recently, new methods for this classification have been proposed, but it is not clear that these are the best. For a JP or ST, work with high-quality catalogs from California, Japan, or elsewhere, to compare existing classification schemes, devise your own, and compare the results to what is known about the local geology, heat flow, etc.

JP or ST 2. Within the last decade, new styles of fault behavior have been discovered at depth within subduction zones and along the San Andreas fault. Rather than undergoing “stick-slip” (earthquake) behavior or creeping steadily at the plate rate, these regions exhibit “episodic slow slip”, where every year or so the fault speeds up to about 100 times the plate rate, producing the equivalent of a magnitude 6+ earthquake over a period of days to weeks. Simultaneously, they produce a “chatter” that is observed on seismometers but that looks nothing like regular earthquakes. This “tectonic tremor” is a low-amplitude signal, continuous in time for minutes to hours, that lacks clear P-wave and S-wave arrivals but that nonetheless provides us with out best chance of mapping out the progression of slow fault slip at depth, if we can learn to locate it. I have been working with a new method that gives tremor locations beneath southern Vancouver Island that are much more accurate than have been obtained previously. We would like to know if this method works as well in other parts of Cascadia or in Japan, which also have dense seismometer networks. For a JP or ST, get available data from one of these regions and explore.
JP 1. Understanding gas exchange through sea ice using biogeochemical profiling floats
Antarctic sea ice forms seasonally and is highly fractured during different times of the year. The recent deployment of profiling floats that measure dissolved oxygen under sea ice indicates a very strong flux of oxygen through cracks in the seasonal sea ice. However, our understanding of how sea ice coverage impacts air sea gas transfer is limited, with a wide range of parameterizations in the literature. This project would use a unique new data set of biogeochemical tracers on under ice floats to better constrain the impact of fractional sea ice on air-sea exchange. During the winter, respiration of organic matter reduces oxygen, increases nitrate, and increases dissolved inorganic carbon in consistent stoichiometric ratios. By analyzing float data for anomalous oxygen and relating that to satellite-based sea ice coverage estimates we can determine the true gas exchange at that time. Familiarity with Matlab or other programming languages required.

JP or ST 2. Estimation of fluxes of particulate organic carbon in the Southern Ocean from bio-optical sensors on profiling floats**
The Southern Ocean is a region of major biogeochemical relevance, as it exports nutrient elements that sustain around 75% of the biological production north of 30° S. This horizontal export of nutrients towards northern latitudes is constrained by the efficiency of the vertical export of particulate organic material from the surface into the deep ocean. This project aims to estimate fluxes of particulate organic carbon from bio-optical sensors of particle backscattering on profiling floats in the Southern Ocean deployed by the SOCCOM project. Combined with float and model-based information on oxygen and chlorophyll, this study aims to quantify rates of organic matter remineralization and discern the main environmental variables controlling the efficiency of carbon export in the Southern Ocean.
**preferably as JP for Spring 2018, with possible extension into ST

JP or ST 3. Extreme climate events in tropical coral reef habitats
Intense natural climatic variability in the Tropical Pacific exposes coral reefs to episodic events of elevated sea surface temperatures and/or low pH, which adversely affect coral health. The ability of coral reefs to withstand such conditions is dependent upon the intensity, duration and frequency of these extreme events. Earth System Models are a powerful tool for predicting how environmental conditions will evolve over the coming century, providing both changes in mean state (e.g. warming and acidification) and natural variability (e.g. intensity of ENSO events). This project will assess the statistics of extreme events as they relate to biological thresholds in biodiversity hot-spots, such as the Coral Triangle. Familiarity with MatLab required.
Seasonality of upper ocean mixing in the Southern Ocean*

Upper ocean mixing processes are a critical factor for the global surface climate because they determine the exchange of important constituents like carbon, nutrients, and heat between the atmosphere, the upper ocean, and the sub-surface ocean. The Southern Ocean is of particular importance, as seasonal, deep mixing brings old, nutrient-, and carbon-rich waters to the surface and facilitates the subduction of anthropogenic heat and carbon with newly formed water masses. This mixing is induced by a combination of strong surface winds and a low static stability of the water column. This project quantifies and explores the seasonal stratification and de-stratification of the upper Southern Ocean by investigating novel data from profiling floats and surface flux data. Thereby, the student will become familiar with basic oceanographic knowledge, such as the application of the equation of state and the study of mixing processes. Some basic experience with Matlab or similar analysis software is required.

*since the advisor will only be present from early 2018 on, the project would start in Spring 2018*
I am interested in the physical and geochemical evolution of Earth’s crust and mantle and the interaction of the solid Earth with the ocean-atmosphere-biosphere system. My research pulls from methods in geochemistry, geochronology, sedimentology, structural geology and petrology. I run a radiogenic isotope geology lab that specializes in high-precision U-Pb geochronology. A few ideas for projects are listed below, but if you find your interests fall within my broad interests and want to discuss other options, please come see me or send an email.

**JP or ST 1. U-Pb geochronology.** The workhorse of my lab is a Thermal Ionization Mass Spectrometer, which measures isotopic ratios with very high precision. This methodology is the focus of many graduate student theses. And graduate students often need help and love teaching and supervising students in the lab. This work is very time consuming and difficult to learn, but will give you both general and specific skills in a modern geoscience isotope laboratory. These projects change on a yearly basis, so please inquire if this sounds interesting. Juniors will be discouraged from taking on projects with U-Pb geochronology unless they think they’ll also want to do this work senior year.

**JP or ST 2. Application of computational methods to igneous geochemistry.** The availability of geochemical data on online databases is opening doors for development of new computational methods towards problems in geochemistry. There are opportunities to explore applications of “big data” methods to understanding secular evolution of the crust and mantle and/or using big data to see through inherently complex processes to looking at driving forces.

**JP or ST 3. Is volcanic output controlled by surface erosion?** Island arcs are thought to be the building blocks of continents through subduction-accretion to larger continental blocks. The rates and mechanisms by which they are built are controlled by partial melting of the mantle above subducted slabs. The rate of magma production in these zones is purported to be roughly constant, but this poses a problem considering erosion rates of different island arcs should be very different, e.g., in Indonesia compared to Alaska. This project involves compiling data for erosion rates and crustal structure from different island arcs globally and asking the question: can surface erosion and climate control mantle melting?

**JP or ST 4. Understanding the Deccan Basalts, India.** I am part of an ongoing project with Prof. Gerta Keller trying to understand the role that massive volcanism could have played in the Cretaceous-Tertiary mass extinction event ca. 66 Ma (the one that killed the dinos). We are currently carrying out U-Pb geochronology on these basalts and various questions about the formation of datable horizons in the basalts need to be addressed. There are a number of projects that could be tailored to a student’s interest that range from petrology and geochemistry to GIS and geophysical techniques.
ST 5. Applications of field geology and geochemistry/geochronology to Appalachian tectonics. The Appalachians are one of the world’s oldest persisting mountain belts, and record a rich history of continental formation, amalgamation and subsequent destruction. Numerous unanswered questions pertaining to the 1.3 Ga crust and ore-deposit formation and the 200 Ma rifting event can be addressed with field-based projects in the New Jersey highlands and surrounding areas. Such projects involve the enthusiastic assistance of experts on the local geology from the New Jersey Geologic Survey. Juniors: it is nearly required that you begin field-work either the spring of junior year and/or summer before senior year for these projects to work out.

JP or ST 6. What can crystals and bubbles tell us about supereruptions? Supereruptions are gigantic volcanic eruptions (think 1000x Mount St. Helens), the likes of which we have never experienced – the last supereruption was 26.5 ky ago. Just because we haven’t seen one, though, doesn’t mean that one won’t happen again in the future. Consequently, it is critical that we study deposits from past volcanic eruptions – both supereruptions and not-so-supereruptions - to understand how these magmatic systems develop, where they reside in the crust, when and why they ultimately erupt, and if/how they differ from the smaller systems that we know (comparatively) well. To do this, we will investigate microscale features of volcanic deposits to try and understand macroscale magmatic processes. This involves collecting and digging in to 3D x-ray tomographic data on textures (shapes, sizes, distributions) of crystals in rocks and melt inclusions in crystals, geochemical analyses, and numerical and thermodynamic models, to examine questions of magma accumulation and storage. Interested students must have taken or be currently enrolled in Mineralogy and Petrology. (Work will be with Dr. Ayla Pamukcu of the Schoene Research Group).

3D rendering of a melt inclusion inside a quartz crystal. An individual quartz crystal is imaged using 3D propagation phase-contrast x-ray tomography. Image processing allows the size, shape, and position of the melt inclusion and to be quantified. These quantities are used to establish quartz crystallization timescales and growth rates.
JP or ST  1.  **Modern nitrogen cycle.** Biologically available nitrogen is a critical nutrient for the algae and plants that represent the base of all foodwebs, but its inputs, outputs and cycling are poorly understood in many environments, and the global nitrogen budget remains extremely uncertain. The stable isotopic composition of nitrogen and oxygen in bio-available nitrogen compounds is a promising tool for providing an integrative picture of the nitrogen cycle. Apply novel methods developed at Princeton to analyze liquid and solid nitrogen samples collected from the environment. Identify your own field site and collect your own samples, or analyze samples collected by the Sigman group during their fieldwork in the ocean.

JP or ST  2.  **Organic matter trapped in fossils.** The Sigman group has developed methods for studying the isotopic composition of the trace organic matter trapped within the fossils of organisms and micro-organisms. Our focus is on the use of fossils from the ocean (diatoms, foraminifera, stony corals, shark teeth, and others), especially for studying biological, chemical, and physical changes in the ocean over ice age cycles and their role in changing the concentration of carbon dioxide in the atmosphere. Identify your own fossils and questions, or ask for suggestions.

JP or ST  3.  **Dissolved organic N in the ocean.** Dissolved organic nitrogen is a dynamic component of the nitrogen cycle in the surface ocean, yet its composition, origin, and fate are a mystery. Work with water samples from different ocean basins to investigate where dissolved organic nitrogen is produced and destroyed and the role that it plays in supplying nitrogen to upper ocean biology.

JP or ST  4.  **Novel microbiological tools for geochemistry.** Microorganisms can be good chemists. Contribute to the development of new, microbe-based methods for the isotopic analysis of trace quantities of bioavailable nitrogen in the environment. This project requires prior experience in microbiological lab techniques.

JP or ST  5.  **Numerical models of biogeochemistry in the present and past ocean.** Studies of environmental geochemistry and Earth history are aided greatly by the use of numerical models that include the circulation of the ocean. A student with the appropriate background could use one of our spectrum of numerical models or build their own to address key questions regarding the biology, chemistry, and physics of the ocean over Earth history.
Prof. Frederik J. Simons, Room 321B - University Ext. 8-2598  
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**Interests:** Geophysics, geodesy, geomagnetism, seismology; structure and evolution of (planetary) lithospheres; seismic waveform analysis and tomography; topography and gravity anomalies; satellite measurements and inverse problems; oceanic instrumentation; earthquake early-warning studies; wavelet analysis; image analysis; spectral analysis; sea level variation; inferential statistics. You can find my evolving areas of expertise on my webpages, see www.frederik.net

**JP 1.** Come talk to me for ideas. Past Junior Papers with me have been on the analysis of tree rings; the use of localizing basis functions to study geomagnetic satellite data; the analysis of hydrophone records in the oceans; the study of acoustic wave speeds in the oceans; the creation of new computer algorithms for the synthesis of seismograms via normal-mode summation; the influence of earthquakes on the Earth's gravity field over the last three decades; the study of gravity hills in New Jersey using relative gravimetry and GPS positioning; geological mapping of the Venusian lithosphere; and the signals of time-dependent mass redistribution in California as measured by the GRACE satellites. All my projects involve computer programming.

**ST 1.** Come talk to me for ideas. Past Senior Thesis with me have been on normal-mode based calculation of gravitational potential differences due to large earthquakes; the statistical (covariance) structure of topography on Venus and Mars; the precision and accuracy of Global Positioning System augmentation techniques; the signature of growth and decay of the Tibetan ice sheets from time-variable gravity; and the analysis of seismic data recorded by a broadband seismometer located in the basement of Guyot Hall. All my projects involve computer programming.
Research Interests: Biological Oceanography, Microbial Ecology
Ward Lab webpage: http://www.princeton.edu/nitrogen/

JP or ST 1. **Primary production in the ocean.** Measure growth rates of phytoplankton using a new method based on DNA sequencing. Grow *Synechococcus*, the most abundant picocyanobacterium in the world, in culture, measure growth rates using various methods to help in development of the new sequencing method. Optimize culturing conditions, perform sequence analysis.

JP or ST 2. **Diversity of marine bacteria and phytoplankton.** Analyze samples from oceanographic cruises to characterize natural assemblages of phytoplankton or bacteria using molecular biological methods. Quantify different species using quantitative PCR, identify the components of natural assemblages using PCR and gene sequencing, and characterize communities using functional gene microarrays.

JP or ST 3. **Nitrogen cycling in marine environments.** Analyze samples from different oceans to measure rates of N transformations with stable isotopes using mass spectrometry.
I am an environmental microbiologist interested in understanding how microbial metabolism shapes the biogeochemical cycling of major (C, N, H) and minor elements (Fe, Mo, V). Research in my group involves both laboratory and field work and the application of methods from culture based microbiology, molecular biology, and stable isotope geochemistry. Current themes of research are biological nitrogen fixation, trace metal acquisition strategies, and methane cycling.

JP or ST 1. **Molecular ecology of N$_2$ fixing enzymes in model environments.** Photosynthesis in marine and terrestrial ecosystems is constrained by the amount of fixed nitrogen. Biological nitrogen fixation, nature’s solution to increasing the size of the fixed nitrogen pool, is catalyzed by the nitrogenase metalloenzyme, which can occur in forms that contain trace metals Mo, V, or Fe at a key active site position. The environmental distribution, activities, and controls on canonical Mo and alternative V and Fe-based variants of nitrogenase are presently unknown, with implications for N budgets and our understanding of N cycling in past and present systems. In this project, you will apply PCR primers, which target different variants of nitrogenase, to assess metalloenzyme diversity in model environmental samples. These include the hindgut microbial communities of wood feeding termites, cyanolichens, N-rich and N-poor soils and sediments. To understand sequence diversity, you will also measure metal content. A solid understanding of molecular biology is required for this project.

*Left to right. Cyanolichen, wood feeding termite, soils.*
**JP or ST 2.** *Enrichment of N₂ fixers.* The lack of cultured representatives of nitrogen fixers that utilize different forms of nitrogenase stands as a major barrier to our understanding of the key factors that control the use of different variants of the N₂ fixing enzyme. In this project, you will use a modular media approach to enrich for and isolate N₂ fixing microbes under aerobic and anaerobic conditions, in the presence of combinations of key metals (Mo, V, Fe). You will then characterize stable enrichments and isolates using molecular biology and physiological measurements.

*Cultures of anaerobic nitrogen fixing purple bacteria.*

**JP or ST 3.** *Characterization of nitrogen fixation across a eutrophication gradient.* The process of nitrogen fixation is typically used for anabolic metabolism, however culture and field studies in N-rich sediments suggest that fixation can also serve as a redox balancing process, thus aiding in catabolism. In this project, you will measure the amount and form of fixed N in sediment and water samples taken from a eutrophication gradient in Barnegat Bay, NJ as well as help construct inventories of microbial genes using PCR techniques.

*Sampling salt marsh sediments at Barnegat Bay.*
**JP or ST4. Siderophores studies in “wild” Azotobacters.** Azotobacter species are commonly found in soils worldwide. In addition to being able to fix N\textsubscript{2}, Azotobacters are well known to produce multiple suites of siderophores, small metabolites that microbes use to acquire Fe for their metabolism. Previous comparisons of Azotobacter genomes have suggested that the weak siderophore “vibrioferrin” is common in all Azotobacter species, making it part of Azotobacter’s “core” metabolism. In this project, you will enrich and isolate “wild” Azotobacters and assess isolates for (a) the presence of vibrioferrin genes using PCR and cloning approaches and (b) production of vibrioferrin using chromatography.

**JP or ST5. Oxygen and methane cycling.** Can oxygen play a role in enhancing methane production? To understand how oxygen can influence methane production, we have set up incubations of peat, a major source of methane, under variable oxygen concentrations. In this project, you will use molecular biology approaches to assess the diversity of microbes present in different treatments and their functional capacities, with the broader goal of relating molecular data to methane production rates. You will also have the opportunity to set up additional incubations with other types of plant material.

These are examples of projects that can be adapted for JP or ST levels. If you have other projects in mind that are broadly related to research in my group, please contact me to set up a meeting.
Associated Scientists

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JP or ST  Both junior paper and senior thesis projects may be arranged, using the collections and field research projects of the New Jersey State Museum. Past projects have included both vertebrate and invertebrate paleontology, most frequently in New Jersey (Cambrian-Pleistocene), but also in the marine Cretaceous of South Dakota, and the terrestrial Cretaceous of the Bighorn Basin of Montana and Wyoming, all of which are traditional field expedition areas of Princeton University.