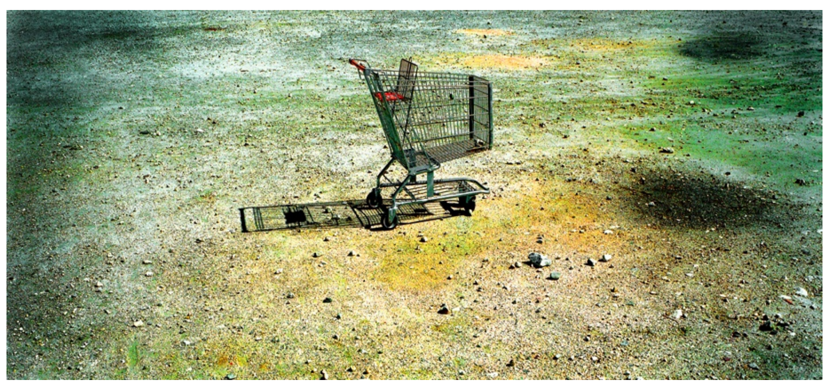
Department of Geosciences
Guyot Hall
JUNIOR INDEPENDENT WORK / SENIOR THESIS
SHOPPING GUIDE

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**

WHATEVER YOUR CHOICE
CHECK OUT THE GEOSCIENCES SHOPPING GUIDE FOR IDEAS

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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.

Prof. Thomas Duffy, Room 218 - University Ext. 8-6769
E-mail: duffy@princeton.edu

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 **Data-driven 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. Elastic properties and sound velocities are among the most important mineral properties and are essential for interpretation of seismic data. We have constructed a database of mineral single-crystal elastic properties comprising the results of nearly 500 measurements on more than 200 different compositions. This compilation can be used to explore data-driven materials discovery. Possible questions to be addressed: How well do existing data describe the compositional variation of sound velocity in important multi-component systems such as garnets? What are the best metrics for characterizing the elastic anisotropy of minerals?

Requirement: Linear algebra.

JP or ST **Shock Compression of Minerals**

In laboratory shock wave experiments, minerals are subjected to very high pressures and temperatures on microsecond time scales. Such experiments are relevant to understanding planetary accretion processes, shock metamorphism, and high-pressure phases of planetary interiors. Interpretation of shock wave data requires careful comparison with measurements under static high-pressure conditions. In this project, you will use new high-pressure experimental data on selected minerals to infer the nature of structures formed under the very high pressure-temperature conditions of shock compression.

Prof. John Higgins, Room 212, Guyot Hall, University Ext. 8-7024
E-mail: jahiggin@princeton.edu

JP 1. What drove Earth's largest $\delta^{13}C$ excursion?

The largest perturbation to the carbon cycle in Earth history, as measured by the stable carbon isotopic composition ($\delta^{13}C$) 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 and 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 O_2 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 ($^{87}Sr/^{86}Sr$) from the Wonoka Formation. The $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ 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 CO_2 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 CO_2 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.

Prof. Adam Maloof, Room 215/213 – University Ext. 8-2844
E-mail: maloof@princeton.edu

I am a field geologist studying Earth history and the limits of global change. My current work involves using modern landscapes and ancient sedimentary rocks to extract information about the coevolution of life and climate.

JP or ST 1. How is climate recorded in the geometry of dendritic channel networks?
Erosional stream networks have fractal branching patterns. The distribution of stream lengths and/or branch angles may be controlled by climate. This project will use available online stream network data and climate indices to test the idea that you can infer something about climate by looking at the geometry of river networks. If one can define such a relationship on Earth, channels on planetary bodies (e.g., Mars, Titan could become useful probes of extraterrestrial climates.

JP or ST 2. The extinction of the Dinosaurs recorded in a Bolivian lake
Sediments from an ancient lake currently outcrop in the Bolivian Altiplano. Radiometric dates from volcanic ash that fell in the lake suggest that the Cretaceous-Paleogene (K-Pg) boundary is preserved somewhere in this stratigraphy. The debate rages about the exact cause of the mass extinction, and few studies have examined the forensics from a restricted lake environment. Your project is to find the K-Pg boundary, using a combination of geophysical and geochemical measurements on samples we have in the lab, and to see if this unique paleolacustrine environment tells us something new about the causes of dinosaur demise. Your work on campus could lead to field research in Bolivia.

JP or ST 3. How do modern carbonates record information about sea water chemistry?
Virtually everything we know about ancient climate history comes from shallow water carbonates (e.g., Bahamas-like environments). However, because we have higher fidelity records of more recent climate change, such as ice cores and deep water fossiliferous sediment, little work has been done to calibrate our understanding of how shallow-water carbonates record changes in climate. In this project, you will work with 3D imagery and samples from the Bahamas or Western Australia to develop an understanding of the patterns in geochemical variability in modern shallow water carbonates. Your data will help you zero-in on the causes of geochemical variability and to sort out changes related to global seawater chemistry versus local processes.

JP or ST 4. A new climate record from Grottes de Bétharram, France
Stalagmites in caves preserve high fidelity records from at least the last half-million years. We collected a suite of beautifully laminated stalagmites from a privately owned cave in France are begging to be studied. Your analyses will include layer-counting (like tree rings), scanning x-ray fluorescence, and carbon and oxygen isotopes. Your goal will be to calibrate recent physical and geochemical patterns to one-hundred years of nearby weather date, and then to use that understanding to build a longer climate record for the Pyrenees.

Prof. Satish Myneni, Room M51 – University Ext. 8-5848
E-mail: smyneni@princeton.edu

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.

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. CO_2 reactions with geologic media.
The focus is on the influence of elevated atmospheric- and soil/sediment-CO_2 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).

Prof. T.C. Onstott, Room B-79 - University Ext. 8-7678
Email: tullis@princeton.edu

Microbiology and Biogeochemistry of Arsenic, the Arctic, the Antarctic, the Deep Subsurface and Mars

JP 1. **Enzymatic Signatures of Biological Methanogenesis in Simulated Martian Subsurface Conditions.** A growing body of evidence has unfolded to suggest episodic appearances (and disappearances) of ppbv-level CH_4 in the Martian atmosphere. Such gases may be biomarkers for subsurface life, as 95% of CH_4 on Earth is of biotic origin. A previous ST has demonstrated the ability of the permafrost methanogen *Methanosarcina soligelidi* to produce CH_4 down to Martian atmospheric pressures. Follow-up research investigating the related lineage *Methanosarcina barkeri* has also shown CH_4 production at 0˚C and in the presence of perchlorates – strong oxidants with low eutectic points initially discovered by the *Phoenix* lander. A JP would involve utilizing bioinformatics to analyze transcriptomes (gene expression profiles) generated from RNA recently extracted and sequenced from these *M. barkeri* cultures, with the goal of determining how *M. barkeri* enzymatically responds to the harsh simulated conditions of subsurface Mars.

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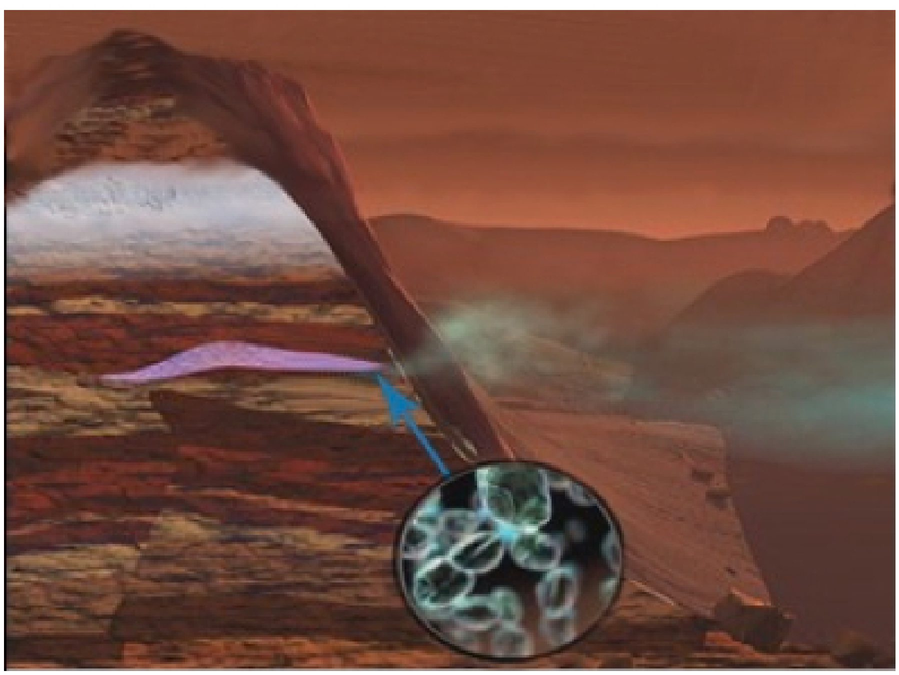
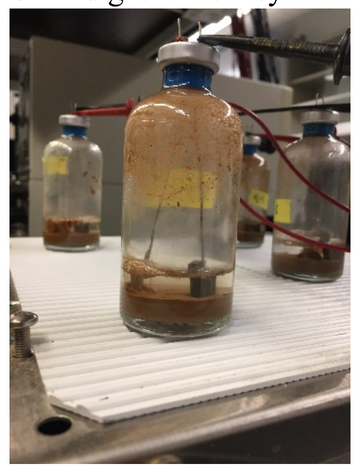


NASA cartoon of hypothetical Martian CH_4 seeps into the atmosphere.

JP 2 or ST 1. Cathodic Shielding of Pipelines, Electron Eating Microbes and Stimulation of Arsenic Cycling

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 H_2 gas, while decreasing the O_2 and increase the pH around the pipelines while reducing corrosion. These conditions could stimulate the growth of anaerobic bacteria that mobilize arsenic. Will the operation of the gas pipelines increase arsenic contamination in the groundwater near the pipelines? The JP project second involves reproducing the cathodic shield in the lab using galvanic microcosm experiments with soil and groundwater and measuring the arsenic, gas chemistry, cell counts and DNA over time. An ST would do the same but also look at the metagenome of the samples to determine how microbial communities changed under the cathodic currents.



Galvanic microcosms using DC current electrodes, soil and water.

ST 3. 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 will be collected from Svalbard and subjected to short term microcosm and long-term thawing experiments. The cores will be analyzed using metagenomics during the thawing experiment while measuring the flux of CH_4 and CO_2. A senior thesis would involve analyses of existing metagenomic data sets from Svalbard with the goal of obtaining draft genomes of other bacteria and determining their role in the cycling of carbon and nitrogen during permafrost thawing.

JP 3 or ST 4. The Hot Springs of the Chilean Northern Altiplano: A Terrestrial Analog for Early Mars. The geothermal hot springs located in the Andes of northern

Graduate student Zachary Garvin collecting soil samples around the Polloquere Hot Spring in the Salar de Surire salt flats of the Andean Altiplano, northern Chile.

Chile represent environments of many extreme conditions. The region is surrounded by sulfurous volcanic formations and is characterized by extremely low temperatures, limited precipitation, and the highest UV flux on the planet. As a result, the springs and surrounding soils resemble the arid, saline, geothermal environments that may have existed on the surface of early Mars. Initial analyses have uncovered evidence for microbes within the spring soils feeding on atmospheric trace gases despite showing extremely low biomass and degraded DNA. As part of a NASA-funded expedition, a JP or Senior thesis would examine the microbiology of these soils around the hot springs to determine whether microorganisms are surviving from the gases released by the hot springs versus those that rely upon photosynthesis. The student would learn how to cultivate microorganisms, use gas chromatographs (GCs) for gas analyses, extract DNA/RNA for molecular sequencing, and perform a variety of bioinformatic techniques for characterizing the microbial communities. Comparisons to Mars geological features and how the data constrains the search for extant life can also be pursued.

JP 4 or ST 5. 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 a large fraction of 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?

Graduate student Cara Magnabosco (GEO) and senior Melody Lindsay (EEB) were collecting in situ geochemical data and molecular samples at Beatrix Gold Mine (1.3 km below surface).

This project will focus on questions 3, 4 and 5 by analyzing metagenomic sequences from and performing geochemical and isotopic analyses of samples recently collected from deep fractures in South Africa that contain ancient brine. A JP or ST project would involve extracting DNA, sequencing DNA and using binning approaches to draft genomes to determine the physiological potential, 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 Moab Khotsong gold mine in South Africa for fieldwork at several kilometers beneath the Earth's surface where scientists are drilling into an active fault zone.

Prof. Michael Oppenheimer - University Ext. 8-2338 - 448 Robertson Hall
E-mail: omichael@princeton.edu

****Prof. Oppenheimer is currently not accepting any Junior Projects**

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.

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.

Prof. Laure Resplandy, Room 418B - University Ext. 8-9017
E-mail: laurer@princeton.edu

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. Ocean de-oxygenation and coastal dead zones

A serious threat from global warming is the loss of dissolved oxygen in the world's ocean and the expansion of oxygen minimum zones (OMZs), where vanishingly low oxygen levels threaten marine life. In coastal areas, anthropogenic activities (waste waters, urbanization, fertilizers etc.) exacerbate the effect of warming and can trigger coastal hypoxia events or "dead zones" associated with mass mortality of marine organisms and severe collapse of local fisheries. The tropical Indian Ocean is at greater risk of coastal dead zones in the near future because of the combined effect of OMZ expansion and rapidly growing population. This project would aim at identifying coastal dead zones in the tropical Indian Ocean leveraging published observations in the literature and analyze the physical and biological conditions that led to these events.

JP or ST 2. Biological pump in the Pacific Ocean

The ocean biological pump removes carbon from the atmosphere and exports it to the deep sea. In the Pacific Ocean, the biological pump is modulated by numerous processes, such as the ocean large-scale circulation, smaller-scale structures like eddies and filaments and the strong year-to-year variations of the El Nino Southern Oscillation (ENSO) or the atmospheric warm 'Blob'. This project involves studying how the biological pump changes in response to these processes that vary on seasonal and year-to-year time-scales, using available observations published in the literature.

Prof. Allan Rubin, Room 319 - University Ext. 8-1506
E-mail: arubin@princeton.edu

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 our 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.

Prof. Blair Schoene, Room 219 - University Ext. 8-5747
E-mail: bschoene@princeton.edu

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.

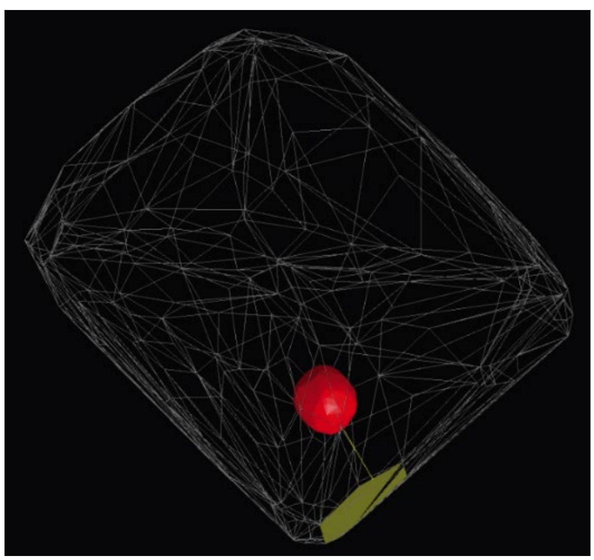
JP or ST 2. **Application of computational methods to igneous geochemistry.** The availability of geochemical data on online databases is opening doors for development of new computational methods towards problems in geochemistry. There are opportunities to explore applications of "big data" methods 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.



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 processingallows 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.

Prof. Daniel Sigman, Room M52 - University Ext. 8-2194
E-mail: sigman@princeton.edu

Website: http://www.princeton.edu/sigman

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
E-mail: fjsimons@princeton.edu

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; the signals of time-dependent mass redistribution in California as measured by the GRACE satellites; a reproducibility study of magnetometry with data collected in the field; the development of a software package for the analysis of cyclicity in outcrop photographs; numerical experiments on the recovery of harmonic components in the Jovian gravity field; evaluating precipitation algorithms in landscape evolution modeling; bathymetric analysis to evaluate geopolitical claims in the South China Sea; oceanic float coarse prediction using historic trajectory data. *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; a study of underground hydrocarbon pipelines in the US and their relationship to groundwater arsenic. *All my projects involve computer programming.*

Prof. Bess Ward, Room 217 - University Ext. 8-5150
E-mail: bbw@princeton.edu

Research Interests: Biological and Chemical Oceanography, Microbial Ecology
Ward Lab webpage: http://www.princeton.edu/nitrogen/

JP or ST 1. **Diversity, distribution and function 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, use metagenomics to investigate relationships among phytoplankton and parasites.

JP or ST 2. **Nitrogen cycling in marine environments.** Analyze samples from the oceans to measure rates of N transformations with stable isotopes using mass spectrometry. Projects concern marine sources and sinks for nitrous oxide, nitrogen transformations in low oxygen waters, nitrogen fixation, etc. Learn to use the mass spectrometer to analyze samples from a research cruise in Chesapeake Bay.

JP or ST 3. **Nitrous oxide flux from the ocean.** Develop and expand big data sets on nitrous oxide in coastal waters. Use the database to investigate the contribution of coastal systems (estuaries) to the global atmospheric flux of this important greenhouse gas.

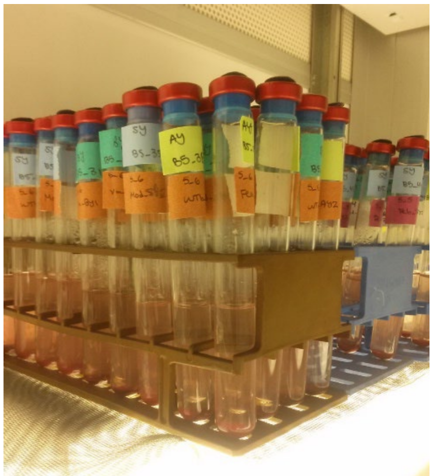
Prof. Xinning Zhang, Room M47 – University Ext. 8-2489
Email: xinningz@princeton.edu

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 N_2 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 N_2 fixing enzyme. In this project, you will use a modular media approach to enrich for and isolate N_2 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_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.

JP or ST6. *Marine geochemistry in the Eastern Tropical North Pacific*

OMZs are microbially diverse regions that play a large role in the ocean's nitrogen budget. These regions are strongly coupled to the global climate system and are predicted to expand with future warming. The aim of this project is to test the effect of environmental gradients and community metabolism on C:N, $\delta^{13}C_{biomass}$, and $\delta^{15}N_{biomass}$ in suspended particles in the Eastern Tropical North Pacific. During a spring 2018 research expedition large (0.7-53 μm) and small (0.3-0.7 μm) suspended particles were collected from surface waters along a north-south transect as well as surface waters and deeper suboxic waters along an east-west transect. The effect of size fractionation has not yet been tested in suspended particle bulk isotopes for this region, but previous compound specific isotope analysis indicates that different size fractions are biologically (and thus geochemically) distinct. This project will give you the opportunity to learn how to handle oceanographic underway data, prepare samples for geochemical analysis, and use equipment to measure element and isotope abundance.

JP or ST7. *2019 Campus as a Lab project: Characterizing microbial communities in aerobic biodigestor compost to improve plant growth and limit greenhouse gas emissions*

As part of Princeton University's efforts to reach sustainability and educational goals, food scraps from dining facilities on campus have been composted since Fall 2018 using a commercial onsite aerobic digestor. However, major questions remain on how the microbial decomposition process within the biodigestor system can be optimized with respect to input waste material composition and aeration programming, to yield compost that enhances plant growth while limiting greenhouse emissions of carbon dioxide, methane, and nitrous oxide from compost during its creation and once applied in the field. The JP/ST student will monitor the microbial community using 16S ribosomal gene sequences and biodigestor gas composition using gas chromatography throughout digestion under different treatments (varied mixtures of food waste/bulking carbon and aeration programs). The results will provide much needed information to help the Campus biodigestor project improve its operations and also reveal mechanistic insights on the microbial and physical processes that control soil carbon storage.

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

David Parris - Paleontological Staff, NJ State Museum, Trenton
E-mail: David.Parris@sos.nj.gov
Telephone: (609) 984-3846, FAX: (609) 292-7636

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.