

The Earth Explorers

The Department of Geosciences, Princeton University

Specializations in Microbiology, Environmental Geochemistry, Oceans, Atmosphere, & Climate,
Geology & Earth History, and Geophysics





*(Above) Al Robert Nazarian *18 and Margaret Lynch '21 collect a water sample from Great Bay in southern New Jersey. Physical, biological and chemical analyses were performed on samples from several locations and depths within the estuary. Photo courtesy of Robert Nazarian *18 (GEO 202)*

(Right) Students investigate the chemical, structural and thermal influences on basalt fields in New Mexico. Photo by Blair Schoene (GEO 372)



(Cover) Field team scouts out potential outcrops near Challu Mayu, Bolivia on a joint undergraduate/graduate student field trip. Photo by GS Ryan Manzuk

Introduction to Geosciences



Students practice their best tiger impressions on a GEO203 Fundamentals of Solid Earth Science field trip to the Delaware Water Gap. Photo by GS Ian Ocampo (GEO 203)

The field of geosciences is central to many of the most pressing issues of today's world: Earth resources and energy, natural hazards, human/environment interaction, and climate change. Through diverse coursework, small class sizes, and strong field and laboratory programs, the Department of Geosciences empowers students to understand how Earth works and how to solve real-world problems.

Undergraduates studying geosciences often pursue careers in basic research, the energy industry, and education. Geosciences also provides a foundation for careers in applied research, environmental consulting, engineering, public policy, conservation, resource economics, environmental education, and general consulting.

Program Information: and Departmental Plan of Study

The intellectual excitement of modern geosciences is fueled by our exploration of the dynamic forces and delicate balances that mold our planet and have rendered it conducive to life for much of its history. Our landscape is continually reshaped by the movement of cold continents atop the hot, viscous mantle, and our lives are altered by the earthquakes and volcanic eruptions that accompany their collision. Rocks that cover the Earth's surface sink to great depths and transform under enormous temperatures and pressures, perhaps to be uplifted as mountains and exposed to future generations by the forces of erosion. The ocean and atmosphere engage in a continuous and complex dialogue that controls Earth's climate. Chemical reactions operating within microorganisms and on a variety of mineral and other natural surfaces are integrated into large geochemical fluxes, which distribute the resources needed for life, and life in turn alters these fluxes. This process operates within the framework of biological evolution, in which diverse organisms appear, evolve, and vanish, sometimes leaving a transfigured world in their wake. All of these processes influence our daily lives in profound and surprising ways.

Many of the great challenges to humanity, today and in the future, involve processes that are studied by Earth scientists, leading to a rapidly increasing role for the field in issues of environmental regulation and public policy. A background in the Earth sciences is an essential component of contemporary education. Practicing geoscientists study nature both in the field and in the lab. To an ever-increasing degree, they must quantify observations with the aim of not only describing the past but also of predicting the future of our planet, often with the aid of rigorous laboratory and field experiments, and intensive computation and modeling. The diversity of processes that characterize Earth as a whole requires geosciences to be an extraordinarily interdisciplinary field with direct connections to mathematics, physics, chemistry, biology, and computer science. As a result of these connections, the Geosciences Department frequently draws students from many backgrounds. Many of our most successful graduates begin their undergraduate careers in subjects ranging from physics to English.

The Department of Geosciences welcomes this intellectual variety, and our undergraduate program allows flexibility while stressing the importance of a sound understanding of the basic sciences.

Visit our website at:
geosciences.princeton.edu



Professor Adam Maloof at the Pompeii Archaeological Site, discussing the finer points of stratigraphy with students in FRS161. Photo by Prof. Frederik Simons (FRS)



James Trailie '19 presents his documentary film "Seismology" in Taylor Auditorium, a full-size cinema in the Frick Chemistry Laboratory, during the 2019 PEI Discovery Day. The video is available at geosciences.princeton.edu/research/geophysics

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Geosciences Requirements

Prerequisites: (See table on page 5)

1a) Three prerequisite requirements for entering the concentration (**MAT 104** or **AP credit**, **COS 126**, and either **GEO 202** or **GEO 203**)

Students should elect **GEO 202** or **GEO 203** with an eye toward their likely track of study. Students who need to take the other course for their specialization may count the course used as a prerequisite as an elective (in #5, below).

1b) With permission of the Director of Undergraduate Studies (DUS), a student can substitute **GEO 102** or **GEO 103**, a Geosciences Freshman Seminar, or certain Geosciences 300/400 level courses for **GEO 202** or **GEO 203**.

General Requirements:

The following courses are required for graduation (with at most one pass/D/fail). AP credit may be used to place into a more advanced math or science course.

2) One statistics requirement, to be completed by the end of the junior year (**GEO 422** or **ORF 245**).

3) Four required core math and science courses that vary depending on the chosen specialization. **ISC 231-234** and/or **AP credit** may substitute for some of these courses. Students interested in graduate school are encouraged to take more than these minimum basic science requirements.

Departmental Requirements:

4) Two core geoscience requirements that vary depending on the chosen specialization.

5) Five elective 300/400 level geosciences courses.

There are five department specializations: Microbiology (**MB**), Environmental Geochemistry (**EG**), Oceans, Atmosphere, & Climate (**OA**), Geology & Earth History (**GE**), and Geophysics (**GP**). Each specialization has a different set of prerequisites (**1,2**), basic science requirements (**3**), geoscience core requirements (**4**) & recommended electives (**5**) as described in the chart on page 5.

Students are urged to consult with the DUS or a member of the Undergraduate Work Committee before choosing hybrid specializations or pursuing specialization-electives outside of geosciences. In general, the department is flexible about course selections and requirements; however, we must ensure a degree of coherency in each student's course of study.

Junior Colloquium is a weekly luncheon meeting, convened during the fall term, to teach Juniors basic techniques in proposal writing and analytical computing. This one-hour colloquium is mandatory for all geosciences concentrators (including those in the geological engineering program).

Certificate Programs:

The Department offers a certificate program in geological engineering in collaboration with the Department of Civil and Environmental Engineering, which is described in the entry for the Program in Geological Engineering. The Department also collaborates with the certificate programs in Environmental Studies (PEI), Materials Science and Engineering (MSE), Planets and Life, and Teacher Preparation. Several geosciences courses fulfill requirements of these certificate programs.

All students considering a concentration in the Department should see the departmental representative. They are encouraged to consult as soon as possible, even as first-year students, to aid in the design of a course of study. The Department offers an open house in both the fall and spring terms to introduce prospective students to departmental courses, faculty, students, and research interests.

Geoscience Advisers:

At the beginning of each academic year, each geosciences junior and senior is assigned an adviser, who is a faculty member and part of the Undergraduate Work Committee. Students are expected to regularly meet with their advisers for discussions on curriculum, course selection, choice of junior and senior research paper topics, study abroad plans, and the like. Once the courses have been selected in consultation with advisers, students turn in their signed fall and spring course worksheet to the undergraduate coordinator. Any course changes should also be discussed and approved by the adviser or the undergraduate chair.

Visit our website to read more about required Independent Work, Grading and Honors and additional information in the Geosciences:
geosciences.princeton.edu/undergraduate/programs-of-study

Departmental Specialization

	MICROBIOLOGY (MB)	ENVIRONMENTAL GEOCHEMISTRY (EG)	OCEANS, ATMO-SPHERE, & CLIMATE (OA)	GEOLOGY & EARTH HISTORY (GE)	GEOPHYSICS (GP)
To declare concentration sophomore year	MAT 104	MAT 104	MAT 104	MAT 104	MAT 104
To declare concentration sophomore year	COS 126	COS 126	COS 126	COS 126	COS 126
To declare concentration sophomore year	GEO 202	GEO 202	GEO 202	GEO 203	GEO 203
By end of junior year	GEO 422 or ORF 245	GEO 422 or ORF 245	GEO 422 or ORF 245	GEO 422 or ORF 245	GEO 422 or ORF 245
Required Core Math and Science	EEB 211	MOL 214	MAT 201	MAT 202	MAT 201
Required Core Math and Science	MOL 214	CHM 201	MAT 202	CHM 201	MAT 202
Required Core Math and Science	CHM 201	CHM 202	CHM 201	CHM 202	PHY 103 or 105
Required Core Math and Science	CHM 202	PHY 103	PHY 103	PHY 103	PHY 104 or 106
Required Core Geoscience	GEO 363	GEO 363	GEO 361	GEO 362	GEO 371 or 442
Required Core Geoscience	GEO 417	GEO 360	GEO 425	GEO 464	MAE 305
Recommended Electives	GEO 362	GEO 361	GEO 362	GEO 378	GEO 419
Recommended Electives	GEO 416	GEO 370	GEO 363	GEO 372	GEO 424
Recommended Electives	GEO 418	GEO 417	GEO 366	GEO 370	GEO 441
Recommended Electives	GEO 428	GEO 418	GEO 367	GEO 373	GEO 422
Recommended Electives	MOL 345	GEO 428	GEO 368	GEO 202	GEO 464
Recommended Electives	MOL 380	GEO 470	GEO 427	FRS	GEO 370
Recommended Electives		FRS	GEO 428	MAE 305	GEO 202
Recommended Electives		CHM 301	GEO 203	MAE 221	FRS
Recommended Electives		CEE 311	FRS		
Recommended Electives		CEE 306/307	MAE 305		
Recommended Electives		CEE 471			

Curriculum: Introductory Courses

FRESHMAN SEMINAR

How have Earth and human histories been recorded in the geology of Princeton, the Catskills, Cyprus, Italy and other locales, and what experiments can you do to query such archives of the past? This seminar provides students with practical experience making geological and geophysical observations designed to shed light on the interplay between cycles, shifts and noise, tectonics, climate, and weather. A one-week field trip is mandatory. (Maloof, Simons)

GEO 102A (without lab) & 102B (with lab) - CLIMATE: PAST, PRESENT & FUTURE (ENV, STC)

Which human activities are changing our climate, and does climate change constitute a significant problem? This course investigates these questions through an introduction to climate processes, an exploration of climate from the distant past to today, and consideration of the implications of climate change for the global environment and humans. Intended to be accessible to students not concentrating in science or engineering. (Sigman)

Ground-truthing a forest fire burn site in Utah for calibration of drone imagery. Photo by Akshay Mehra '19 (GEO 201)

GEO 103 - NATURAL DISASTERS

This course examines natural (and some society-induced) hazards and the importance of public understanding of related issues. Learn about the geological processes that underlie hazards, and discuss policy implications. Topics include earthquakes, volcanoes, landslides, tsunamis, hurricanes, floods, meteorite impacts, and global warming. A weekly laboratory is required. Intended primarily for non-science majors. (Rubin)

Field trips will resume after COVID-19 related restrictions are lifted.



Sisi Peng '19 samples a local stream during a summer internship with the Myneni Lab. Photo by Marah Sakkal '20



Ayame Whitfield '20 measures the orientation of aeolian cross bedding to determine which way ancient winds blew in coastal France. Photo by Sierra Castaneda '20 (FRS)



GEO 202 - OCEAN, ATMOSPHERE & CLIMATE

The ocean and the atmosphere control Earth's climate, and in turn climate and atmospheric changes influence the ocean. This course explores what sets the temperature of Earth's atmosphere and the connections between oceanic and atmospheric circulations including exchanges of heat and carbon. It also investigates how these circulations control marine ecosystems and the cycling of chemicals in the ocean. The final part of the course focuses on human impacts, including changes in coastal environments and the acidification resulting from increased atmospheric carbon dioxide. (Resplandy)

GEO 203 - FUNDAMENTALS OF SOLID EARTH SCIENCE (ENE)

A quantitative introduction to solid Earth system science, focusing on the underlying physical and chemical processes and their geological and geophysical expression. The course investigates the Earth starting from its accretion, differentiation, and evolution, and discusses how these processes create and sustain habitable conditions. Topics include nucleosynthesis, planetary thermodynamics, plate tectonics, seismology, geomagnetism, petrology, sedimentology and the global carbon cycle. Includes a field trip. (Staff)



Students in FRS161 at the Convento SS Ecce Homo in Mesoraca, Italy preparing soil samples from the Enotre olive grove for acidity analysis. Standing tall in the background is course Al Bolton Howes, graduate student.. Photo by Prof. Frederik Simons



GS Bolton Howes, Galen Cadley '22 and GS Ryan Manzuk investigate Earth's first reefs built by animals, Ketzka River Mine, Yukon. Photo by Prof. Adam Maloof



Soil sampling for analysis in the Myneni Lab during a summer internship. Photo by Marah Sakkal '20

Field trips will resume after COVID-19 related restrictions are lifted.

Intermediate Courses



Department members hike through the geothermally altered landscape at Hveragerð, Iceland.
Photo by Prof. Satish Myneni

GEO 360 - EARTH'S ATMOSPHERE (ENV)

Humans have profoundly altered the chemistry of Earth's air, water, and soil. This course explores these changes with an emphasis on the analytical techniques used to measure the human impact. Topics include the accumulation of greenhouse gases (CO_2 and CH_4) in Earth's atmosphere and the contamination of drinking water at the tap and in the ground. Students will get hands-on training in mass spectrometry and spectroscopy to determine the chemical composition of air, water, and soil, and will participate in an outreach project providing chemical analysis of urban tap waters to residents of Trenton, New Jersey. (Higgins)

GEO 361 - EARTH'S ATMOSPHERE (ENV, CEE)

This class discusses fundamental aspects of Earth's climate with a focus on the fundamental atmospheric processes that render Earth "habitable," and how they may respond to the forcing from natural (such as volcanoes) and anthropogenic (such as emission of carbon dioxide and ozone-depleting gases) processes. (Fueglistaler)

GEO 362 - EARTH'S HISTORY (ENV)

We are the product of 4+ billion years of geological, chemical, and biological evolution in a thin veneer on the surface of a rocky planet ~150 million kilometers from a mid-life main sequence star. This course seeks to understand the 'how' of Earth history by integrating many branches of Earth system science including geochronology, paleomagnetism, tectonics, petrology, paleoclimate, sedimentology, geochemistry, and geobiology. Through a detailed study of the relevant datasets, models, and theories students in this course will engage and struggle with these seemingly disparate fields to arrive at a better understanding of how an imperfect geologic record can be used to produce an accurate reconstruction of our planet's history. (Higgins, Schoene)

GEO 363 - ENVIRONMENTAL GEOCHEMISTRY: CHEMISTRY OF THE NATURAL SYSTEMS (CHM, ENV)

The interaction between atmosphere and continent; special emphasis on atomic theory, chemical bonding, crystal chemistry, reaction equilibrium, and chemistry of soils, oceans and the atmosphere. (Myneni)

GEO 366 - CLIMATE CHANGE: IMPACTS, ADAPTATION, POLICY (ENV, SPI, ENE)

An exploration of the potential consequences of human-induced climate change and their implications for policy responses, focusing on risks to people, societies, and ecosystems. (Oppenheimer)

ENV 367 / GEO 367 - MODELING THE EARTH SYSTEM: ASSESSING STRATEGIES FOR MITIGATING CLIMATE CHANGE

This course is an introduction to earth system modeling for students interested in global environmental issues. Students will use a "compact" or "reduced" Earth system model, including the ocean, the land and the atmosphere, to examine how the system responds to human activities and natural climate variations. They will design mitigation scenarios, test their impact using the model and analyze and discuss their results. This course is designed to give students a critical thinking about climate models, their strengths and their limitations. (Resplandy)

ENV 354 / GEO 368 - CLIMATE AND WEATHER: ORDER IN THE CHAOS

This course focuses on the relationship between climate and weather events: each weather event is unique and not predictable more than a few days in advance, large-scale factors constrain the statistics of weather events, those statistics are climate. Various climatic aspects will be explored, such as the geographic constraints, energy and water cycling, and oceanic and atmospheric circulation, solar heating, the El Niño phenomenon, ice ages, and greenhouse gases. These climate features will be used to interpret the statistics of a number of weather events, including heat waves, tropical cyclones (hurricanes and typhoons) and floods. (Vecchi)

GEO 370 - SEDIMENTOLOGY (ENV, CEE)

The physics and chemistry of the Earth surface processes that generate, transport, and deposit sediments; emphasis is on the interpretation of sedimentary records of modern and ancient environmental change. (Malooof)

GEO 371 - GLOBAL GEOPHYSICS (PHY)

An introduction to global geophysics. Topics include Earth's shape, gravitational and magnetic field, seismology, and geodynamics. (Simons)

GEO 372 - ROCKS

An introduction to the processes that govern the distribution of different rocks and minerals in the Earth. Learn to make observations from the microscopic to continental scale and relate these to theoretical and empirical thermodynamics. The goal is to understand the chemical, structural, and thermal influences on rock and mineral formation and how this in turn influences the plate tectonic evolution of our planet. Includes local and extended field trips. (Schoene)

Testimonial from Adrian Tasisto-Hart '17

*"Joining the Department of Geosciences was one of the most fulfilling decisions I made at Princeton — academically, socially, and for my own personal growth. **I was able to combine my interests in physics, chemistry, math, and computer science in an interdisciplinary fashion, both in a flexible curriculum and also in my own research.** I had incredible support and freedom for planning my independent work, which additionally allowed me to travel across the world, with destinations ranging from Utah to Bolivia. Facilitated by small classes and social events like weekly departmental tea times, I met many of my closest friends in the Department. These close relationships, along with a collaborative environment, fostered my growth intellectually and also inspired me and others to plan events like a department field trip to Iceland. I'll never forget my time in the Department, and, looking forward, I realize that the knowledge I gained has opened many doors for me."*



GEO 373 - STRUCTURAL GEOLOGY

An introduction to the physics and geometry of brittle and ductile deformation in Earth's crust. Deformation is considered at scales from atomic to continental, in the context of mountain building, rifting, and the origin of topography. (Schoene)

GEO 378 - MINERALOGY (MSE)

A survey of the structure and crystal chemistry of major rock-forming minerals. Topics include: symmetry, crystallography, physical and chemical properties of minerals, mineral thermodynamics, systematic mineralogy, and techniques of modern mineralogy. Includes a weekly laboratory and a one-day field trip. (Duffy)



A portable weather station at a field site on the coast of Zumaia, Spain. Photo by Liam O'Connor '20 (FRS)

Field trips will resume after COVID-19 related restrictions are lifted.

Advanced Courses

GEO 416 - MICROBIAL LIFE - A GEOBIOLOGICAL VIEW (ENV)

Microbes were the first life forms on Earth and are the most abundant life forms today. Their metabolisms underpin the cycling of carbon, nitrogen, and other important elements through Earth systems. This course will cover the fundamentals of microbial physiology and ecology and examine how microbial activities have shaped modern and ancient environments, with the goal of illustrating the profound influence of microbial life on our planet for over 3 billion years. (Zhang)

GEO 417 - ENVIRONMENTAL MICROBIOLOGY (CEE, EEB)

The role of bacteria in elemental cycles, in soil, sediment, and marine and freshwater communities, and in bioremediation and chemical transformations. (Ward)

GEO 418 - ENVIRONMENTAL AQUEOUS GEOCHEMISTRY (CHM)

Application of quantitative chemical principles to the study of natural waters; equilibrium computations, weathering processes, precipitation of chemical sediments, and water pollution. (Morel-Kraepiel)

GEO 419 - PHYSICS AND CHEMISTRY OF EARTH'S INTERIOR (PHY) Physics and chemistry of Earth materials and the nature of dynamic processes in Earth's interior. (Duffy)

GEO 422 - DATA, MODELS & UNCERTAINTY

An introduction to data analysis and interpretation in the natural sciences. Topics include statistics, time series analysis, and matrix-based inverse theory. (Simons)

GEO 424 - SEISMOLOGY (CEE, ENE)

Basic concepts in seismology. Topics covered: theories of wave propagation in the earth, instrumentation, Earth's structure and tomography, theory of the seismic source, physics of earthquakes, and seismic hazard assessment. Emphasis will be placed on how quantitative mathematical and physical methods are used to understand complex natural processes, such as earthquakes. (Tromp)

GEO 425 - INTRODUCTION TO OCEAN PHYSICS FOR CLIMATE (MAE)

Detailed examination of thermohaline and wind-driven circulation and the ocean as a major influence on the atmosphere and global environment. (Vecchi)

GEO 427 - FUNDAMENTALS OF EARTH'S CLIMATE SYSTEM (CEE, ENV)

This class provides an overview of the broad factors that determine our current climate, as well as past and future climates. The focus is on Earth's energy and water cycles, the processes determining the principal atmospheric and ocean circulation features, climate feedback processes, and dominant modes of variability. (Delworth)

GEO 428 - BIOLOGICAL OCEANOGRAPHY

Biological processes in the context of their chemical and physical environment; primary production and marine food webs, ocean ecology. (Ward)



A stable isotope mass spectrometer in Prof. Bess Ward's Guyot Hall laboratory.

GEO 429 - OCEAN BIO-PHYSICAL INTERACTIONS AND CLIMATE (ENV)

This course explores the interaction between ocean physics and fluid dynamics and biological processes from global ocean scale (>1000 km) to small eddies and frontal structures (<1km). Questions that will be addressed are: How is the ocean ecosystem shaped by the ocean circulation? What is the impact of ubiquitous eddies, fronts, and waves on ecosystems? Are these biophysical interactions modulated by climate variations? Addressing these issues requires an interdisciplinary approach, bringing together the ocean physical, chemical, and biological dynamics. (Resplandy)

GEO 441 - COMPUTATIONAL GEOPHYSICS (APC)

Finite-difference, pseudospectral, finite-element, and spectral-element methods presented and applied to a number of geophysical problems including heat flow, deformation, and wave propagation. Students will program simple versions of these methods. (Tromp)

GEO 442 - GEODYNAMICS (PHY)

An advanced introduction to setting up and solving boundary value problems important to the Solid Earth sciences. Topics include elasticity and plate flexure, heat and fluid flow, with applications to mantle convection, magma transport, structural geology, and the thermal evolution of the terrestrial planets. (Rubin)

GEO 464 - QUANTIFYING GEOLOGIC TIME

Geologists have argued for centuries that Earth must be very old, but have only begun to quantify the age of Earth and measure the rates of geologic processes. This rapidly improving field is critical for understanding the rates of plate tectonics, climate change, volcanic eruptions, and landscape evolution. This course focuses on the methodology and applications of how we measure geologic time, from radiometric methods, or geochronology, to cyclostratigraphic analysis of sedimentary rock sequences. (Schoene)

GEO 470 - ENVIRONMENTAL CHEMISTRY OF SOILS (CHM)

Inorganic and organic constituents of aqueous, solid and gaseous phases in soils, and the fundamental chemical processes that govern reactions between these constituents. (Myneni)

Testimonial from Kellie Swadba '17

"I entered Princeton without a clear idea of what I wanted to study, knowing only that I enjoyed science in high school and wanted the freedom to choose a wide array of classes that would expose me to fields I had not yet encountered. I found in the Geoscience Department a field that took the fundamental studies of physics, chemistry, biology, and math, and applied them to questions both big and small about our Earth, its systems, and the processes that shape it. It was amazing to find that the basic sciences could be combined and applied to address these "real-world" problems in exciting and novel ways.



*From the first class I took as a freshman, I gained an appreciation of the ways in which the GEO Department was special. The class size was small compared with my other introductory freshman courses, and the older GEO majors were incredibly friendly and helpful. Working on problem sets was a group activity and the professors and AIs were always available for questions and guidance. The sense of community in the Geo Department is incomparable. What also sets the GEO Department apart is the sheer diversity of study that one can find within it. I realized this most fully when we had our first Junior Project poster session, where I found that my classmates were studying things as different as ocean circulation to coral composition to arsenic contamination, all within the same department. The GEO Department gives you the opportunity to engage in diverse and interesting research projects in a hands-on way. **Working with Professor Duffy, I was able in my junior year to travel to the Advanced Photon Source at Argonne National Laboratory to perform x-ray diffraction experiments for my junior project. As a senior I got the opportunity to return to Argonne, this time to visit a new sector that is at the cutting edge of dynamic compression research.** It was incredible to be able to be involved in these projects as an undergraduate. The experiences and opportunities provided by the GEO Department have greatly shaped my path through Princeton. Though I entered Princeton uncertain about my direction, the GEO Department offered a welcoming and engaging environment and exciting and challenging opportunities that have allowed me to look back on my time with a sense of achievement and pride."*



Students on board ship at the Jersey shore, observing coastal environments and collecting water samples for analysis. Photo courtesy of Robert Nazarian *18 (GEO 202)

Geosciences Courses with Field Trips

Field trips are an important component of many undergraduate Geoscience courses. A number of Geoscience courses require either day trips or extended field trips during the semester breaks. These field trips provide students with critical hands-on learning experiences. Applications of classroom learning, introduce them to the real world of research science in the field, and teach them to think and reason on their feet while confronted with problems that often require an interdisciplinary science approach. Field trip funds are provided by the Geosciences Department.

Field trips will resume after COVID-19 related restrictions are lifted.



FRS 124 State of the Earth: Shifts and Cycles – Prof. Adam Maloof and students analyse the Paleocene turbidites at Zumaia, Spain. Photo by Emily Geyman '19.

FRESHMAN SEMINAR (FRS)

In this Freshman Seminar (not offered every year), students will combine field observations of the natural world with quantitative modeling and interpretation to answer questions like: How have Earth and human histories been recorded in the geology of Princeton, the Catskills, and elsewhere, and what experiments can you do to query such archives of the past? In the classroom, through problem sets, and around campus, students will gain practical experience collecting geological and geophysical data in geographic context, and analyzing these data using statistical techniques such as regression and time series analysis, with the programming language Matlab. During the required one-day trip to the Catskills and week-long semester break trip, students will engage in research projects that focus on the cycles and shifts in Earth's shape, climate, and life that occur now on timescales of days, and have been recorded in rocks over timescales of millions of years.

GEO 202 – OCEAN, ATMOSPHERE & CLIMATE

This course includes one-day or overnight trips to coastal environments to investigate processes that shape the shoreline or to collect water samples for physical, chemical and biological analyses.



*GEO 202 Ocean, Atmosphere & Climate – Searching for layers that record history of storm activity. Photo by GS Nick Peng *16*

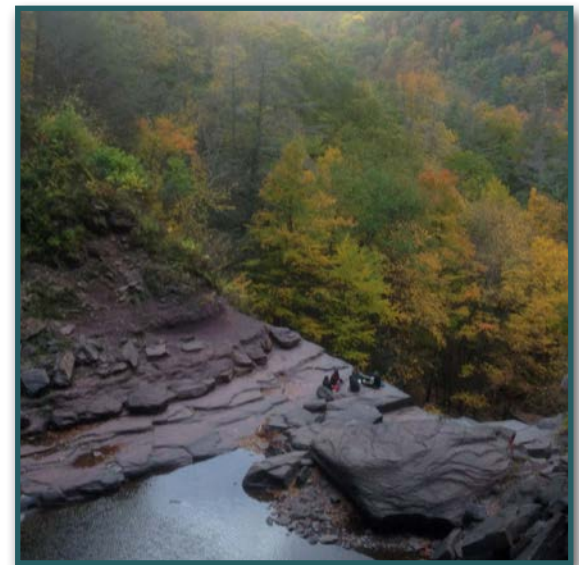
GEO 203 – FUNDAMENTALS OF SOLID EARTH SCIENCE

Field trips for this course give students hands-on experience with concepts they learn about in class and grapple with in problem sets. Starting with a look at the local geology: why does Washington Road go down a hill? Why is Nassau Hall built of such a poor building stone? A weekend field trip gives a deeper look into the physical and chemical processes that control the properties and behavior of the solid Earth. Sites visited have included the Catskills of New York, the folded Appalachians of Pennsylvania, the highlands of

New Jersey and the New Jersey Coastal Plain. During Reading Period, the class spends a day at the American Museum of Natural History in New York City.

GEO 363 – ENVIRONMENTAL GEOCHEMISTRY

Several weekend field trips are organized during the fall semester. These trips are to the Hackensack River Estuary and Newark Bay (NJ), Pine Barrens (NJ), and the coal mines of Pottsville and surrounding areas (PA). The goals of these trips are to collect soil and sediment cores and examine chemical variations in their profiles, collect water samples and conduct analysis to evaluate important biogeochemical variables, and introduce students to the variations in the biogeochemistry of pristine and polluted environments.



*GEO 203 Fundamentals of Solid Earth Science – students at the sandstone cliffs that form Kaaterskill Falls near Hunter, NY. Photo by Joel Simon *20*

GEO 370 – SEDIMENTOLOGY

This course has up to three regional weekend field trips designed to complement problem sets and take students to the New Jersey Pine Barrens, Eastern Kentucky Appalachia, and the Catskills Mountains of New York. The fourth is a mandatory spring-break field trip with varying locations (e.g., Bahamas, New Mexico, Australia) where students focus on specific research projects that range from dune migration and tidal channel dynamics, to generating records of sea level rise in the Caribbean or climate change in the American West. The field data collected on this trip are the focus of the final research projects.



*GEO 370 Sedimentology – Prof. Adam Maloof describes the Pleistocene glacial-interglacial cycles and their effect on karst formation from inside Henry Morgan’s Cave, the Bahamas. Photo by Blake Dyer *15.*



GEO 372 Rocks – A geologist’s hammer used for splitting and breaking rocks, is used to indicate scale for this metamorphic rock outcrop in New Mexico. Photo by GS Jack Murphy.

GEO 372 – ROCKS

Students participate in a one-week field trip over spring break. In the field, students learn to make observations in order to untangle the complicated tectonic and thermal histories recorded by rocks in Earth’s crust and mantle. Students visit modern continental rifts and active faults, super volcanoes, deep crustal terranes exhumed during mountain building, and granitic batholiths. The main objective is to collect rock samples and field data that form the basis of students’ final projects. Past excursions have included northern New Mexico and southern California.

GEO 373 – STRUCTURAL GEOLOGY

This course includes a one-week field trip over fall break. The goals of this trip are to teach students how to observe and characterize small and large scale evidence of rock deformation, take structural field data, and learn to make geologic maps. This trip forms the basis of a final project in which the students combine and analyze field data, make interpretational cross sections of the Earth’s upper crust, finalize a geologic map, and place it into the regional tectonic context. Field trip locations have recently been in the Mojave desert of Southern California.



GEO 373 Structural Geology – Prof. Blair Schoene hiking along the deformed Barstow Formation in the Mojave Desert, a sequence of sedimentary rocks and volcaniclastic debris deposited during the Miocene epoch. Photo courtesy of Prof. Blair Schoene

Summer Field Course

Geosciences provides financial support to allow students to take a summer field course for Princeton course credit. Field schools range from hard rock geology, to geophysics, to glaciology (see photo on right), to microbiology, to oceanography at sea. Students should contact the Director of Undergraduate Studies if they have any questions.

Summer Internships

Geoscience Concentrators often participate in the Princeton Environmental Institute (PEI) internship program, where faculty from Geosciences and other departments in the university host 8-10 week long research projects both on campus and in the field.



Benjamin Getraer '19 sent this photo from his summer glaciology field course with the Juneau Icefield Research Program in Alaska.

Testimonial from Paul Yi '17

*"As I entered my first summer in college, I was still quite unsure about what I wanted to study during my remaining years at Princeton. **That summer, however, I learned about and developed a passion for oceanography and climate science while working as a summer research intern with Dr. Keith Rodgers in the Atmospheric and Oceanic Sciences Program — a part of the Geosciences Department.** I was fascinated by how diverse skill sets (e.g., chemistry, physics, applied math, computer science, etc.) were needed to tackle questions about Earth's climate, and when the fall semester began, I quickly enrolled in two Geosciences courses because I wanted to better understand the underlying physics of the oceanic and the atmospheric circulations. I thoroughly enjoyed these courses and soon signed on to be a Geosciences major.*

I am very thankful for my time as a member of the Department. First, the professors and lecturers were so welcoming and willing to meet with me for questions about coursework and research, even when I had not been in a class with them. I thrived in this tight-knit and supportive environment, and I want to remember and hope to emulate their examples in the future. Second, the Department's flexible requirements allowed me to take a wide range of courses in other departments, and I benefited especially from the engineering math and fluid mechanics sequences in the Mechanical and Aerospace Engineering Department. These two sets of courses helped me to dig deeper in both my coursework and research endeavors as a Geosciences major. For these reasons and many more, I graduated feeling satisfied about my academic pursuits and would join the Geosciences Department without hesitation if I was to do it all over again."



Testimonial from Ethan Campbell '16

"The best decision I made at Princeton was to major in Geosciences. I switched over from the BSE program after freshman year, drawn in after an exciting summer research internship with a GEO professor. Studying the earth, for me, offered a captivating mix of phenomena that are readily observable—weather, volcanic eruptions, and rock strata, for example—as well as those that are hidden—ocean circulation, microbial life, and seismic waves, to name a few.

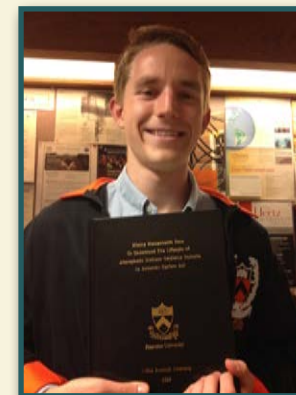
The unifying characteristic of GEO courses has been their lively spirit of scientific inquiry, pushing students to discover and understand the connections between these phenomena that create dynamic, ever-changing earth systems. Other highlights include attentive professors, small class sizes, a flexible curriculum, and a balance between descriptive lectures and rigorous derivations. But the most fun part for me was applying this newfound knowledge outside of class. From running a global climate model simulation for my spring JP, to collecting seawater samples on an oceanographic research cruise to the Antarctic ice edge—then analyzing them for my senior thesis, to an incredible department-wide field trip exploring the geology of Iceland, GEO has opened my eyes to the many wonders of the earth. I am now entering a Ph.D. program in oceanography, and I look forward to a lifetime of further exploration."



Testimonial from Collin R. Edwards '16

"I chose Princeton because of its emphasis on research and its focus on the individual, undergraduate experience. Nowhere are these qualities better exemplified than in the Department of Geosciences. I was fortunate enough to learn this during my first semester. As an aspiring pre-med with a general passion for science, I applied for and was accepted into the Geosciences Freshman Seminar: Earth's Environments and Ancient Civilizations. Over the course of a semester's worth of group projects, fascinating research and an incredible weeklong trip to Cyprus, I found myself ready and excited to commit to a Geosciences concentration. Within a single freshman course, any concerns about my major and joining the Department had disappeared.

Like many people, I had assumed that "geosciences" actually meant "geology," thus limiting my possible areas of study. I quickly learned how interdisciplinary the Geosciences Department actually is. In addition to housing leading geophysics and geology research, the Department contains faculty and offers courses in nearly all areas of Earth sciences. This diversity allowed me to explore unique fields early on in my Princeton career and to find and ultimately focus in on areas I am passionate about with no sense of limitation. In no other department could I have done a molecular biology-based thesis studying global warming and extraterrestrial life! This diversity of subjects is amplified by the close mentorship and active guidance of each of the esteemed faculty. While the prospect of advanced independent research often seems inconceivable to Princeton underclassmen, Geosciences majors hold an important advantage provided by the resources of a small, intimate department. Faculty with novel areas of research and excited to engage and challenge their undergraduates leads to a vast array of projects available to students as well as the resources and guidance needed to forge your own path."



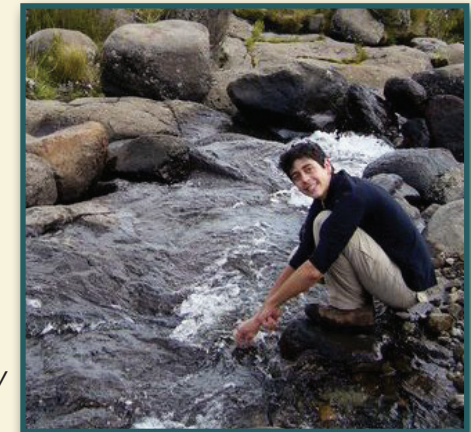


Testimonial from Atleigh G. Forden '16

"Deciding to become a part of the Geosciences Department was the best decision I have made in my time at Princeton. **The access I had to my professors, the effectively unlimited research and travel opportunities and the diverse and interesting classes offered made the department unlike any other at this school.** I am so grateful for what I have learned and experienced while being a part of the Geosciences Department and I would advise any student interested in the sciences in general to think about joining coming sophomore year."

Testimonial from Preston Kemeny '15

"It is difficult to stress how extensively the Department of Geosciences influenced both my growth as a scholar and my overall experience at Princeton. Through seminars and field trips, independent research and tea time, Guyot and its inhabitants became my academic home and family at the university. I find geosci-



ence fascinating because it applies chemistry, physics, and biology to study Earth, taking from each field its most powerful tools but without focusing too narrowly on any one technique. Within the Department I thus had the opportunity to study topics ranging from crystal symmetry to mass extinction events, isotope geochemistry to inverse modeling, and always with brilliant professors who strove to create an inviting and invigorating dialogue. Aside from the breadth of its subject, the GEO Department shines relative to other concentrations because of the quality of its faculty. Every professor is approachable and extremely willing to invest time and resources into hard-working students; I'm still only beginning to appreciate the rarity of this caliber of mentorship. Outside of the classroom, the GEO Department provides unparalleled opportunities for fieldwork. Beginning with freshman seminars, it enables all students to study abroad. Through this fieldwork I learned not only the specifics of a given outcrop or feature, but more broadly about the process and techniques of scientific research itself. **My only regret about concentrating in GEO is that I didn't join the Department sooner, for it is the best kept secret at Princeton.**"

For more information about our programs contact the

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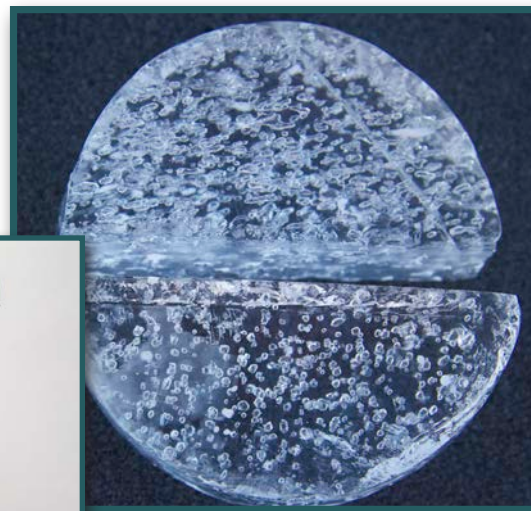
STAFF

Sheryl Robas

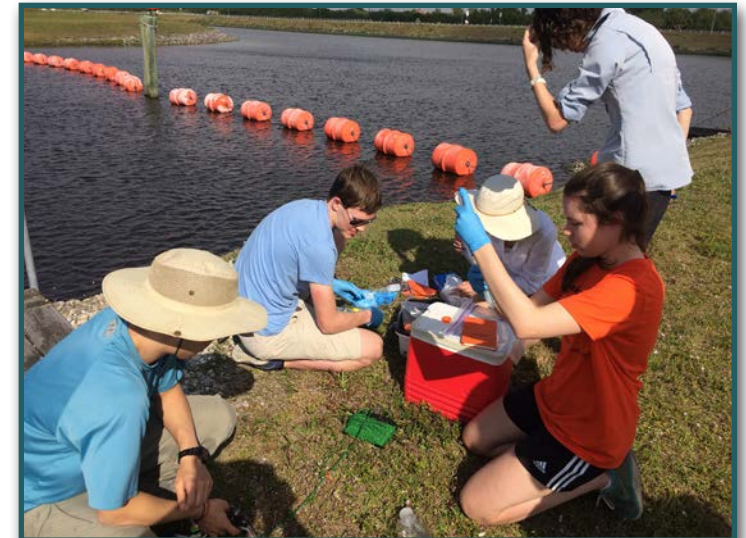
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Administrator and Faculty Assistant
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Three gem varieties on display at an activity night at the Frick Laboratory. The Department's Mineral and Gem Collection consists of approximately 6000 cataloged specimens, including samples from many classic European and American localities.



One-million-year-old ice core from the remote Allan Hills of Antarctica. Analysis of gas trapped in ice indicates the composition of Earth's atmosphere in the past. Photo by Preston C. Kemeny '15 (Higgins Lab)



Students collect samples from water treatment plants upstream of the Florida Everglades, to measure the concentrations of nitrogen and phosphorus, two important pollutants. Photo by GS Katja Luxem (FRS)

Senior Thesis Titles

HOLOCENE CLIMATE CHANGE IN NORWAY: A MULTI-PROXY LACUSTRINE RECORD FROM PROGLACIAL LAKE KONGRESSVATNET

TURBULENT INFLUENCE ON THE TROPICAL TROPOPAUSE LAYER: GLOBAL CONVENTION-RESOLVING MODEL STUDY

ENVIRONMENTAL EFFECTS OF DECCAN VOLCANISM DURING THE LATE CRETACEOUS

SEED THEORY AND ENSO VARIABILITY: RE-EVALUATING THE DISTRIBUTION OF TROPICAL CYCLOGENESIS

COMPOST CHEMISTRY: UTILIZING FOOD WASTE AS A SOIL AMENDMENT

DYNAMICS OF COUPLED SOIL MOISTURE AND PLANT CAPACITANCE SYSTEMS FROM DAILY TO INTERANNUAL SCALES

COUPLED SOIL MOISTURE AND PLANT WATER STORAGE DYNAMICS

CA AND MG FRACTIONATION IN C3 AND C4 GRASSES AND THEIR IMPLICATIONS FOR RECONSTRUCTING PALEODIETS AND SERVING AS BIOSIGNATURES

ISOTOPIC ANALYSIS OF Pb IN TRENTON TAP WATER AND THE IMPLICATIONS FOR CONSTRAINING SOURCES OF Pb CONTAMINATION

PINPOINTING THE PROVENANCE OF DECCAN ZIRCONS

EFFECT OF Fe AND OXYGEN ADDITION ON METHANE RELEASE FROM TEMPERATE WETLAND SOIL

EVALUATION OF A HANDHELD RAMAN SPECTROMETER FOR CHARACTERIZING CULTURAL HERITAGE MATERIALS



Testimonial from Kathleen Ryan '14

"I came to Princeton with a vague idea that I wanted to understand the natural world. I didn't want to just pass science classes and earn a degree, **I wanted to develop a literacy that would allow me to interrogate, understand, and appreciate the amazing environment around me on the smallest scales but also as an integrated whole.** Looking back, this was perhaps quite a tall order. Nonetheless, the Department of Geosciences completely exceeded my expectations.

As an undergraduate member of the Department of Geosciences, you are not just a student. You are a growing, contributing member of a scientifically-oriented community. You are given the opportunity to explore natural systems in fun, intimate, and challenging classroom and field settings. You are given the responsibility of contributing to meaningful group projects and the challenge of creating high-quality independent work. You are valued for all of your interests and contributions, geoscientific and beyond, and you are supported as a student and as an alumnus, regardless of your developing career goals.

While I may not become a career geoscience researcher, I have no doubt that the Geosciences was the major for me. I faced real academic challenges in the department, but also found my greatest mentors and a few of my closest friends. This Department is the best Princeton has to offer."

ATTRIBUTION OF U.S. ECONOMIC LOSSES DUE TO TROPICAL CYCLONES

A NUMERICAL AND FIELD-DATA EVALUATION OF THE CRITICAL TAPER MODEL FOR OROGENIC WEDGE STABILITY

RAMAN SPECTROSCOPY OF NEAR-ENDMEMBER TOURMALINES DRAVITE AND MAGNESIO-FOITITE TO 24 GPa

ESTIMATING RATES OF ANAEROBIC NITRITE OXIDATION IN THE EASTERN TROPICAL NORTH PACIFIC OXYGEN MINIMUM ZONE THROUGH INCUBATION EXPERIMENTS

LIANA, ARRESTED SUCCESSION, AND DECREASED CARBON STORAGE: EXAMINING THE LINKS BETWEEN TOPOGRAPHY, LIANA DENSITY, AND THE PERSISTENCE OF LOW-CANOPY AREAS

THE EFFECT OF GEOMETRIES IN CURVED-CREASE ORIGAMI PATTERNED SURFACES ON THE ACOUSTICS OF SPACES

TRIBUTARY SLOPES RECORD REGIONAL CLIMATE AND CONSTRAIN BRANCHING ANGLES IN U.S. RIVER NETWORKS

COMPARISON OF GRACE DERIVED GREENLAND MASS WASTING TO NEAR SURFACE TEMPERATURE FROM MERRA-2 REANALYSIS

HOW DO SHALLOW CARBONATES RECORD SEA LEVEL AND SEAWATER CHEMISTRY? THE BAHAMAS AS A MODERN ANALOGUE FOR CLIMATE RECORDS PRESERVED IN ANCIENT CARBONATES

AN EXTREME VALUE ANALYSIS (EVA) OF EXTREME SEA-LEVEL (ESL) EVENTS IN HAWAII TO EVALUATE THE HAWAII SEA-LEVEL RISE VULNERABILITY AND ADAPTATION REPORT

PROCHLOROCOCCUS & THE SECONDARY CHLOROPHYLL MAXIMUM IN THE EAST TROPICAL NORTH PACIFIC OXYGEN DEFICIENT ZONE

ENVIRONMENTAL FACTORS INFLUENCING THE FORMATION OF ORGANOBROMINES IN COASTAL SOILS

Testimonial from Christine Chen '13

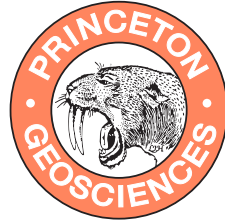
If you're a science-y person but don't know what you want to study, you can't go wrong with geosciences. Before college, the idea of choosing a major was incredibly intimidating. I knew that I was interested in science, but between chemistry, biology, physics, and computer science, I had absolutely no clue which subject I enjoyed the most. I loved them all—what if I chose wrong? **That's when I discovered geosciences, perhaps better known as Earth science, the all-encompassing field that seeks foremost to understand the planet Earth.** I realized that I didn't have to choose at all; Earth science combined every discipline of the natural and physical sciences into an integrated study of the planet and the processes that make Earth what it is today. It was as simple as that, and after cavorting around the Mono-Inyo Craters and the star sand dunes of Death Valley on a GEO class trip during freshman fall, I was hooked. I like to think that I've returned to my roots as a kid who watched Bill Nye the Science Guy and Magic School Bus. Rocks, earthquakes, dinosaurs, and volcanoes—those were the stuff of legends back then, and I can hardly believe that I am actually allowed to have this much fun learning about the Earth."



CONTRIBUTIONS OF OVERSHOOTING CONVECTION OVER THE SOUTH ASIAN MONSOON REGION TO STRATOSPHERIC WATER VAPOR

SEISMOLOGICAL ANALYSIS OF THE MOHOROVICIC AND MANTLE DISCONTINUITIES BELOW CAPE VERDE USING RECEIVER FUNCTIONS

PRIMARY PRODUCTIVITY IN THE GULF OF ALASKA IN A HIGH-RESOLUTION GLOBAL CLIMATE MODEL



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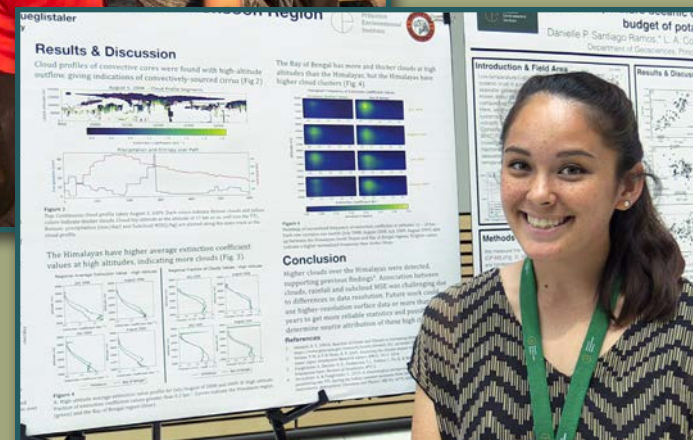
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Students in FRS 161 at Vesuvius' crater in Ercolano, Naples, Italy, 2019. Photo by Prof. Adam Maloof



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Kimberly Peterson '19 showcasing her senior thesis at Research Day 2019.

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