Introduction to Geosciences

The field of geosciences is central to many of the 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 the Earth works and how to solve real-world problems.

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

The Department of Geosciences offers a concentration in one of three tracks: Environmental Biogeochemistry (EBC), Ocean, Atmosphere & Climate (OAC), and Geophysics & Geology (GPG). Princeton University, in collaborations with Geosciences offers a Program in Planets and Life certificate in Astrobiology. The Department of Civil and Environmental Engineering, in collaboration with Geosciences, also offers a certificate in Geoengineering.

(Cover) Atlantic coast of southern Morocco. Oil shales from the late Cenomanian Oceanic Anoxic Event 2 were deposited about 93.9 million years ago and are now exposed on a vertical cliff along the southern coast of Tarfaya in southern Morocco. [GEO 365]

(Left) Students try their hand at excavation while retrieving a lost piece of equipment in the Bahamas. [GEO 370]
Geoscience is a unique blend of lab experiment, field observation, data analysis, and computer modeling. Courses in geosciences apply principles of biology, chemistry, physics, and mathematics to real Earth problems, deal with length scales from global to atomic, and consider time scales from billions of years to less than a second. The flexible academic program allows students to develop individualized courses of study.

Geosciences Prerequisite Requirements:
All concentrators are required to take one introductory Geoscience course: GEO 202 or GEO 203, or Geosciences Freshman Seminar with permission of the Undergraduate Work Committee (UWC). Students with adequate preparation may proceed directly to GEO 300-level courses with the consent of their GEO adviser, but this cannot substitute for one of the eight upper-level geosciences courses. Other introductory geosciences courses, such as GEO 102, 103, 107, and 197 (formerly 297), are intended primarily for non-science majors and are not ideal for students anticipating majoring in geosciences. Please note that no other GEO 200 level courses or other courses satisfy this requirement.

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, but it does not provide credit toward the geosciences concentration.

Mathematics Prequisite: MAT 104 or MAT 175 or one more advanced course in math. AP credit does not fulfill this requirement.

Geosciences Core Science Requirements: Students must complete two of the following core science requirements at Princeton; PHY 104, CHM 202, COS 226, and MOL 214. AP credits do not fulfill this requirement, but students with AP credit may choose to substitute a more advanced course to satisfy a core science requirement. For example, CHM 215 or CHM 301 could substitute for CHM 202.

Students interested in graduate school are encouraged to take more than these minimum basic science requirements.

Departmental Requirements:
Concentrators are required to take eight upper-level geosciences courses (300 level or higher, not including GEO 499 and GEO 503).

Upper Level Science Courses: Up to two of the following classes may be substituted for GEO 300+ classes. Students may substitute other advanced science courses not listed below with permission of the UWC: CHM 301, CHM 302, CHM 305, CHM 306, CEE 306, CEE 323, COS 323, EEB 306, EEB 309, EEB 312, EEB 320, ENV 302, MAE 305, MAE 306, MAE 328, MSE 301, MSE 302, PHY 301, PHY 304, PHY 305, and WWS 350.

Students are urged to consult with the departmental representative or their junior or senior adviser before choosing departmental courses outside geosciences. In general, the department is flexible about course selections and requirements; however, we must ensure a degree of coherency in the curriculum of each student.

Junior Colloquium. This is a weekly luncheon meeting, convened during the fall term, to acquaint juniors with research and career opportunities. This is mandatory for all geosciences majors (including those in the geological engineering program).
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.”

Testimonial from MICHAEL EDDY ’11

“My name is Michael Eddy and I think geology rocks. When I started school at Princeton I had no idea that I would join the Geosciences Department. However, within the first two years Guyot had become my new home. The department’s work combines three of my great passions, science, the outdoors, and travel. By my graduation, I had climbed volcanoes in Alaska, seen the K-T boundary in Tunisia, and done scientific research with professors who are on the cutting edge in their fields. These types of opportunities are unique to the Princeton Geosciences Department, and I encourage interested students to explore its opportunities.”

Testimonial from AMY GOBEL ’12

“I joined the Geosciences Department because I read course reviews, when trying to decide how to study environmental chemistry. I noticed that an overwhelming theme for the other departments I was considering, was that students despised the required courses. But, in the Geosciences Department, I found not a single negative review. Small classes and invested faculty meant excellent instruction across the board. And while I didn’t appreciate it at the time, this also meant access to a range of research opportunities in environmentally-focused science that I would not find anywhere else on campus. The fact that I got to spend a summer in Bermuda didn’t hurt, either. I have spent two years tolerating “rocks for jocks” jokes, however, I feel this is the best department for my field of interest that I could have asked for.”
**Departmental Tracks**

**ENVIRONMENTAL BIOGEOCHEMISTRY (EBC)**
Study the geochemical and biological processes modifying Earth's surface (atmosphere, soils, sediments, oceans). How do biogeochemical interactions modify the behavior of elements and molecules responsible for global climate change, ecological variations and toxicity, and bioaccumulation of anthropogenic contaminants.

**GEOPHYSICS & GEOLOGY (GPG)**
Study the structure and evolution of Earth as a physical system, by theory, experiment, observation, and numerical simulation. The emphasis is on physical processes of global relevance including the history of Earth and life in the rock record. The quantitative concepts and techniques covered in class are also relevant to applied sciences and industry.

**OCEAN, ATMOSPHERE & CLIMATE (OAC)**
Study the coupled ocean and atmosphere system as it interacts with life to set the physical and chemical conditions of Earth's surface. Students with backgrounds in subjects as diverse as chemistry, biology, physics, public policy, and economics with an interest in climate and global environmental conditions will find this track a challenging and relevant addition to their coursework.
Introductory Courses

FRS - GLOBAL CHANGE AND THE IMPACT OF HUMAN ACTIVITIES ON THE BIOSPHERE EBC, OAC*
The biogeochemical cycles of major nutrients (C, N, P) and contaminants (Hg, As) in oceanic and terrestrial ecosystems are examined in the context of global change. A one-week field trip to Everglades National Park in Florida is mandatory. [Kraepiel, Myneni]

FRS - EARTH’S ENVIRONMENTS & ANCIENT CIVILIZATIONS OAC, GPG*
How does Earth’s surface evolve in response to internal (e.g., tectonic and magmatic), surficial (e.g., weather, climate, and anthropogenic effects), and external (e.g., extraterrestrial) forcing? This seminar provides students with practical experience making geological and geophysical observations designed to shed light on the interplay between active tectonic landscapes, changing climate, and ancient civilizations. A one-week field trip to Cyprus is mandatory. [Maloof, Simons]

GEO 102A (without lab) & 102B (with lab) - CLIMATE: PAST, PRESENT & FUTURE
An introduction to the processes and conditions that control Earth’s climate; an overview of past climate evolution on various time scales, from the full sweep of Earth time to the period of human history; and an investigation of ongoing and predicted future climate changes, including the potential for human activities to alter climate and the impacts of climate change on environment and society. Three lectures and one three-hour laboratory. Intended for students not concentrating in science or engineering. [Bender, Sigman]

GEO 103 - NATURAL DISASTERS
The theory of plate tectonics is used to explain the occurrence, distribution and hazard of earthquakes and volcanoes. Three lectures and one three-hour laboratory. Intended for students not concentrating in science or engineering. [Rubin]

GEO 197 - ENVIRONMENTAL DECISION MAKING
The development of environmental policy based on the integration of scientific, engineering, economic, political and social considerations. [van der Vink]

*7-day field trip during Fall/Spring Break
GEO 202 - OCEAN, ATMOSPHERE & CLIMATE OAC
The physical, chemical and biological processes in the oceans and atmosphere; the interactions of these processes that control Earth's climate; evidence and theories of past climate change; scientific basis for current concerns regarding changes in the global environment. Topics include physical, chemical and biological processes in the oceans and atmosphere. [Sarmiento]

GEO 203 - FUNDAMENTALS OF SOLID EARTH SCIENCE (CEE) GPG
A quantitative introduction to Solid Earth System Science, focusing on the underlying physical processes and their geological and geophysical expression. Topics include basic physical conservation laws, examples of constitutive relationships, waves, transport phenomena, geopotential fields, geologic time, basic thermodynamics and mineralogy. Single variable calculus is a prerequisite. The course serves as a prerequisite for several upper-level GEO and CEE courses. [Higgins/Irving]

GEO 207 - A GUIDED TOUR OF THE SOLAR SYSTEM (AST) GPG
Examines the major bodies of our solar system, emphasizing their surface features, internal structures and atmospheres. Intended for students not concentrating in science or engineering. [Duffy]

GEO 255A (without lab) and 255B (with lab) - LIFE IN THE UNIVERSE (AST, EEB, CHM)* Astrobiology. Topics include the origin of life on Earth, and the prospects of life beneath the surfaces of Mars, Europa and even nearby extra-solar planets with an optional field trip to Yellowstone National Park. [Onstott, Turner, Landweber]

*7-day field trip during Fall/Spring Break
Intermediate Courses

GEO 361 - PHYSICS OF THE EARTH, THE HABITABLE PLANET (ENV) OAC  Physical concepts related to atmospheric and ocean structure and motion. Topics include clouds and precipitation, solar and terrestrial radiation, wind, and ocean circulation. [Philander]

GEO 363 - ENVIRONMENTAL GECHEMISTRY: CHEMISTRY OF THE NATURAL SYSTEMS (CHM) EBC, OAC, GPG  The interaction between atmosphere and continent; special emphasis on atomic theory, chemical bonding, crystal chemistry, reaction equilibrium and soil geochemistry. [Myneni]

GEO 364 - EARTH CHEMISTRY: THE MAJOR REALMS OF THE PLANET (CHM) EBC, OAC, GPG  History and dynamics of the core, mantle, crust, ocean and atmosphere as reflected in their geochemical properties. [Bender, Sigman]

GEO 365 - EVOLUTION & CATASTROPHES OAC, GPG*  Examines the major stages and critical events in the history of the Earth, with emphasis on the fossil record of biological evolution and the environmental record of mass extinction. [Keller]

GEO 366 - CLIMATE CHANGE: SCIENTIFIC BASIS, POLICY IMPLICATIONS (ENV) EBC, OAC  An exploration of the causes and potential consequences of human-induced climate change and their implications for policy responses. [Oppenheimer]

Testimonial from ANDREW BUDNICK ’13

“Unlike a lot of geosciences majors, I had a good idea that when I came to Princeton I wanted to major in geology. I had known since 8th grade in fact, when I took a fantastic middle school geology class. And it only took a freshman seminar and a few interactions with the faculty for me to make up my mind fully—I am now a geoscience major getting ready to write my first junior paper.

What interested me most in the Geosciences Department, aside from my initial interest in the subject, was how close all of the students and faculty were. Because the number of undergraduates in the department is small, it’s possible to get to know everybody and form a tightly knit group. At the same time, the department faculty is world-class, and they get to dedicate more time to each student because of the small class size.

I’m studying things that are immediately relevant to issues such as climate change and oil dependence, which requires deep knowledge in a broad range of scientific fields. Also, I get to take amazing trips to all corners of the globe with my friends for my work. It’s hard to argue with that!”

*7-day field trip during Fall/Spring Break

(Top left) Students examine earth history and catastrophic events in the sediment layers of the Swiss Alps. [GEO 365]  (Top right) Raleigh Martin ’08 doing a laser survey of the topography of Bahamian tidal flats and (right) Meredith Wall ’08 wearing protective eye gear in the Bahamas. [GEO 370]
GEO 370 - SEDIMENTOLOGY (CEE, ENV) EBC, OAC, GPG* The physics and chemistry of the Earth surface processes that generate, transport, and deposit sediments; Emphasis on the interpretation of sedimentary records of modern and ancient environmental change. [Maloof]

GEO 371 - GLOBAL GEOPHYSICS (PHY) GPG An introduction to global geophysics. Topics include Earth’s shape, gravitational and magnetic field, seismology, and geodynamics. [Simons]

GEO 372 - EARTH MATERIALS GPG* An introduction to the processes that govern the distribution of different rocks and minerals in the Earth. We 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. [Schoene]

GEO 373 - STRUCTURAL GEOLOGY GPG* 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. [Maloof, Schoene]

GEO 374 - PLANETARY SYSTEMS: THEIR DIVERSITY AND EVOLUTION GPG Origin of the solar system and the internal structures, surface features, atmospheres and habitability of major planetary bodies. [Onstott]

GEO 378 - MINERALOGY GPG 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]

*7-day field trip during Fall/Spring Break
Advanced Courses

GEO 415 - ATMOSPHERIC SCIENCE OAC
This course discusses aspects of weather and climate, from phenomenological and analytical points of view. Complements material in GEO 423. [Fueglistaler]

GEO 417 - ENVIRONMENTAL MICROBIOLOGY (CEE, EEB) EBC, OAC
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) EBC
Application of quantitative chemical principles to the study of natural waters; equilibrium computations, weathering processes, precipitation of chemical sediments, and water pollution. [Morel]

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

GEO 422 - DATA, MODELS & UNCERTAINTY EBC, OAC, GPG
An introduction to data analysis and interpretation in the natural sciences. Topics include statistics, time series analysis, and matrix-based inverse theory. [Simons]

GEO 423 - DYNAMIC METEOROLOGY OAC
This course provides the rigorous introduction to the moving atmosphere needed to understand Earth’s weather and climate. The fundamental forces of the atmosphere will be described and conservation laws will be developed. Approximations relevant to Earth’s large-scale circulation and regional-scale extreme events will be discussed. Complements material in GEO 415. [Medvigy]

GEO 424 - SEISMOLOGY (CEE) GPG
Review of basic concepts in seismology. Topics to be 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 - PHYSICAL OCEANOGRAPHY (MAE) OAC
Detailed examination of thermohaline and wind-driven circulation and the ocean as a major influence on the atmosphere and global environment. [Philander, Vecchi]

*7-day field trip during Fall/Spring Break

Alexander Chuka ’14 and Tracie Kong ’14 collecting water samples in the Everglades. [FRS 114]
GEO 428 - BIOLOGICAL OCEANOGRAPHY (EEB) EBC, OAC  Biological processes in the context of their chemical and physical environment; properties of seawater and atmosphere that affect life in the ocean; primary production and marine food webs. [Ward]

GEO 430 - CLIMATE AND THE TERRESTRIAL BIOSPHERE EBC, OAC  An exploration of the key mechanisms that link climate (e.g., cloudiness, rainfall, and temperature) with the terrestrial biosphere (e.g., ecosystem composition, structure, and functioning), and how these mechanisms are altered by humans. [Medvigy]

GEO 441 - COMPUTATIONAL GEOPHYSICS (CEE) OAC, GPG  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) GPG  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 - RADIOGENIC ISOTOPES GPG  Theory and methodology of radiogenic isotope geochemistry, as applied to topics in the geosciences, including the formation and differentiation of the Earth and solar system, thermal and temporal evolution of orogenic belts, and the rates and timing of important geochemical, biotic, and climatic events in earth history. [Schoene]

GEO 470 - ENVIRONMENTAL CHEMISTRY OF SOILS (CHM) EBC  Inorganic and organic constituents of aqueous, solid and gaseous phases in soils, and the fundamental chemical processes that govern reactions between these constituents. [Myneni]

GEO 499 - ENVIRONMENTAL CHANGE, POVERTY AND CONFLICT  Evaluates our vulnerability to natural hazards and future humanitarian, economic, and political impact of such events given changes in sea level, climate and demographics (students also taking GEO 197 may not count GEO 499 toward GEO requirements). [van der Vink]

*7-day field trip during Fall/Spring Break

Note: Combining ores of these three minerals are the ingredients for bronze, one of the staple alloys of human civilization.

Specimens from Geosciences’ Mineral Collection (approx. 10,000 specimens). A cluster of cassiterite (tin oxide) crystals on limonite (hydrous iron oxides) from the Viloco Mine in Bolivia. An exquisite azurite (hydrous copper carbonate) rose from the famous Tsumeb Mine in Namibia. This radiating crystal cluster measures a remarkable three inches across, and represents one of the collection’s finest specimens. A classic specimen of bladed bluish devilline (hydrous calcium copper hydroxyl sulphate) on malachite sheets (hydrous copper carbonate) from the ancient copper mines at Herregrund, now Spania Dolina, Slovakia. Delicate translucence of the devilline crystal clusters.
Field trips are an important component in many undergraduate Geoscience classes. A variety of Geoscience courses require extended field trips during the semester breaks. These field trips provide students with a critical ‘hands-on’ learning experience and application of classroom learning, introduces them to the real world of research science in the field, and teaches them to think and reason on their feet while confronted with problems that often require an interdisciplinary science approach.
FRS – GLOBAL CHANGE AND THE IMPACT OF HUMAN ACTIVITIES ON THE BIOSPHERE A one-week field trip to the Florida Everglades during the spring break is mandatory to evaluate water quantity and quality in the context of geology, chemistry, and biology of the ecosystem. During this trip students observe the environment and collect samples that are subsequently analyzed in the laboratory at Princeton University. The resulting data is interpreted, synthesized, and written up for a final class report. Funds are provided by the Geosciences Department.

FRS – EARTH’S ENVIRONMENTS & ANCIENT CIVILIZATIONS In this Freshman Seminar, students learn how to make geological and geophysical field observations, then analyze and model the data to shed light on the interplay between active tectonic landscapes, changing climate, and ancient civilizations. During the fall-break students visit sites of geological and archaeological significance on Cyprus and collect material for subsequent analysis and presentation. Scientific writing is an integral part of this seminar and its assessment. The field trip is mandatory. All expenses are covered by the University, the Geosciences Department, and a donation by Richard L. Smith ’70.

GEO 255B – LIFE IN THE UNIVERSE (with lab) A one-week field trip during the semester break is optional. During this trip students visit, sample, and perform experiments on several of the many hot springs in and around Yellowstone National Park (YNP) that are accessible and host a plethora of microscopic to macroscopic life forms living in a wide range of geochemical environments. Students are provided with field notebooks and instructed on how to make field measurements, sketch what they see, and critically observe relationships between the biology and the geology of an active volcanic caldera. The microbial mats at YNP provide a portal through which students can glimpse the nature of Earth’s early biosphere and experience first-hand life in extreme environments. Funds are provided by the Geosciences Department.

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 coalmines of Pottsville and surrounding areas (PA). The goal of these trips is 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. Funds are provided by the Geosciences Department.
GEO 365 – EVOLUTION AND CATASTROPHES  A one-week field trip during the semester break is mandatory. During this trip students visit localities where rocks detail the transitions across major mass extinctions and climatic and environmental changes. They are actively involved in fieldwork, including digging trenches to expose fresh rocks, observing, describing and measuring rock sequences, and collecting sediment samples for analysis in the laboratory. Evenings are devoted to lectures, discussions of the day’s work and reports. The results of fieldwork and laboratory analyses form the basis for the term report. Past field trips have visited Mexico, Texas, Tunisia, Morocco, Egypt, Israel, and the Alps. Funds are provided by the Geosciences Department.

GEO 370 – SEDIMENTOLOGY  This course has 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) 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. Funds are provided by the Geosciences Department.

GEO 372 – EARTH MATERIALS  Students participate in a mandatory one-week field trip over fall break. In the field, students learn to make observations in both outcrops regional scale geology in order to untangle complicated tectonic and thermal histories recorded by rocks in the 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 centerpiece of this trip is to collect rock samples and field data that form the basis of the students’ final projects for the second half of the course. The field trip in the fall of 2010 visited New Mexico, though future locations may vary. Funds are provided by the Geosciences Department.

GEO 373 – STRUCTURAL GEOLOGY  This course involves numerous local field trips to observe rocks that were deformed during the Appalachian mountain building event, and one spring break field trip to a more distant location (SW U.S. such as Utah, Arizona, California or Nevada). Students learn to observe and measure large and small scale structures and determine the mechanisms that deform Earth’s crust during episodes of plate tectonic interactions and mountain building. Field work involves making geologic and structural maps in beautiful areas.
GEOLOGICAL ENGINEERING CERTIFICATE PROGRAM (ABET Accredited)

Geological Engineering is the application of science to problems and projects involving Earth, its physical environment, Earth materials, and natural resources. The curriculum is offered in a cooperative effort between the Department of Civil and Environmental Engineering and the Department of Geosciences, and is specially designed for the student who wishes to build upon the freshman and sophomore mathematics and engineering courses as a basis for studies in Geosciences.

All Geological Engineering students must acquire a strong background in Mathematics and the Basic Sciences, followed by specific courses in Engineering Sciences that stress basic geological, geophysical, and geochemical principles. These are followed by a sequence of four Engineering Design courses which are complemented by electives. The electives should form a coherent sequence of at least four courses in the student's area of interest. Engineering Design must be a significant component of the thesis for students in the Geological Engineering Certificate, which is accredited by the Engineering Accreditation Commission of ABET.

Math and Basic Science Requirements
- MAT 201
- PHY 103, 104
- CHM 201/2
- COS 126

Engineering Science Requirements
- CEE 205, 303, 306, 308, 361, 316
- GEO 203
- CEE 365 or GEO 373
- GEO 363 or 418
- MAE 305 or APC 350
- Any two from: CEE 471, 461 or 477
- CEE 478 Senior Thesis — All Seniors write a thesis and give an oral presentation (in both GEO and CEE departments) on a subject chosen by the student with the advice of their advisors.

Certificate Elective Requirements
Four or more (maximum one 200-level) of the following courses that form a coherent sequence in the student’s area of interest:
- CEE 262, 263, 362, 264, 366, 376, 460, 461, 472, 477
- MAE 221, 222, 323
- ORF 301, 307
- CHM 303, 306, 307

The Program in Planets and Life is an interdepartmental multidisciplinary plan of study. The goal is to provide students with an understanding of the fundamental astro-physical, chemical, biological, and geological principles, and engineering challenges that will guide our search for life in extreme environments on Earth and on other planets and satellites in the Solar System and among neighboring planetary systems. The Certificate Program draws faculty and other resources from Astrophysics, Chemistry, Ecology and Evolutionary Biology, Electrical Engineering, Geosciences, Mechanical and Aerospace Engineering, Operations Research and Financial Engineering, and the Woodrow Wilson School.

Program of Study: By the appropriate choice of courses, a student may satisfy the requirements of the program and the department of concentration, as well as the University distribution. Students may take the following course of study:

1. Fall semester core course AST/CHM/EEB/GEO 255

2. Students must take an additional four cognate courses. Only two of these can be in the student’s department of concentration. Cognate courses must be approved by the program chairperson.

3. Participation in a noncredit Planets and Life Undergraduate Colloquium is strongly encouraged. This colloquium will aid in thesis research and writing, assist in identifying resources

4. Independent research on topics relevant to the certificate program must be approved by the program chairperson and the undergraduate representative in the student’s department of concentration.

5. At least one JP or part of the senior thesis must include a chapter on an astrobiology theme.

For more information and a complete list of cognate courses visit: http://www.princeton.edu/astrobiology

Qualifying courses in GEOSCIENCES:

GEO 207 – A Guided Tour of the Solar System

GEO 255 – Earth Chemistry: The Surface Environment

GEO 256 – Earth Chemistry: The Major Realms of the Planet

GEO 371 – Global Geophysics

GEO 372 – Earth Materials

GEO 374 – Planetary Systems

GEO 417 – Environmental Microbiology

GEO 425 – Physical Oceanography

GEO 428 – Biological Oceanography

GEO 442 – Geodynamics

GEO 523 – Geomicrobiology

(Top) Tau Boötis b, an extrasolar planet approximately 50 light-years away around the primary star of the Tau Boötis system in the constellation of Boötes. (Artist’s conception courtesy of NASA/JPL-Caltech)

(Bottom) During a GEO 255 field trip, Mason Herson-Hord ’15, Evan Saitta ’14, Robert Cooper (Instructor’s Assistant), Jianxiao Lu ’13, Danni Tu ’15, Priscilla Chan ’14, and Nicole Bornkamp ’14 collect samples at Bear Creek, Gardiner, MT. On field trip nights, students perform telescopic observations of the planets and star clusters.
Testimonial from DAVID H. BARTELS ’06

“...It's now 5 years since I walked through the Fitz-Randolph Gate, and I am still as happy and proud that I concentrated in Geosciences as when I received my diploma. Starting at Princeton, I knew I wanted to explore and develop my interests in archaeology, paleo-anthropology, and more generally, the interaction of environment with evolution. Geosciences allowed me to pursue these interests, challenged me, and allowed me to ask the big questions – how did we get here? – while grounding me in hard science and world-class instruction from some of the most inspiring, yet down-to-earth scientists I have met. Of course, incredible geo field-trips from New Mexico to Morocco were not only amazing ways to get to know faculty in a small group setting but also to bond with my classmates.

Now, I’ve almost completed my MD at Harvard Medical School, and the basic lessons of careful observation, critical thinking, and rigorous scientific analysis, which I learned at Princeton Geosciences, continue to be invaluable. In fact, studying paleo-environmental change with Dr. Keller for my Junior Paper and Senior Thesis taught me how to synthesize large amounts of disparate data – a skill fundamental to being a physician. Then, I was taught how to synthesize geochemical, stratigraphic, and microfossil data to compose a coherent story to explain what I thought happened so many millions of years ago. Now, I use those same skills to synthesize medical history, imaging, and physical exam data to make a diagnosis.

Medical school is still a far cry from Geosciences, you might say. In fact, increasing awareness of the interaction of the physical environment with human health is driving the growth of a new multidisciplinary field called medical geology/ecology. Harvard Medical School has a dedicated Center for Health and the Global Environment. Many pressing health threats stem from issues that my Geosciences background has enabled me to better understand – natural disaster, asthma and air quality, heavy metal poisoning and hydrology, climate change and emerging infectious disease. I am currently aiming for residency training in emergency medicine with an eye to pursue disaster medicine and medical toxicology fellowships. Although I now carry a stethoscope instead of a rock hammer, my Geosciences experience continues to shape the way I view the world. Long live the Smilodon!”
Testimonial from OWEN COYLE ’12

“I came to the Princeton GEO department by a rather roundabout way. I always loved Math and Science, but I came into Princeton wanting to studying genetics in the MOL department. I pursued this line of study Freshman year but began wondering whether I might find a major that allowed me to study the natural environment a bit more interesting. When it came time to select courses for spring semester I decided to register for a GEO freshman seminar about the Florida Everglades, both because of its focus on the natural environment and because of the free trip to Florida during spring break. I didn’t know what I was getting myself into, but pretty soon I was bombing around marshes, taking tree cores, and cruising Florida Bay for water samples. More important than any of these experiences however, was a long conversation I had with one of my professors (Satish Myneni) as we drove to the Florida Keys. He mentioned how his research group was looking for a programmer to help them make a tool to analyze some mass spectrometry data they had collected. I had programmed in High School and told him I’d give it a shot. Because of my work with Satish I decided to take his Environmental Chemistry course the next fall, and from there I never looked back.

So that’s how I joined the department, but as for why I stayed here, and have been so happy with my experience in the GEO department it comes down to a few things. I love how interdisciplinary the work in this department is; we get to use chemistry, math, computer science, biology, geology, and physics to look at how the Earth was in the past and how it continues to evolve today. I love that our work very often takes us beyond the classroom and sometimes even out of the country to places that are wild and beautiful. I love that this whole huge field of Earth Science is still so young (plate tectonics was only accepted about 50 years ago) that it sometimes feels like a huge scientific frontier with revolutionary ideas just waiting to be discovered. More than any of this however, I love the people who make up this department. We are a small and devoted group of people, equal parts brilliant and wonderful where everyone is on a first name basis. While I have always been in awe of the intellect around me here, I have never once been intimidated by it. I can’t imagine a better environment in which to learn and grow.”

Testimonial from RALEIGH MARTIN ’08

“In retrospect, my choice to concentrate in Geological Engineering at Princeton was a gradual but inevitable outcome. I entered Princeton with no interest in geosciences. The Freshman Seminar, “Active Geological Processes,” sparked an initial interest in learning through fieldwork. So I decided to explore a bit more. In my sophomore year, I took Prof. Dahlen’s intro course and Prof. Suppe’s structural geology course. What really did it for me was the idea, so eloquently portrayed by these two grand masters of scientific research, that we can come up with quantitative predictions of really complicated but beautiful earth processes. Finally, Prof. Maloof’s earth surface processes course, as well as thesis research with Prof. Smith (CEE), revealed that I can actually contribute to this grand research enterprise. Now, I spend all my time thinking about the earth! I’m now in the fourth year of my Ph.D. at the University of Pennsylvania, researching sediment transport, and geomorphology. My Princeton background in Geological Engineering prepared me very well for the Ph.D., providing in particular the fundamental quantitative knowledge, research experience, and expressive skills to be successful in my work.”
Testimonial from JACQUIE NESBIT ‘12

“Why Jacquie became a Geo major:
Like many of my peers, I was first introduced to geology through a Freshman Seminar, Earth’s Changing Surface and Climate. I came to Princeton as a prospective EEB major; I had never even considered the possibility of studying rocks! The opportunity to do field work and original research as part of Freshman Seminar was the first time that I understood what it felt like to be a scientist. As I continued in the sciences at Princeton, I found myself more engaged in my courses in geology than chemistry, physics, or biology. In my Geo classes, even at the 200-level I felt like I was integrating basic knowledge with real research methods that would prepare me to do my own independent work in the future. I became very well-acquainted with my Geo professors—not only did they know me by name, but they were unmatched in their availability and dedication to helping me succeed. For me, other intro science courses never exceeded expectations as mere introductory requirements, but I loved my Geo classes and knew that I wanted to take more. Not only did I like the material, many classes involved field trips, which bring learning and class cohesion to a whole new level. The clear next step was to concentrate in geosciences, focusing on geology.

Why I like Geo:
Once I decided to be a Geo major, I knew immediately that I had made the right choice. The tight, welcoming community of undergrads, grad students, faculty, and staff cannot be matched! Additionally, Princeton Geosciences has given me opportunities that I would not have in other departments. Geo is unparalleled in its abundance of professors and select group of students. This advantageous ratio is beneficial in everything from getting your desired independent work advisor to developing strong relationships with multiple faculty members. Even as a freshman, I was given the opportunity to work in a research laboratory for one of my professors! Though my coursework has been challenging, my love of the earth, rocks, and science has only grown. I know that my Geosciences degree means I will graduate with a real skill set that will prepare for my future both academically and professionally.”

Testimonial from ZACH MORSE ‘10

“When I came to Princeton, I planned on being a Chemistry major but quickly found myself more at home in the Geo Department. One of my first classes at Princeton was a Geo freshman seminar called FRS 149: Active Geological Processes [now FRS 171], during which we traveled to the Sierra Nevada Mountains in California. The trip was as awesome as I had hoped when I signed up for FRS 149, and the course was an excellent introduction to geology. My experience in the class inspired me to take Introduction to Oceanography, another Geo course, during my freshman spring. Intro Oceanography was such a great class that I decided to spend a month in Bermuda that summer taking another Geo oceanography course.

The exceptional professors, incredible opportunities for field work and travel, and very interesting coursework in the Geo department made my choice of major during sophomore year very easy. The Geo department was also unique in being an interdisciplinary department as well as a discipline unto itself and the opportunity to look at physical systems from chemical, biological, and physical perspectives at the same time appealed to me. After taking the necessary pre-requisites, I jumped into as many Geo courses as I could take and had two excellent years in the department. I was able to take diverse courses, work directly with leading researchers in the geosciences via coursework and independent research, and build lasting relationships with other Geo majors and professors.”
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GEO 365 field trip to the pre-alps in Switzerland, along the border of France. (First row) Prof. Annie Arnaud (Univ of Grenoble, France), graduate student, Jahnani Punekar, Emily V. Trost '13, Prof. Gerta Keller, and Vis. Prof. Alfonso Pardo ’98; (Back row) research staff, Carl Hamming ’10, Andrew S. Busnick ’13, Andrea Beale ’14, Nathan P. Mathabane ’13, Charlotte Conner ’14, graduate students, Maria Paula Mateo and Bomou Brahimsamba (UNIL), Elizabeth M. Shoenfelt ’13, Gabriel L. Eggers ’13, Prof. Thierry Adatte (UNIL), and technical staff, Alexa Weigand.
SENIOR THESIS TITLES

“Distribution of Relative Humidity Observed by the VCSEL Hygrometer in the Tropical Troposphere, Interpreted Through Tracers”

“Examining Benthic Nitrogen Dynamics Using a Whole Core Squeezer”

“What Caused the Abrupt Increase in Net Global Land Carbon Uptake in 1989?”

“Isotopic Evidence for Source Changes in Aerosol Nitrate Deposition in the North Atlantic”

“Permafrost and Global Climate Change: Novel Models and Policy Implications”

“The Effects of Elevated Soil CO₂ on Plant Uptake of Metals”

“Calcite-Graphite Thermometry in the Southwestern most Central Metasedimentary Belt, Grenville Province, Southern Ontario”

“Constrained Parameterization of the Duel Arhennius and Michaelis-Menton Model of Soil Carbon Respiration for a Central Amazonian Terra Firme Rainforest Site”

“Testing the N Isotopes of Marine Particles as a Tool to Study Nitrogen Sources to Flow Cytometrically Sorted Phytoplankton In the Subtropical Ocean”

“U-Pb Geochronology from the Pimple Hills near Ogdensburg, NJ: Implications for the Tectonic History of the Losee-Wanaque Composite Arc”

“Pushing the 123KA Barrier in Greenland: A Revisitation in the Reconstruction of the Disturbed Section of GISP2/GRIP”

“Global Effects of Seismic Wave Propagation from the Chicxulub Asteroid Impact”

“Geophysics: Imaging a Salt Dome in West Africa Based on Spectral-Element and Adjoint Methods”

“Bio-optical Properties and Mixed Layer Net Community Production of Southern Ocean Phytoplankton”
“The Cretaceous-Tertiary (K-T) Boundary at Wadi Nukhul, Egypt: Planktic Foraminiferal Turnover and Environmental Changes”

“Dynamic vs. Static Triggering: An Evaluation of Aftershock Decay with Distance”

“Reinterpretation of the Elatina Rhythmite Fold Structures: Evidence for a Seasonal Slushball Earth and Giant Impact Lunar Formation ~ 4.4 Ga”

“Trichodesmium Response to Ocean Acidification”

“Methanobacterium sp. MK4 Under Conditions of Simulated Martian Regolith and Atmosphere”

“Evaluating the Haynesville Black Shale Resource Play”

“A New Record of Environmental Change in the Late Cretaceous from Brazil”

“Environmentally-Sustainable Poverty Reduction: Rural Road Development in Liberia”

“Utilizing Ground Penetrating Radar and the Hough Transform to Investigate Spatial Patterns of Tree Root Systems”

“The Risks and Behavior of Carbon Dioxide Leakage From Geologic Reservoirs”

“Redevelopment of Iraqi Hydrocarbon Resources and Infrastructure, A GIS Investigation into the Interplay Between Resources and Insurgency”

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A typical field lunch in Morocco, 2008.
Audrey Yau ’14 and research mate traveled via helicopter in Antarctica. Audrey is studying the geochemistry of trapped air in glacial ice of Antarctica, in the hopes of extending the current paleoclimate record (namely greenhouse gases like carbon dioxide). The area is called Mullins Valley; it is known to have the oldest ice and trapped air on the planet.