Introduction to **Geosciences**

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.

The Department of Geosciences offers a concentration in one of three tracks: Environmental Biogeochemistry (EBC), Ocean, Atmosphere, & Climate (OAC), and Geophysics & Geology (GPG). In collaboration with other departments, Geosciences offers two certificate programs: Planets and Life Certificate Program in Astrobiology and Certificate in Geological Engineering.
Geosciences is a unique blend of lab experiments, 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:
1. All concentrators are required to take either GEO 202 or GEO 203.

Students must take an additional introductory course selected from GEO 201, GEO 202, GEO 203, GEO 255 or a Geosciences Freshman Seminar prior to graduation (but not necessarily before declaring the concentration). Students with adequate preparation may substitute a GEO 300-level course for this second introductory class. Other introductory geosciences courses, such as GEO 102 and 103 are intended primarily for non-science concentrators and do not count toward a concentration in the geosciences.

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.

Mathematics: MAT 104 or MAT 175 or (with AP credit) one more advanced course in math.

Geosciences Core Science Requirements:
There are three ways to satisfy this requirement:

1. Recommended for students without AP credit: Students must complete two core science requirements at Princeton. Five acceptable course combinations to fulfill one core science requirement are: (a) PHY 103-104, (b) MAT 201-202, (c) CHM 201-202, (d) COS 126 & one of COS 226/ORF 309, (e) EEB 211, MOL 215.
2. Recommended for students with or without AP credit: ISC 231-234.
3. Recommended for students with AP credit: In lieu of the intro sequences, students with AP credit may choose to substitute a more advanced course to satisfy a core science requirement. For example, CHM 215, CHM 303 or CHM 305 could substitute for CHM 201-202. Permission from the Undergraduate Work Committee (UWC) is required if you would like to pursue this option.

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

Departmental Requirements:
Concentrators are required to take seven upper-level geosciences courses (300 level or higher, not including 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: APC 350, AST 204, AST 301, CHM 303, CHM 304, CHM 305, CHM 306, CEE 205, CEE 303, CEE 305, CEE 306, CEE 365, COS 323, COS 333, EEB 324, EEB 355, ENV 302, MAE 221, MAE 222, MAE 223, MAE 305, MAE 306, MAT 323, MAT 325, MOL 342, MOL 345, ORF 405, PHY 208, PHY 301, PHY 304, and PHY 305.

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). Read more about required independent work in the Geosciences here: www.princeton.edu/geosciences/undergraduate/
Departmental Tracks

**ENVIRONMENTAL BIOGEOCHEMISTRY (EBC)**
Study the geochemical and biological processes modifying Earth’s surface (atmosphere, soils, sediments, oceans), and explore how 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 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 - STATE OF THE EARTH: SHIFTS AND CYCLES OAC, GPG*
How have Earth and human histories been recorded in the geology of Princeton, the Catskills, France and Spain, 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 to France/Spain is mandatory. [Maloof, Simons]

GEO 102A (without lab) & 102B (with lab) - CLIMATE: PAST, PRESENT & FUTURE (ENV)
Which human activities are changing our climate, and does climate change constitute a significant problem? We will investigate these questions through an introduction to climate processes and an exploration of climate from the distant past to today. We will also consider the implications of climate change for the global environment and humans. Intended to be accessible to students not concentrating in science or engineering. [Sigman]

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, tsunami, hurricanes, floods, meteorite impacts, and global warming. A weekly laboratory is required. Intended primarily for non-science majors. [Rubin]

*7-day field trip during Fall/Spring Break
GEO 201 - Methods in Data Analysis and Scientific Writing (ENV) GPG, OAC, EBC*
Drone-derived models of landscapes, georeferenced field observations of the natural world, and data mining of the primary literature combined with quantitative modeling to answer questions like how has climate changed in the past, how is it changing now, and how do we measure it. Students will build on what they learned as freshmen in the Writing Seminars. [Maloof, Irwin-Wilkins]

GEO 202 - OCEAN, ATMOSPHERE & CLIMATE OAC
An introduction to the ocean, atmosphere, and climate from the perspective of oceanography. Topics include coastal processes and ecosystems; open ocean processes including atmospheric circulation and surface ocean ecosystems; deep ocean circulation and chemical cycling, climate history of Earth and impacts of humans on the earth system (e.g. ocean resources and climate change). [Sarmiento]

GEO 203 - FUNDAMENTALS OF SOLID EARTH SCIENCE (CEE) GPG
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. Two field trips. [Higgins, Irving]

GEO 255A – LIFE IN THE UNIVERSE (AST, EEB, CHM)
This course introduces students to a new field, Astrobiology, where scientists trained in biology, chemistry, astronomy and geology combine their skills to discover life’s origins and to seek extraterrestrial life. Topics include the origin of life on Earth and the prospects of life on Mars, Europa and extra-solar planets. [Onstott, Chyba]

*7-day field trip during Fall/Spring Break

(Top left) Soil sampling for analysis in the Myneni lab during a summer internship. Photo by Marah Sakkal ’20
(Top right) Students trek through snow to measure accumulation at a high altitude for climate studies research. Photo by Liam O’Connor ’20
(FRS) (Bottom right) An opportunity to watch the sunset after a long day of summer research in the Bolivian mountains. Photo by Adrian Tasistro-Hart ’17

[Maloof/Schoene]
Intermediate Courses

GEO 361 EARTH’S ATMOSPHERE (ENV, CEE) OAC
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 originating from natural (such as volcanoes) and anthropogenic (such as emission of carbon dioxide and ozone-depleting gases) processes. [Fuglistaler]

GEO 362 - EARTH’S CLIMATE HISTORY EBC, OAC, GPG
The nature and causes of major events in Earth’s 4 billion year climate history. The course integrates topics in stable isotope geochemistry that are fundamental to understanding surface processes, past and present. [Bender]

GEO 363 - ENVIRONMENTAL GEOCHEMISTRY: 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 chemistry of soils, oceans and the atmosphere. [Myneni]

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: IMPACTS, ADAPTATION, POLICY (ENV, WWS, ENE) EBC, OAC
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]

GEO 370 - SEDIMENTOLOGY (CEE, ENV) EBC, OAC, GPG*
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. [Maloof]

Testimonial from Casey Ivanovich ’17
“When I came to Princeton, I knew that I wanted my studies to be centered upon learning about the environment, but I wasn’t sure which major would be best for exploring this interest. I jumped around between concentrations quite a bit my freshman year, and it wasn’t until my sophomore fall when I took my first Geosciences course that I knew where I was meant to be. Immediately I felt the dedication of the Geosciences staff to its students and their desire to instill in us an excitement and passion about the world around us. From introductory laboratory courses to completing my senior thesis, from international field trips to learning about the stone that provides the physical foundation for our own campus, this grounding has been there every step of the way. I could not have asked for a more personal and hands-on learning experience, and I am so grateful for the Geosciences Department for ensuring that for its students.”

*(Above) Department members hike geothermally altered landscape at Hveragerdiin, Iceland. Photo by Prof. Satish Myneni [PUGS]*
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 - ROCKS GPG* 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. [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. [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

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.”
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, OAC
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. [Staff]

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 - INTRODUCTION TO OCEAN PHYSICS FOR CLIMATE (MAE) OAC
Detailed examination of thermohaline and wind-driven circulation and the ocean as a major influence on the atmosphere and global environment. [Vecchi]

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]

(Top) Analysis of ice issued to measure the past concentration of carbon dioxide in Earth’s atmosphere. One-million-year-old ice core from the remote Allan Hills of Antarctica. Photo by Preston C. Kemeny ’15 [Higgins Lab] (Top center) Students work with a Kestrel portable weather station on the coast of Zumaia, Spain. Photo by Liam O’Connor ’20 [FRS] (Bottom) This visualization is the first global tomographic model constructed based on adjoint tomography. Photo by David Pugmire, ORNL. [GEO 424/441]
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. [Staff]

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]

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 TAs 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.”
Geoscience Courses with Field Trips

Field trips are an important component of many undergraduate Geoscience classes. 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 and 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.
FRS – STATE OF THE EARTH: SHIFTS AND CYCLES
In this Freshman Seminar, 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 France/Spain, 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 Fall or Spring break trip to Spain/France, 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 a 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 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 in October 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 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.

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.

GEO 372 – ROCKS
Students participate in a mandatory 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 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 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 involves local field trips to observe rocks that were deformed during Appalachian mountain building events, and a fall break field trip to a more distant location (typically the southwestern U.S.) Students learn to observe and measure large and small scale structures and determine the mechanisms that deform Earth’s crust during episodes of mountain building and rifting. 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

Geological engineers examine construction practices on the Princeton campus. Photo courtesy of The Department of Civil and Environmental Engineering
PLANETS AND LIFE
CERTIFICATE PROGRAM

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 astrophysical, 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, and 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: www.princeton.edu/astrobiology

Qualifying courses in GEOSCIENCES:
GEO 362 – Earth’s Climate History
GEO 363 – Environmental Geochemistry: Chemistry of the Natural Systems
GEO 368 – – Sedimentology
GEO 370 – Global Geophysics
GEO 371 – Rocks
GEO 372 – Structural Geology
GEO 373 – Planetary Systems: Their Diversity and Evolution
GEO 374 – Mineralogy

GEO 417 – Environmental Microbiology
GEO 425 – Introduction to 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) 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 near Yellowstone National Park. On field trip nights, students perform telescopic observations of the planets and star clusters. Photo by: Dr. Maggie Lau [GEO 255]
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 geoscience 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 hardworking 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.”

Testimonial from Charlotte Conner ’14

“Looking back on my four years at Princeton, I cannot overstate how important being a part of the Geosciences department shaped my university experience. For my first course in the department as a sophomore, I travelled to the Alps with ten GEO upperclassmen. While I learned a lot in the course itself, what made the experience memorable was that I was exposed to the enthusiasm, generosity, and good humor that are characteristic of the GEO department. I can very honestly say that I met some of my best friends from the GEO department. What made GEO stand out for me is that everyone is so passionate about their research and their courses. Given the wide range of topics we can study, everyone is able to find their niche. Originally I was attracted to the Geosciences department because of its research on climate change; but throughout my years in the department I found my interests expand to areas I would have never even thought about before. For my own independent research projects, I worked with the archeology department to understand the chemistry of Ancient Cypriot cement, I modeled the effect of deforestation in Central America on precipitation patterns, and finally for my senior thesis I measured nitrogen isotope ratios in algae fossils to infer changes in ocean circulation at the time of the onset of the Northern Hemisphere Glaciations. Studying Geosciences at Princeton allowed me to develop my analytical skills in all the major sciences as well as to understand the interplay between the Earth systems and the importance of the Earth sciences to our society.”
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(Left) Students observe the recently collapsed arches on a 2016 trip in Ghzira Beach, Morocco.  
[GEQ 365]  
(Top center) Vivian Yao ’17 and grad student Tori Luu with Bermuda Institute of Ocean Sciences mentor, Sam de Putron, monitor water conditions of juvenile coral tanks for a coral feeding and light experiment in Bermuda. Photo by Tiffany Wardman, BIOS program  
[Sigman/BIOS]  
(Right) Waiting for the Great Geysirto eruption in southwestern Iceland. Photos by Steve Goodell  
[PUGS]
SENIOR THESIS TITLES

“EXPLORING THE RELATIONSHIPS BETWEEN MARINE CLOUD BRIGHTENING, THE WALKER CIRCULATION, AND BOREAL SUMMER ASIAN MONSOON PRECIPITATION”

“WEAK INNER CORE ANISOTROPY ALONG POLAR PATHS UNDER THE WESTERN PACIFIC OCEAN”

“INTERIOR STRUCTURE OF JUPITER’S SATELITE IO BASED ON THERMAL EQUATION OF STATE DATA”

“UNCOVERING THE SOURCES OF ELEVATED ARSENIC IN CLASSIC MAYA HUMAN REMAINS: IMPLICATIONS FROM ANTIQUITY TO MODERNITY”

“ESTIMATING ATMOSPHERIC METHANE EMISSION BY MINERAL CRYOSOLS IN THE ARCTIC REGION USING THE EXPLICIT HIGH AFFINITY METHANOTROPH (XHAM) MODEL”

“POTENTIAL SOURCES OF HEMISPHERIC ENERGETIC ASYMMETRY”

“A CALCIUM AND STRONTIUM ANALYSIS OF SHARK TEETH TO CONSTRAIN PAST OCEAN CHEMISTRY”

“SURVIVAL AND METABOLISM OF METHANOSARCINA SOLIGELIDII UNDER SIMULATED MARTIAN SUBSURFACE CONDITIONS”

“WAVE PROFILE ANALYSIS OF THE BEHAVIOR OF SiO₂ UNDER SHOCK COMPRESSION”

“ASTRONOMICALLY FORCED HYDROLOGY OF THE LATE CRETACEOUS SUB-TROPICAL POTOSI BASIN”

“CALIBRATION AND NOISE CHARACTERIZATION OF A NEWLY INSTALLED SEISMOmeter AT PRINCETON UNIVERSITY”

“MODELING THE RELATIONSHIP BETWEEN CLIMATE AND CONFLICT: NIGERIAN INTERGROUP CONFLICT, BOKO HARAM VIOLENCE, AND THE ISRAEL/PALESTINE CONFLICT”

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 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.”
“STABLE ISOTOPIC SIGNATURES IN SYMBIOTIC BERMUDA CORALS: A STUDY OF NUTRIENT AND LIGHT VARIABILITY ON $\delta^{15}$N IN PORITES ASTREOIDES AT BERMUDA”

“NUMERICAL INVESTIGATION OF THE DEPENDENCE OF TIDAL MIXING BY WAVE-WAVE INTERACTION ON TOPOGRAPHIC AND FLOW PARAMETERS”

“U-Pb TIMS-TEA GEochronology and a NEW Chronostratigraphy for the CAÑADON ASFALTO Basin, CENTRAL PATAGONIA”

“MEASURING THE CHANGING MASS OF GLACIERS ON THE TIBETAN PLATEAU USING TIME-VARIABLE Gravity FROM THE GRACE MISSION”

“WHERE THREE OCEANS MEET: NITRATE ISOTOPE MEASUREMENTS FROM THE SOUTH ATLANTIC ALONG 34.5° S”

“CONSTRAINING THE TIMING AND AMPLITUDE OF PROPOSED GLACIOEUSTASY DURING THE LATE PALEOZOIC ICE AGE WITH A CONTINUOUS CARBONATE RECORD IN SPAIN”

“ABANDONED OIL AND GAS WELLS IN PENNSYLVANIA: WELL ATTRIBUTES AND EFFECTIVE PERMEABILITY”

“TOWARDS QUANTIFYING THE RISK OF COMPOUND HEAT WAVE EVENTS: PROJECTIONS OF FREQUENCY AND SEVERITY”

“MINING METAGENOMIC DATA TO UNDERSTAND THE LIFESTYLE OF ATMOSPHERIC METHANE OXIDIZING BACTERIA IN ANTARCTIC SURFACE SOIL”

“RECONSTRUCTING FISH ECOLOGY FROM OTOLITH GEOCHEMISTRY: PAST AND PRESENT”

“ANALYSIS OF MARTIAN TOPOGRAPHY VIA A PARAMETERIZED SPECTRAL APPROACH”

“ARSENIC ADSORPTION ON Fe-OXIDES MIXED WITH Mn-OXIDES: POTENTIAL OF Fe-Mn NANOcrystalline CoATED CALCITE GRAINS FOR FILTRATION OF ARSENIC CONTAMINATED DRINKING WATER”

“AN INTER-TROPHIC EXAMINATION OF NITROGEN ISOTOPES PAST AND PRESENT”

Testimonial from Christen 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.”

“A MULTIPLE STRESSOR MODEL OF CLIMATE CHANGE EFFECTS ON GROWTH AND SURVIVAL OF LARVAL CRASSOSTREA GIGAS”

“LONG TERM DROUGHT SIGNATURE OF STANDARDIZED VEGETATION INDEX”

“AN EXAMINATION OF CLIMATE VARIABILITY AND INTERNATIONAL MIGRATION IN SUB-SAHARAN AFRICA”

“A PHYSIOLOGICAL APPROACH TO DETERMINING ECOSYSTEM PRODUCTIVITY IN THE ARCTIC”
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(Above) Students hike deep inside an underground cave in France to observe and analyse mineral formations of stalactites and stalagmites. Photo by Emily Geyman '19 [FRS].

(Left) Zoe Sims '17 and a fellow Bermuda Institute of Ocean Sciences (BIOS) intern conduct coral reef ecology surveys on nearshore Bermuda reefs that may be influenced by island groundwater discharge. Photos by GS Victoria Luu [Sigman Lab].

(Far Left) Undergrads view sedimentary rock through a hand lens on a Moroccan field trip. Photo by Prof. Gerta Keller [GEO 365].