Earth and Planetary Sciences

For students interested in studying the world beneath their feet or other worlds farther away, the Department of Earth and Planetary Sciences provides the tools for understanding the processes that shape our planet and other bodies within the solar system. Understanding the Earth system is also the key to addressing many environmental challenges, including climate change, water supply and energy issues. An Earth scientist is uniquely poised to help solve some of society's most pressing problems. Because planets are complex systems, Earth and planetary sciences is by necessity an interdisciplinary field. It applies biology, chemistry, physics and math to the investigation of topics such as early life on Earth, the structure of the Earth’s deep interior, the nature of contaminant transport, and the surfaces of other planetary bodies.

For students who have developed a passion for the basic sciences and who are looking for a way to study these sciences outside of traditional disciplinary boundaries, Earth and planetary sciences is an ideal choice of major. The department offers majors in geology, geophysics, geochemistry, and environmental Earth sciences as well as minors in Earth and planetary sciences and environmental Earth sciences. All programs offer a range of customization that allows students to focus on topics with the greatest relevance to their academic interests and career plans.

All students have the opportunity to participate in faculty research programs, although this is not required. Many of our students take advantage of these varied research opportunities, which provide them with valuable experience for future employment or for graduate school. Each year, several scientific papers and abstracts are co-authored by undergraduates, and undergraduates have presented papers at many national science meetings.

**Department Policies for Majors and Minors**

Minimum grade performance: A grade of C- (C for summer field camp) is the minimum acceptable performance for each unit of credit for each required course, including those in mathematics, chemistry and physics. Courses with grades of D may fulfill the college's 120 total hours requirement, but they do not meet the departmental requirements. A grade of C- is also the minimum acceptable performance for each unit of credit for any course required as a prerequisite to enrolling in advanced or sequential courses.

Transfer credits and University College: Course work completed at another college or university must have prior approval of the department to be used to fulfill major requirements. Courses taken at University College normally may not be substituted for the courses required for an Earth and planetary sciences major. Written consent from the director of undergraduate studies is required for any such substitutions to apply and must be sought before the course is taken.

**Graduate-level courses:** All Earth and Planetary Sciences graduate courses (i.e., courses numbered 500 and above) are open to advanced undergraduates with permission of the undergraduate adviser and the specific course instructor.

**Contact:** Philip Skemer, Director of Undergraduate Studies
Phone: 314-935-3584
Email: pskemer@wustl.edu
Website: http://eps.wustl.edu

**Faculty**

**Chair**
Viatcheslav S. Solomatov (https://eps.wustl.edu/people/slava-solomatov)
PhD, Moscow Institute of Physics and Technology

**Endowed Professors**
Raymond E. Arvidson (https://eps.wustl.edu/people/raymond-e-arvidson)
James S. McDonnell Distinguished University Professor
PhD, Brown University

Bradley L. Jolliff (https://eps.wustl.edu/people/bradley-l-jolliff)
Scott Rudolph Professor of Earth and Planetary Sciences
PhD, South Dakota School of Mines and Technology

Douglas A. Wiens (https://eps.wustl.edu/people/douglas-wiens)
Robert S. Brookings Distinguished Professor
PhD, Northwestern University

**Professors**
Jeffrey G. Catalano (https://eps.wustl.edu/people/jeffrey-g-catalano)
PhD, Stanford University

Robert F. Dymek (https://eps.wustl.edu/people/robert-f-dymek)
PhD, California Institute of Technology

M. Bruce Fegley (https://eps.wustl.edu/people/m-bruce-fegley)
PhD, Massachusetts Institute of Technology

David A. Fike (https://eps.wustl.edu/people/david-fike)
PhD, Massachusetts Institute of Technology

William B. McKinnon (https://eps.wustl.edu/people/william-b-mckinnon)
PhD, California Institute of Technology

Jill D. Pasteris (https://eps.wustl.edu/people/jill-d-pasteris)
PhD, Yale University
There are four majors in this department:

- Geology (p. 2)
- Geophysics (p. 3)
- Geochemistry (p. 3)
- Environmental Earth Sciences (p. 4)

For the most current information, visit the Department of Earth and Planetary Sciences website (http://eps.wustl.edu/undergraduate).

All majors are required to complete a capstone experience during their junior or senior year. Information regarding the capstone experience (https://eps.wustl.edu/capstone-experiences) can be found on the departmental website. The majors in Earth and planetary sciences focus on the application of chemistry, biology and physics to Earth and planetary sciences and on the nature of planets, their resources and their relationships to human activity. The curriculum is broad, and the requirements are flexible enough to accommodate diverse needs and interests. Many courses present hands-on, problem-oriented experiences, including ample opportunity for fieldwork, laboratory work, and the use of state-of-the-art computational facilities and research instrumentation.

The Major in Geology

Geology addresses the formation processes, spatial organization, tectonic origins, age and chemistry of rocks on Earth and other planets. In addition to other requirements, geology track students take EPSc 437 Introduction to Petrology and a 6-credit field camp.

Core courses: EPSc 201 Earth and the Environment, EPSc 352 Earth Materials, EPSc 353 Earth Forces and EPSc 437 Introduction to Petrology

Additional required course work: Chem 105, Chem 106 (or Chem 111A, Chem 112A); Math 131, Math 132, Math 233; Physics 191, Physics 192

Electives: At least four courses must be selected from those listed below, with at least three in Geology and one in Geophysics & Remote Sensing or Geochemistry.

Geology: EPSc 361 Structural Geology, EPSc 385 Earth History, EPSc 386 The Earth's Climate System, EPSc 400 Topics in the Geosciences, EPSc 409 Surface Processes, EPSc 413 Introduction to Soil Science, EPSc 422 Sedimentary Geology, EPSc 429 Environmental Hydrogeology, EPSc 430 Environmental Mineralogy, EPSc 473 Planetary Geology

Geochemistry: EPSc 323 Biogeochemistry, EPSc 401 Earth Systems Science, EPSc 441 Introduction to Geochemistry, EPSc 444 Environmental Geochemistry, EPSc 445 Organic Geochemistry, EPSc 446 Stable Isotope Geochemistry, EPSc 474 Planetary Geochemistry, EPSc 486 Paleoclimatology

Capstone experience: All majors are required to complete a capstone experience during their junior or senior year.

Field camp: Students must complete an approved geology field camp worth at least 6 units of credit. The field camp must be attended during the summer, after either the junior or the senior year. It is important to take the appropriate courses (usually listed by the camp) before attending the field camp.

Senior Honors (optional): A thesis is required for Senior Honors (https://eps.wustl.edu/honors-and-distinctions); please visit the departmental website for details.

The Major in Geophysics

Geophysics uses methods of physics to understand the structure and evolution of the Earth and other planets. In addition to other requirements, geophysics students must take courses in differential equations and matrix algebra. These are prerequisites for most advanced-level geophysics courses that are available to the geophysics students.

Core courses: EPSc 201 Earth and the Environment, EPSc 352 Earth Materials and EPSc 353 Earth Forces

Additional required course work: Chem 105, Chem 106 (or Chem 111A, Chem 112A); Math 131, Math 132, Math 233, Math 217, Math 309; Physics 191, Physics 192

Electives: At least four courses must be selected from those listed below, with at least three in Geophysics & Remote Sensing and one in Geology or Geochemistry.

Geology: EPSc 361 Structural Geology, EPSc 385 Earth History, EPSc 386 The Earth's Climate System, EPSc 400 Topics in the Geosciences, EPSc 409 Surface Processes, EPSc 413 Introduction to Soil Science, EPSc 422 Sedimentary Geology, EPSc 429 Environmental Hydrogeology, EPSc 430 Environmental Mineralogy, EPSc 437 Introduction to Petroleum, EPSc 473 Planetary Geology

Geochemistry: EPSc 323 Biogeochemistry, EPSc 401 Earth Systems Science, EPSc 441 Introduction to Geochemistry, EPSc 444 Environmental Geochemistry, EPSc 445 Organic Geochemistry, EPSc 446 Stable Isotope Geochemistry, EPSc 474 Planetary Geochemistry, EPSc 486 Paleoclimatology


Capstone Experience: All majors are required to complete a capstone experience during their junior or senior year.

Senior Honors (optional): A thesis is required for Senior Honors (https://eps.wustl.edu/senior-honors); please visit the departmental website for details.

The Major in Geochemistry

Geochemistry uses methods of chemistry to understand the chemical composition of the Earth and other planets. In addition to other requirements, geochemistry track students take EPSc 441 Introduction to Geochemistry and one additional math course either in differential equations, matrix algebra, or probability and statistics. These are prerequisites for the advanced-level geochemistry courses that are available to the geochemistry students.

Core courses: EPSc 201 Earth and the Environment, EPSc 352 Earth Materials, EPSc 353 Earth Forces and EPSc 441 Introduction to Geochemistry

Additional required course work: Chem 105, Chem 106 (or Chem 111A, Chem 112A); Math 131, Math 132, Math 233, and either Math 217 or Math 309 or Math 2200 or Math 3200; Physics 191, Physics 192

Electives: At least four courses must be selected from those listed below, with at least three in Geochemistry and one in Geology or Geophysics & Remote Sensing.

Geology: EPSc 361 Structural Geology, EPSc 385 Earth History, EPSc 386 The Earth's Climate System, EPSc 400 Topics in the Geosciences, EPSc 409 Surface Processes, EPSc 413 Introduction to Soil Science, EPSc 422 Sedimentary Geology, EPSc 429 Environmental Hydrogeology, EPSc 430 Environmental Mineralogy, EPSc 437 Introduction to Petroleum, EPSc 473 Planetary Geology

Geochemistry: EPSc 323 Biogeochemistry, EPSc 401 Earth Systems Science, EPSc 441 Introduction to Geochemistry, EPSc 444 Environmental Geochemistry, EPSc 445 Organic Geochemistry, EPSc 446 Stable Isotope Geochemistry, EPSc 474 Planetary Geochemistry, EPSc 486 Paleoclimatology, EPSc 511 Minerals in Aqueous Environments, EPSc 545 Radiogenic Isotope Geochemistry, EPSc 569 Thermodynamics & Phase Equilibria, EPSc 571 Meteorites


Capstone experience: All majors are required to complete a capstone experience during their junior or senior year.

Senior Honors (optional): A thesis is required for Senior Honors (https://eps.wustl.edu/senior-honors); please visit the departmental website for details.
The Major in Environmental Earth Sciences

The environmental Earth sciences major provides students with a grounding in the geosciences, forming a basis for the interdisciplinary study of critical environmental topics. Student understanding of environmental science is fostered both by a broad base of course work across the natural sciences and by the unique context and perspective Earth science provides for the complexity of environmental systems.

Core courses: Phil 235F Introduction to Environmental Ethics or Pol Sci 2010 Introduction to Environmental Policy, Biol 2950, EPSc 201 Earth and the Environment, EPSc 323 Biogeochemistry, EPSc 336 Minerals and Rocks in the Environment or EPSc 352 Earth Materials, EPSc 413 Introduction to Soil Science

Additional required course work: Chem 105, Chem 106 (or Chem 111A, Chem 112A); Math 131, Math 132, Physics 191

Electives (choose seven, at least three of which must be from EPSc):

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>Anthro 3322</td>
<td>Brave New Crops</td>
<td>3</td>
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<td>Anthro 361</td>
<td>Culture and Environment</td>
<td>3</td>
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<tr>
<td>Biol 2960</td>
<td>Principles of Biology I</td>
<td>4</td>
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<tr>
<td>Biol 2970</td>
<td>Principles of Biology II</td>
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<tr>
<td>Biol 349</td>
<td>Microbiology</td>
<td>4</td>
</tr>
<tr>
<td>Biol 381</td>
<td>Introduction to Ecology</td>
<td>3</td>
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<tr>
<td>Biol 419</td>
<td>Community Ecology</td>
<td>4</td>
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<tr>
<td>Biol 4193</td>
<td>Experimental Ecology Laboratory</td>
<td>4</td>
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<tr>
<td>Biol 4810</td>
<td>General Biochemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 261</td>
<td>Organic Chemistry I with Lab</td>
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<tr>
<td>Chem 401</td>
<td>Physical Chemistry I</td>
<td>3</td>
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<tr>
<td>Econ 451</td>
<td>Environmental Policy</td>
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<td>EECE 210</td>
<td>Introduction to Environmental Engineering</td>
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<td>EECE 531</td>
<td>Environmental Organic Chemistry</td>
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<td>EnSt 3068</td>
<td>An Inconvenient Truth: The Human History of Climate Change</td>
<td>3</td>
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<tr>
<td>EnSt 380</td>
<td>Applications in GIS</td>
<td>3</td>
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<td>EnSt 539</td>
<td>Interdisciplinary Environmental Clinic max</td>
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<td>EPSc 219</td>
<td>Energy and the Environment</td>
<td>3</td>
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<tr>
<td>EPSc 308</td>
<td>Topics in Environmental Sustainability</td>
<td>3</td>
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<tr>
<td>EPSc 319</td>
<td>Physical Oceanography</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 353</td>
<td>Earth Forces</td>
<td>4</td>
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<tr>
<td>EPSc 361</td>
<td>Structural Geology</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 385</td>
<td>Earth History</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 386</td>
<td>The Earth's Climate System</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 401</td>
<td>Earth Systems Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 407</td>
<td>Remote Sensing</td>
<td>3</td>
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<tr>
<td>EPSc 408</td>
<td>Earth's Atmosphere and Global Climate</td>
<td>3</td>
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<tr>
<td>EPSc 409</td>
<td>Surface Processes</td>
<td>4</td>
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<tr>
<td>EPSc 422</td>
<td>Sedimentary Geology</td>
<td>4</td>
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<tr>
<td>EPSc 428</td>
<td>Hydrology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 429</td>
<td>Environmental Hydrogeology</td>
<td>3</td>
</tr>
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<td>EPSc 430</td>
<td>Environmental Mineralogy</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 441</td>
<td>Introduction to Geochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 444</td>
<td>Environmental Geochemistry</td>
<td>3</td>
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<tr>
<td>EPSc 445</td>
<td>Organic Geochemistry</td>
<td>3</td>
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<tr>
<td>EPSc 446</td>
<td>Stable Isotope Geochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 454</td>
<td>Exploration and Environmental Geophysics</td>
<td>4</td>
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<tr>
<td>EPSc 486</td>
<td>Paleoclimatology</td>
<td>3</td>
</tr>
<tr>
<td>Math 217</td>
<td>Differential Equations</td>
<td>3</td>
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<tr>
<td>Math 2200</td>
<td>Elementary Probability and Statistics</td>
<td>3</td>
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<tr>
<td>Math 233</td>
<td>Calculus III</td>
<td>3</td>
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<tr>
<td>Math 309</td>
<td>Matrix Algebra</td>
<td>3</td>
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<tr>
<td>Math 3200</td>
<td>Elementary to Intermediate Statistics and Data Analysis</td>
<td>3</td>
</tr>
<tr>
<td>Pol Sci 332B</td>
<td>Environmental and Energy Issues</td>
<td>3</td>
</tr>
</tbody>
</table>

Capstone experience: All majors are required to complete a capstone experience during their junior or senior year.

Senior Honors (optional): A thesis is required for Senior Honors (https://eps.wustl.edu/senior-honors); please visit the departmental website for details.

Minors

The Minor in Earth and Planetary Sciences

A minor in Earth and planetary sciences (EPS) consists of at least 16 units of EPS courses, including EPSc 201 Earth and the Environment, EPSc 352 Earth Materials and EPSc 353 Earth Forces. At least one additional EPS course numbered 300 or above, not including EPSc 390 Independent Study and EPSc 490 Independent Study, is required.

A faculty adviser is assigned to each student at the time that the minor is declared. Minor programs must be approved by the student’s minor adviser. The grades and performance policy for the EPS major applies to all course work required for the EPS minor program. The department requirements also meet those for a minor as defined by the College of Arts & Sciences.
The Minor in Environmental Earth Sciences

The minor in environmental Earth sciences (EES) is an attractive option for students majoring in a variety of other fields. The growing national concern for the natural environment and natural resources means that an EES minor is also valuable professionally to students who intend to pursue these and other fields, including law and architecture. Following the philosophy of the EES major, the minor combines interdisciplinary with a solid grounding in Earth science.

A minor in environmental Earth sciences consists of three core courses, EPSc 201 Earth and the Environment, Biol 2950 Introduction to Environmental Biology, and Pol Sci 2010 Introduction to Environmental Policy or Phil 235F Environmental Ethics. It also includes at least three elective courses from the following list:

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>EPSc 308</td>
<td>Topics in Environmental Sustainability</td>
<td>3</td>
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<tr>
<td>EPSc 323</td>
<td>Biogeochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 336</td>
<td>Minerals and Rocks in the Environment</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 352</td>
<td>Earth Materials (5 credits, counts as 2 courses)</td>
<td>5</td>
</tr>
<tr>
<td>EPSc 353</td>
<td>Earth Forces</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 385</td>
<td>Earth History</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 386</td>
<td>The Earth's Climate System</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 401</td>
<td>Earth Systems Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 413</td>
<td>Introduction to Soil Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 428</td>
<td>Hydrology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 429</td>
<td>Environmental Hydrogeology</td>
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<td>EPSc 430</td>
<td>Environmental Mineralogy</td>
<td>3</td>
</tr>
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<td>EPSc 444</td>
<td>Environmental Geochemistry</td>
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</tr>
<tr>
<td>EPSc 486</td>
<td>Paleoclimatology</td>
<td>3</td>
</tr>
</tbody>
</table>

A faculty adviser is assigned to each student at the time that the minor is declared. Minor programs must be approved by the student’s minor adviser. The grades and performance policy for EPS and EES majors applies to all course work required for the EES minor program. The department requirements also meet those for a minor as defined by the College of Arts & Sciences.

Courses


L19 EPSc 100A Environmental Geology
Examines the interaction between Earth system and processes with human activities and how solutions can be developed to address environmental problems. Broad topics include: Earth materials, resources, pollution, geologic hazards and global climate change. No prerequisite needed for this class, and is suitable for students with little or no background in Earth or environmental science. Homework assignments or case study discussions will help students make vital connections between class concepts and real-world scenarios. There will also be 1-2 day field trips designed to help students develop field observation and data collection skills.
Credit 3 units. A&S IQ: NSM: Art: NSM BU: SCI

L19 EPSc 103A Oceanography
Emphasis on geological, chemical and physical oceanography. Topics: topography and origin of ocean basins; origin and composition of sea water; effect of compositional variations on biological productivity; dynamics of water movements, including coastal processes.
Credit 3 units. A&S IQ: NSM: Art: NSM BU: SCI

L19 EPSc 104 First-Year Seminar: Geology in the Field
This course is designed to develop foundational skills in field geology and Earth science while promoting leadership and teamwork. There are no prerequisites, and the class is suitable for students with little or no academic background in Earth science. Students are not required to have extensive outdoor experience, but they must demonstrate enthusiasm for work in challenging environments. Students will receive training in a variety of geological field methods, including field mapping; sampling protocols; section measurement; and structural identification and analysis. This course is field-intensive, with multiple field exercises during class periods and two to three weekend field trips that will involve camping, caving, and backcountry hiking. This course is primarily suited for students who enjoy working outdoors and who intend to major in Earth and Planetary Sciences, Biology, Anthropology, or Archaeology. Course enrollment preference is given to first-year students.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 105 First-Year Seminar: Habitable Planets
Why does the Earth have water oceans? Where did our atmosphere come from? Is Earth uniquely habitable among solar system bodies? This course is an exploration of the origins of volatiles such as water and carbon on planetary bodies and of the internal features that help to regulate our planet’s surface conditions. The importance of magnetic fields, plate tectonics, and climate feedbacks with respect to the origins and sustenance of life on Earth will be discussed. This course is for first-year, non-transfer students only.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 106 First-Year Opportunity: Exploring the Planets
Each week a different faculty member presents a lecture or laboratory demonstration relating to recent discoveries in geology and the planetary sciences, or about general topics dealing with volcanism, earthquakes, plate tectonics, geological hazards, fossil life or earth history. Prerequisite: freshman standing or sophomore standing with permission of instructor.
L19 EPSc 131 Natural Disasters
Examination of the effects of natural hazards on landscapes of the Earth in general, as well as on populated areas specifically, through numerous case studies. Social, economic and political consequences of natural disasters. Locations, particularly in the United States, where disasters are likely to occur in the future. Nature of the hazards and what preparations are possible to minimize damage and the number of casualties.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPSc 140 First-Year Seminar: Geology and Human Health
This course explores the connections between human health and geological processes. Key concepts in geology are introduced as well as the pathways through which natural systems affect human health. A series of case studies will be presented, each describing a specific health hazard and its geological origin. The first set of studies will focus on human health effects associated with windborne exposure to harmful materials, including volcanic emissions, asbestos, dust and aerosols, and the products of coal combustion. The course will then use the topic of mercury, which is emitted into the atmosphere and then accumulates in aquatic systems, to transition to water and soil borne pathways of exposure. This will be followed by case studies exploring water availability and quality, arsenic in groundwater, with a special emphasis on widespread arsenic poisoning in South and Southeast Asia, lead in mining areas and urban soils, and radon and radioactive materials. Students will conduct team risk assessment projects as well as an individual project.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 171A The Solar System
Survey of the planets and satellites of our solar system. Includes results from Apollo manned missions to the Moon and spacecraft missions to the planets and their major satellites. Present ideas about the age, formation and early history of the sun, Earth and meteorites.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 201 Earth and the Environment
Introduction to the study of the Earth as a dynamic, evolving planet. Emphasis on how internal and surface processes combine to shape the environment. Themes: Earth’s interior as revealed by seismic waves; Earth history and global tectonics shown by changes to ocean floors, mountain-building, formation of continents, earthquakes and volcanism; climate history and global biogeochemical cycles, influenced by circulation of atmosphere and oceans, ice ages and human activity. Composition and structure of rocks and minerals. Part of the introductory sequence of courses for all Earth and Planetary Sciences and Environmental Studies majors. Three class hours and one two-hour lab a week.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 219 Energy and the Environment
Examination of the topic of energy from many human-relevant perspectives. Humans use an enormous amount of energy, at the rate of 18 terawatts. Where does this energy come from? How long will it last? What are the consequences? Examination of energy resources and consumption from scientific, social, economic and political viewpoints. Relationship of energy to
concepts such as heat, work and power. Energy use by society. Energy sources, pros and cons of use, availability now and in the future. Types, abundance, advantages, challenges of renewable energy sources. Prerequisite: one year of high school physics or chemistry.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPsc 221A Human Use of the Earth
Examination of the impacts of a growing population on the Earth, including habitat destruction, resource depletion, and air and water pollution. Population growth, landscape change, and the distribution and uses of the water, mineral and energy-producing resources of the Earth.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPsc 308 Topics in Environmental Sustainability
Mathematical sustainability models: ocean, atmospheric, wetland, agricultural, hydrological, and energy sustainability; depletion of non-renewable resources; effects of pollution, human population, urban environment. Prerequisite: Chem 111A and Chem 112; or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPsc 319 Physical Oceanography
Ocean circulation, El Niño, dynamical lides, tsunami, coastal ocean, enclosed seas, paleo-ocean, sedimentation, ice-atmosphere-ocean interaction, biology-carbon cycle. Prerequisites: Chem 112A, Physics 118A, Math 133; or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPsc 323 Biogeochemistry
Basic concepts of how elements cycle among the Earth's crust, the oceans, and the atmosphere, including perturbations due to human activities. Carbon, nitrogen, phosphorus, sulfur, and water cycles. Isotopic tracers. Feedbacks, forcings, and residence times. Redox cycling and thermodynamics. Biogeochemical box models and changes in biogeochemical cycles over Earth's history. Biogeochemistry of greenhouse gases, biogeochemical feedbacks in the climate system. This course is appropriate for EPS students, engineering students, environmental science majors, and other students with interest in the environmental or geological sciences.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPsc 336 Minerals and Rocks in the Environment
Combined rock and mineral course with focus on environmental issues and applications. Introduction to mineralogic and petrologic concepts relevant to environmental geoscience pursuits. Foundations of mineralogy and crystallography, key mineral groups, foundations of igneous, sedimentary, and metamorphic rock systems. Mineralogy of environmental systems such as soils, marine environments, aerosols, mines and radioactive wastes. Overview of analysis methods used for environmental geoscience applications. One full-day field trip required. Prerequisites: EPSc 201, Chem 111A or AP Chem score of 4; or permission of instructor. Both EPS 336 and EPS 352 may be taken for credit, but only one may count toward the EPS or EES majors and minors.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPsc 352 Earth Materials
Fundamental principles of crystal chemistry; symmetry and structure of crystals (minerals); X-ray analysis of crystalline materials; information on the important mineral groups (definition of the groups; composition, structure, physical properties, occurrence and usage of major mineral species); optical mineralogy. Geological and environmental aspects of earth materials. Prerequisites: EPSc 201 (may be taken concurrently) and Chem 112A (or AP Chem score of 4); or permission of instructor. Both EPS 352 and EPS 336 may be taken for credit, but only one may count toward the EPS or EES majors or minors. Three class hours, one two-hour laboratory, and one two-hour discussion period a week.
Credit 5 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPsc 353 Earth Forces
Basic concepts regarding the forces that act upon the Earth, how geological materials react to these forces, and the time scale over which they respond. Emphasis on physical concepts needed to understand the geodynamical behavior of the Earth over a broad range of length and time scales. Application and interpretation of geophysical methods to probe the interior of the Earth. Prerequisite: EPSc 201 (may be taken concurrently), Phys 117A (or Phys 197); or permission of instructor. Three class hours and one two-hour laboratory a week.
Credit 4 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPsc 361 Structural Geology
The landforms that surround us are constantly being modified by tectonic forces. Structural geology provides a framework for investigating, describing, and quantifying these changes. This course will provide an introduction to the structures that form at all scales, from millimeter-sized fractures to rifts in Earth's lithosphere thousands of kilometers long. Through the study of these features and processes that form them, students will gain a fundamental understanding of the physical evolution of our planet. Topics will include descriptive analysis of microscopic and macroscopic structures, field methods, the physical bases for rock deformation, and global tectonics. Prerequisites: EPSc 201 Earth and the Environment.
Credit 4 units. A&S IQ: NSM BU: SCI

L19 EPsc 385 Earth History
Introduction to the concept of “deep time” and the parallel biological evolutionary and environmental changes that have occurred throughout Earth history. Topics include early evolution of life, rise of atmospheric oxygen, global glaciation, mass extinctions. Prerequisite: EPSc 201 or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPsc 386 The Earth's Climate System
This course introduces an integrative view of the Earth’s climate system and its coupled components — the atmosphere, the oceans, the cryosphere, the biosphere, and the geosphere — and how they interact with each other. The goal is to provide the physical scientific background that is needed to understand climate variability and climate change, both natural and anthropogenic. Topics include energy balance; the general circulation of the atmosphere and the oceans; the greenhouse effect; modes of variability, such as El Nino; geologic-scale climate change in the geologic past; climate models; climate change detection and attribution; the projection of future climates; and societal impacts. In addition to lectures, students will gain hands-on experience analyzing and interpreting real
datasets through inquiry-based "practicum" exercises and in-class discussions. Prerequisite: EPS 201 or permission of the instructor.
Credit 3 units. A&S IQ: NSM Art: NSM Bu: SCI

L19 EPSc 390 Independent Study
Independent study for undergraduates, to be supervised by a faculty member. Prerequisite: permission of instructor. Credit to be determined.
Credit variable, maximum 3 units. Art: NSM

L19 EPSc 400 Topics in the Geosciences
The content of this course varies each time it is offered, as announced by the department. With permission of the adviser, this course may be repeated for credit. Prerequisite: permission of instructor.
Credit variable, maximum 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 401 Earth Systems Science
This is a quantitative introduction to physical and chemical interactions among the atmosphere, oceans and solid earth. Topics covered include terrestrial atmospheric chemistry, geochemical cycles, inventories, and reservoirs of carbon, nitrogen, and sulfur, and bulk composition of the Earth. Prerequisite: EPS 336 or 352 or permission of instructor or the graduate adviser.
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 404 Ideas and Controversies In the Geosciences
Great ideas and controversies in the geological sciences and how ideas change and become accepted in science. The format is part lecture, part discussion. Writing and oral presentation are emphasized. Students read primary sources, as well as books, journals and Web-based historical accounts and interpretations. Among the topics addressed are: continental drift and plate tectonics, development of the geological time scale, age of the earth, mass extinctions and the Snowball Earth hypothesis. Prerequisites: EPS 352 and EPS 353 (may be taken concurrently) or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM WI: NSM

L19 EPSc 407 Remote Sensing
Use of different parts of the electromagnetic spectrum (visible, ultraviolet, infrared, and radio wavelengths) for interpretation of physical and chemical characteristics of the surfaces of Earth and other planets. Digital image systems and data processing. Prerequisite: Physics 118A or Physics 197; or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 408 Earth's Atmosphere and Global Climate
Structure and dynamics of Earth's atmosphere. Basic factors controlling global climate of Earth. Quantitative aspects of remote sensing of atmosphere. Remote sensing instrumentation. Prerequisites: Math 233 and Physics 117A (or Physics 197), or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 409 Surface Processes
How do landscapes evolve? Examination of chemical and physical processes that modify earth's surface. Introduction to soil formation. Focus on modern systems, particularly fluvial, karst and desert terrains. Brief discussion of coastal and glacial systems. Human agency in geomorphic change. Lab covers survey techniques for acquisition of topographic data and use of geographic information systems for geomorphic and hydrologic analysis. Field trips required. Prerequisite: EPS 352 or permission of instructor. Three class hours and one three-hour lab a week.
Credit 4 units. A&S IQ: NSM Art: NSM Bu: SCI

L19 EPSc 410 Earth Remote Sensing Methods and Instrumentation
Detection of electromagnetic radiation reflected, scattered or emitted by components of the Earth system. Spectroscopy of remote sensing. Interpretation of received radiation via radioactive transfer within a context of real measurements. Theory of instruments and detectors. Comparison of realized equipment to theoretical models. Prerequisite: Physics 118A, Chem 112A (or AP Chem score of 4), Math 233, or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM Bu: SCI

L19 EPSc 413 Introduction to Soil Science
Physical, chemical and biological processes that occur within soil systems. Types of soils and how these relate to soil formation. Major components of soil, including soil water, minerals, organic matter and microorganisms. Soils in wetlands and arid regions. Cycling of nutrients and contaminants in soils. Soil quality, conservation and sustainability. Two one-day field trips required. Prerequisite: EPS 323 or Chem 112A (or AP Chem score of 4), or permission of instructor.
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 422 Sedimentary Geology
Survey introduction to sedimentary processes and materials, including description, formation and interpretation. Sedimentary materials account for most of the Earth's crust, and much of our understanding of Earth history comes from their examination. Many of our economic resources, such as coal, oil and natural gas, and many environmental problems, are related to or derive from sediments. Goals: understanding and identifying sediments and processes and using them to interpret stratigraphic, paleoenvironmental and tectonic information; obtaining the understanding of sedimentology that is relevant to environmental issues; increasing scientific literacy and critical thinking. Prerequisites: EPS 201 or permission of instructor. Three class hours and one two-hour lab a week. Mandatory field trips.
Credit 4 units. A&S IQ: NSM Art: NSM

L19 EPSc 425 Invertebrate Paleontology
Study of fossil invertebrates with emphasis on morphology of hard parts, geochronological and geographical distribution, and taxonomy. Comparison of fossil taxa with living representatives and interpretation of paleobiological patterns. Two class hours and one two-hour lab a week. Prerequisite: EPSc 200A or permission of instructor.
Credit 3 units. Art: NSM

L19 EPSc 428 Hydrology
Survey of principles that govern the flow of water in river and groundwater systems in deep geologic environments. Basic equations of fluid flow, dynamics, and the characteristics of drainage basins, rivers, floods, and important aquifers.
L19 EPSc 429 Environmental Hydrogeology
Introduction to principles that govern the flow and geochemistry of water in river and shallow groundwater systems. Characteristics of drainage basins, rivers, floods and important aquifers. Anthropogenic impact on fresh water systems and efforts to remediate damaged systems. Prerequisite: EPSc 201 or permission of instructor. Fulfills the Natural Systems elective requirement for Master of Landscape Architecture students. Both EPS 428 and EPS 429 may be taken for credit, but only one may count toward the EPS or EES majors and minors. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 430 Environmental Mineralogy
Topics connected with environmental mineralogy, some selected by students. Topics may include: mineral dust such as asbestos; containment materials for nuclear waste disposal; environmental ramifications of the processing and use of phosphate fertilizers; lead in the environment; acid mine drainage; microbial mediation of sulfide oxidation; minerals in the human body; weathering of building materials; materials engineering; and engineering of materials for more effective recycling. Three class hours and one two-hour laboratory a week. Participation in discussions, term paper, two field trips required. Most readings from primary sources. Prerequisite: EPSc 352 or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 437 Introduction to Petrology
Classification, origin, mineralogy and geological occurrence of major igneous and metamorphic rocks. Laboratory emphasis on identification of rocks and minerals in hand specimens and in thin sections. Prerequisite: EPSc 352 or permission of instructor. Three class hours and one two-hour laboratory a week. Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 441 Introduction to Geochemistry
Application of the principles of nuclear and physical chemistry to problems of the composition and differentiation of the Earth. Introduction to nucleosynthesis of the elements, stellar evolution, the periodic properties of the elements, chemical bonding and ionic substitution, geochronology and stable isotope geochemistry, and the age and composition of the Earth, moon and meteorites. Prerequisites: EPSc 201 and Chem 112A (or AP Chem score of 4), or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 443 Methods in Biogeochemistry
Lab-based course to provide theoretical understanding of, and practical experience in, biogeochemistry tools and techniques. Topics introduced through lecture and discussion of classic scientific papers. Hands-on experience applying techniques in the laboratory. Research project, based on data collected using these techniques, required. Students develop understanding of tools used for modern and ancient biogeochemistry research. Hands-on experience with sample preparation, operation of gas source mass spectrometers, and data analysis. Prerequisite: EPSc 323 or permission of instructor. Credit 3 units. A&S IQ: NSM

L19 EPSc 444 Environmental Geochemistry
Introduction to the geochemistry of natural waters and the processes that alter their composition. Key principles of aqueous geochemistry and their application to describe the main controls on the chemistry of pristine and polluted soil, surface and groundwater environments. Acids and bases; mineral solubility; carbonate chemistry; chemical speciation; redox reactions adsorption and ion exchange; and the speciation, mobility and toxicity of metals. Prerequisite: EPSc 201 and Chem 112A (or AP Chem score of 4), or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM BU: SCI

L19 EPSc 445 Organic Geochemistry
Introduction to the composition and analysis of organic material in the environment and geological record. Molecular to global-level perspective of organic matter cycling, reactivity and fluxes; formation and classification of organic matter, its preservation potential, diagenesis, catagenesis and kerogen formation; coal, petroleum, and gas formation and accumulation; biomarkers in Earth history; genetics and phylogeny of biomarker compounds; overview of analytical techniques including both structural and isotopic aspects; oceanographic and paleoenvironmental applications of organic biomarkers; contaminants and residue analysis. Prerequisites: EPSc 201 and Chem 112A; or permission of instructor. Credit 3 units. A&S IQ: NSM

L19 EPSc 446 Stable Isotope Geochemistry
Applications of equilibrium and kinetic isotope fractionation and material balance principles to the distribution of oxygen and hydrogen isotopes in natural systems. Geothermometry and paleotemperatures, mass spectrometry, isotopic hydrology and ice cores, fluid-rock interaction, igneous rocks and meteorites. Prerequisites: EPSc 441 and Math 233, or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 452 Introduction to Seismology
Introduction to earthquake and exploration seismology. Seismic wave propagation, data analysis and processing, earthquake mechanisms, seismic constraints on the structure of the Earth, relationship of seismicity to plate tectonics. Prerequisites: EPSc 353 and Math 217, or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 453 Interior of the Earth
Composition and temperature of Earth's mantle and core, determined by geophysical methods. Inferences about mantle and core dynamics, especially interactions. Current understanding and history of interior in fields of seismology, geomagnetism, mineral physics, geodynamics. Prerequisite: EPSc 353 or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 454 Exploration and Environmental Geophysics
Basic geophysical techniques used in exploration and environmental geophysics, emphasizing seismic and electromagnetic methods. Basic theory, field procedures, and interpretation of data. Use of geophysical instruments on field trips, followed by reduction and analysis of acquired data. Prerequisites: EPSc 353, Phys 117A (or Phys 197), Math 132; or permission of instructor. Two class hours and one two-hour
laboratory a week, and approximately four one-day field trips during the semester.
Credit 4 units. A&S IQ: NSM Art: NSM

L19 EPSc 459 Geodynamics
Fundamental physical processes necessary to understand plate tectonics and a variety of geological phenomena. Heat flow, gravity, elasticity and flexure, rheology of Earth materials. Prerequisites: EPSc 353, Math 217; or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 460 Introduction to Structural Geology
Stress, strain, rheology, ductile and brittle deformation processes and structures from microscale to macroscopic. Applications to tectonics and whole Earth structure. Labs cover stress/strain analysis, experimental rock deformation, field techniques, interpretation of geologic maps and cross sections. Prerequisites: EPSc 352 and EPSc 353 or permission of instructor. Three hours of lecture and one two-hour laboratory a week. Credit 4 units. A&S IQ: NSM Art: NSM

L19 EPSc 473 Planetary Geology
Discussion of the evolution of the terrestrial planets and the outer-planet satellites as evidenced by the geologic records left on the surfaces of these bodies. Focus on major processes affecting planetary surfaces: impact cratering, volcanism, tectonism, and erosion and sedimentation by wind and water. Prerequisites: EPSc 352 and EPSc 353, or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 474 Planetary Geochemistry
A survey of the geochemistry of the planets and their satellites using data from Earth-based, Earth-orbital and spacecraft observations. Prerequisite: EPSc 352 or permission of instructor. Credit 3 units. A&S IQ: NSM Art: NSM

L19 EPSc 486 Paleoclimate
The history of Earth's changing climates and environments on timescales from decades to millions of years. Key concepts in paleoclimate include: external factors affecting the climate system (e.g., orbital cycles, volcanic eruptions, greenhouse gases); internal feedbacks, such as with monsoons and the El Nino-Southern Oscillation; abrupt versus gradual change; interactions with the biosphere (including hominins/humans); and comparison to present-day climate change. Current controversies in paleoclimate. EPS 201 or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 490 Independent Study
Independent study for advanced undergraduates or for graduate students, supervised by a faculty member. Prerequisite: permission of instructor. Credit variable, maximum 12 units.

L19 EPSc 492 Field Camp
Practical methods of data collection and interpretation in Earth and Planetary Sciences. Content may include field-based geologic mapping or laboratory-based studies emphasizing particular analytical tools. Prerequisite: permission of major adviser. Credit variable, maximum 6 units. A&S IQ: NSM

L19 EPSc 493 Internship
Internship experience in Earth and Planetary Sciences, providing learning opportunities with future careers and employers. Direct supervision by approved partner, with oversight by Earth and Planetary Sciences faculty. Prerequisite: permission of major adviser. Credit variable, maximum 6 units.

L19 EPSc 494 Study Abroad
Studies related to Earth and Planetary Sciences conducted with external institutions. Prerequisite: permission of Department Study Abroad Coordinator. Credit variable, maximum 6 units.

L19 EPSc 496 Undergraduate Field Geology
Hands-on application of geological field methods, providing an opportunity for students to synthesize classroom knowledge in a field setting. Students will develop the ability to recognize and analyze Earth processes, and deconstruct complex regional geology. Participation in an extended international field trip during spring break is required. Students must be prepared for an intensive, group-oriented experience. Prerequisite: must be an Earth and Planetary Sciences major and have permission of instructors. Enrollment is limited, and students will be selected through a written application. May be repeated for credit, with instructor permission. Juniors and seniors may use to fulfill Capstone experience. Credit 3 units.

L19 EPSc 498 Undergraduate Research Seminar
Provides an opportunity for advanced undergraduates to synthesize many of the diverse subdisciplines of Earth and Planetary Sciences while focusing on a research topic. Subject changes each offering. Each subject is unique and timely, but broad enough to encompass wide-ranging interests among students. Students conduct original research, make written reports of the results, and make oral presentations of their projects in class. Prerequisite: senior standing or permission of instructor. Credit 3 units. A&S IQ: NSM, WI Art: NSM

L19 EPSc 499 Honors Research
Independent work for undergraduate Honors, supervised by a faculty member. Prerequisites: senior standing, eligibility for Honors and permission of instructor. Credit 3 units. Art: NSM