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. Earth, environmental, and planetary scientists are 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 and minors in Earth Science, Environmental Science, and Planetary Science. 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 acceptable performance: A grade of C- 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 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 and the Schmidt Institute of Physics of the Earth

Endowed Professors
Feng Sheng Hu (https://eps.wustl.edu/people/feng-sheng-hu/)
Dean of the Faculty of Arts & Sciences
Professor of Biology and of Earth and Planetary Sciences
Lucille P. Markey Distinguished Professor in Arts & Sciences
PhD, University of Washington

Bradley L. Jolliff (https://eps.wustl.edu/people/bradley-l-jolliff/)
Director of the McDonnell Center for the Space Sciences
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/bruce-fegley-jr/)
PhD, Massachusetts Institute of Technology
The Department of Earth and Planetary Sciences offers majors in earth science, environmental science, and planetary science. 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. All majors are required to complete certain core courses as well as electives and a capstone experience (https://eps.wustl.edu/capstone-experiences/) that must be presented at the Spring EPS Undergraduate Research Symposium.

Note: The following requirements apply to students matriculating in Fall 2022 and later. For earlier requirements, please visit our prior Bulletin pages (https://bulletin.wustl.edu/prior/) and consult with the department’s director of undergraduate studies.

Requirements for All Majors

Required Core Courses

Students pursuing any Earth and Planetary Sciences major must complete the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 202</td>
<td>Introduction to Earth, Environmental, and Planetary Science</td>
<td>3</td>
</tr>
<tr>
<td>Math 131</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Math 132</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 2200 or Math 233 or Math 3200</td>
<td>Elementary Probability and Statistics or Calculus III or Elementary to Intermediate Statistics and Data Analysis</td>
<td>3</td>
</tr>
<tr>
<td>Chem 105</td>
<td>Introductory General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
</tbody>
</table>

Additional Electives

In addition to the disciplinary elective below, which are specific to each major, students must choose three L19 EPSc elective courses at the 300, 400, or 500 level.
Skills Course

Students must complete one of the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnSt 380</td>
<td>Applications in GIS</td>
<td>3</td>
</tr>
<tr>
<td>EnSt 364</td>
<td>Field Methods for Environmental Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc XXX</td>
<td>Geospatial Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 400</td>
<td>Special Topics</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 492</td>
<td>Field Camp</td>
<td>var., max 6</td>
</tr>
<tr>
<td>EPSc 496</td>
<td>Undergraduate Field Geology</td>
<td>3</td>
</tr>
</tbody>
</table>

Capstone Experience

Students completing any Earth and Planetary Sciences major must also build a portfolio of their work from projects completed in courses such as EPSc 496 Undergraduate Field Geology, EnSt 405 Sustainability Exchange: Community and University Practicums, EnSt 539 Interdisciplinary Environmental Clinic or EnSt 452 International Climate Negotiation Seminar; internship experiences; or research. All capstones must be presented at the Spring EPS Undergraduate Research Symposium.

The Major in Environmental Science

Students must complete all of the requirements listed above for all majors as well as the following:

Disciplinary Requirements

Students complete the following two courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 340</td>
<td>Minerals, Rocks, Resources and the Environment or EPSc 353 Earth Forces</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 342</td>
<td>Environmental Systems</td>
<td>3</td>
</tr>
</tbody>
</table>

Disciplinary Electives

Students select five of the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 317</td>
<td>Soil Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 323</td>
<td>Biogeochemistry</td>
<td>3</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>
</tr>
<tr>
<td>EPSc 409</td>
<td>Surface Processes</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 422</td>
<td>Sedimentary Geology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 428</td>
<td>Hydrology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 437</td>
<td>Igneous &amp; Metamorphic Petrology</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 441</td>
<td>Introduction to Geochemistry</td>
<td>3</td>
</tr>
</tbody>
</table>

The Major in Planetary Science

Students must complete all of the requirements listed above for all majors as well as the following:

Disciplinary Requirements

Students complete the following two courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 452</td>
<td>Introduction to Seismology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 453</td>
<td>Interior of the Earth</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 454</td>
<td>Exploration and Environmental Geophysics</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 459</td>
<td>Geodynamics</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 460</td>
<td>Introduction to Structural Geology</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 486</td>
<td>Paleoclimatology</td>
<td>3</td>
</tr>
</tbody>
</table>
Disciplinary Electives
Students select five of the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc XXX</td>
<td>Planetary Mission Design</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>
</tr>
<tr>
<td>EPSc 437</td>
<td>Igneous &amp; Metamorphic Petrology</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 441</td>
<td>Introduction to Geochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 459</td>
<td>Geodynamics</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 460</td>
<td>Introduction to Structural Geology</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 473</td>
<td>Planetary Geology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 474</td>
<td>Planetary Geochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 567</td>
<td>Planetary Materials</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 568</td>
<td>Scientific Exploration of the Moon</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 570</td>
<td>Planetary Geophysics &amp; Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 571</td>
<td>Meteorites</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 576</td>
<td>Advanced Planetary Geology: Ice Worlds</td>
<td>3</td>
</tr>
</tbody>
</table>

Minors
Requirements for All Minors
Students pursuing any Earth and Planetary Sciences minor must complete the following course:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 202</td>
<td>Introduction to Earth, Environmental, and Planetary Science</td>
<td>3</td>
</tr>
</tbody>
</table>

The Minor in Earth Science
Students must complete all of the requirements listed above for all minors as well as the following:

Disciplinary Requirements
Students complete the following two courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 340</td>
<td>Minerals, Rocks, Resources and the Environment</td>
<td>4</td>
</tr>
<tr>
<td>or EPSc 353</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>EPSc 342</td>
<td>Environmental Systems</td>
<td>3</td>
</tr>
</tbody>
</table>

Disciplinary Electives
Students select two of the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 308</td>
<td>Topics in Environmental Sustainability</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 317</td>
<td>Soil Science</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 323</td>
<td>Biogeochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 386</td>
<td>The Earth’s Climate System</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 407</td>
<td>Remote Sensing</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 409</td>
<td>Surface Processes</td>
<td>3</td>
</tr>
</tbody>
</table>
The Minor in Planetary Science

Students must complete all of the requirements listed above for all minors as well as the following:

**Disciplinary Requirements**

Students complete the following two courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSc 340</td>
<td>Minerals, Rocks, Resources and the Environment</td>
<td>4</td>
</tr>
<tr>
<td>EPSc 353</td>
<td>Earth Forces</td>
<td>4</td>
</tr>
</tbody>
</table>

**Disciplinary Electives**

Students select two of the following courses:

<table>
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<tbody>
<tr>
<td>EPSc XXX</td>
<td>Planetary Mission Design</td>
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<td>Earth Systems Science</td>
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<td>EPSc 437</td>
<td>Igneous &amp; Metamorphic Petrology</td>
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</tr>
<tr>
<td>EPSc 441</td>
<td>Introduction to Geochemistry</td>
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<tr>
<td>EPSc 473</td>
<td>Planetary Geology</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 474</td>
<td>Planetary Geochemistry</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 567</td>
<td>Planetary Materials</td>
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<td>Planetary Geophysics &amp; Dynamics</td>
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<tr>
<td>EPSc 571</td>
<td>Meteorites</td>
<td>3</td>
</tr>
<tr>
<td>EPSc 576</td>
<td>Advanced Planetary Geology: Ice Worlds</td>
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</tbody>
</table>

**Courses**


**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 or 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, geologic hazards, fossil life, or earth history. Prerequisite: Freshman standing; or sophomore standing with permission of instructor. Credit/No Credit only. Students attend all lectures and write a short summary of each. Priority for enrollment in this course goes to first-year students. Credit 1 unit. A&S: FYO A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

**L19 EPSc 108A Oceans and the Atmosphere**

Basic concepts of the evolution and physical structures of the Earth's oceans and the atmosphere. Dynamic aspects of the oceans (waves, tides, tsunamis) and atmospheric circulation (weather). Role of biological processes (including anthropogenic) in defining the present oceans and atmosphere. Global climate issues discussed in EPSc 111. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

**L19 EPSc 109A Quantitative Reasoning in Environmental Science**

Introduction to practical mathematical methods for understanding environmental aspects of our planet, particularly how the environment changes with time through human interactions. Emphasis on intuitive approaches in devising simple
relationships for understanding quantitative outcomes of natural processes. Introduction to basic statistical methods, including hypothesis testing, and how statistics can be applied to environmental problems.
Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI

L19 EPSc 111 Introduction to Global Climate Change in the 21st Century
Global climate and global climate change and their impacts on life and civilization. Integrated view of global climate and the diverse forces that can alter global climate. Historical and potential future consequences of global climate change on human life, our industrial civilization, and its sustainability.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 112 First-Year Seminar: Engineering the Climate
Geoengeering, the deliberate manipulation of the Earth's climate, may be part of a solution to the predicted future global warming. Is this advisable, or even possible? Discussions, lectures and readings used to learn how earth's climate works. Examination of some proposals for altering the climate. Past attempts for deliberate human alteration of natural systems discussed and evaluated. Consideration of geoengineering as an ethical issue. Prerequisite: first-year undergraduate status.
Credit 3 units. A&S: FYS A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 118A Geology of National Parks
Survey of geologic processes occurring at the Earth's surface and its interior using national parks and monuments as the prime venue for presentation. Volcanism and mountain-building; the work of streams, glaciers and wind; lake and coastline development; stratigraphy and sedimentation; and Earth history. Material presented in a geographic context, with emphasis on landforms and landscape evolution, relating geology to the development and settlement of the U.S.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

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 Arch: 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 BU: SCI

L19 EPSc 145 Land Dynamics: Case Studies of Environmental Sustainability
This course is designed for first- and second-year students and will use lectures, discussions, GIS-related and computational exercises, and field trips to introduce students to a systems approach for identifying, characterizing, and solving issues associated with environmental degradation. The course will focus on three case studies. The first will cover rapid lake drawdown of Mono Lake in northern California due to engineered diversions and subsequent court-ordered recovery to an environmentally sustainable lake level. The second will focus on unresolved consequences associated with channelization and levee development on the lower Missouri River, which put federal agencies in conflict with one another on how to manage the river and its floodplains. The third will cover past and present Pb-Cu-Zn sulfide mining practices in Missouri and attempts to balance the need for these nonrenewable resources while minimizing environmental consequences.
Credit 3 units. 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 202 Introduction to Earth, Environmental, and Planetary Science
Introduction to the Earth, its environment, and its place in the solar system. This course is intended to be a starting point for majors in the Department of Earth and Planetary Sciences, or as a standalone course for students from all interests and backgrounds. Themes for this course include Earth's history; the structure and composition of Earth and other planets; the evolution of Earth's surface; natural hazards; climate history; global biogeochemical cycles; and the solar system. No Prerequisites. Students may not take both EPS 202 and EPS 201 for college credit.
Credit 3 units. A&S IQ: NSM, AN 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.
Credit 3 units. A&S IQ: NSM Arch: 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 Arch: NSM Art: NSM BU: SCI

L19 EPSc 317 Soil Science
Physical, chemical, and biological processes that occur within soil systems. Types of soils and their formation. Major components of soil, including soil water, minerals, organic matter, and organisms. Soils in wetlands and arid regions. Mapping of soils and their spatial variability. Cycling of nutrients and contaminants in soils. Sustainable use of soils and their role in climate change. Prerequisites: EPS 201 or 202, EPS 323 or Chem 106 (or AP Chem score of 4); or permission of instructor.
Credit 3 units. A&S IQ: NSM

L19 EPSc 319 Physical Oceanography
Ocean circulation, El Niño, dynamical tides, 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 Arch: NSM Art: NSM BU: SCI

L19 EPSc 323 Biogeochemistry
Basic concepts of how elements cycle among Earth's crust, oceans, and 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 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. Prerequisite: EPS 202 or EECE 101.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 340 Minerals, Rocks, Resources and the Environment
This course is designed for undergraduate majors and minors in the Department of Earth and Planetary Sciences to master fundamentals of mineralogy and their context within sedimentary, metamorphic, and igneous rock systems. It will provide an overview and lab demo of the modern analytical methods used in mineralogy. The course includes lecture (three hours per week) and a lab component (two hours per week). Prerequisites: EPS 201, Chem 105, and Chem 106, or permission of instructor.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 342 Environmental Systems
Introduction to the science of environmental systems and processes. Exploration of key functions of major environmental systems on land, in rivers and lakes, in air, at sea, and in diverse transitional settings at the boundaries between these environments. Evaluation of the ways in which humans alter and are affected by environmental systems. Interspersed throughout the semester will be a review of the major U.S. laws governing human management of environmental systems as well as case studies of environmental disparities in the St. Louis region. Prerequisites: EPS 201 or 202, or permission of the instructor.
Credit 3 units. A&S IQ: NSM, AN

L19 EPSc 353 Earth Forces
This course covers 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 is on the physical concepts needed to understand the geodynamical behavior of the Earth over a broad range of length and time scales. The application and interpretation of geophysical methods to probe the interior of the Earth are also discussed. Prerequisite: EPSc 201 (may be taken concurrently), Phys 191, or permission of instructor. The course involves three classroom hours and one two-hour laboratory session each week.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: 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: EPS 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 Niño; 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 Arch: 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 Special Topics
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 3 units. A&S IQ: NSM Arch: 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: EPSc 336 or 352 or permission of instructor or the graduate adviser. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 407 Remote Sensing
This course addresses the use of different parts of the electromagnetic spectrum (visible, ultraviolet, infrared, and radio wavelengths) for the interpretation of the physical and chemical characteristics of the surfaces of Earth and other planets. Digital image systems and data processing are also discussed. Prerequisite: Phys 192 or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 408 Earth’s Atmosphere and Global Climate
This course discusses the structure and dynamics of Earth’s atmosphere. Other topics include basic factors controlling the global climate of Earth, quantitative aspects of remote sensing of the atmosphere, and remote sensing instrumentation. Prerequisites: Math 233 and Phys 191, or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 409 Surface Processes
How do landscapes evolve? This course focuses on the physical processes of erosion and deposition that shape Earth and planetary surfaces. Course aims include the following: (1) understanding emergent landscape patterns; (2) reconstructing past conditions using the sedimentary record; and (3) predicting landscape change under climate scenarios. We will review relevant climatic and tectonic processes, and this will be followed by a detailed discussion of rivers and deltas, hillslopes, weathering, glaciers, and coasts. Two one-day field trips are required. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EPSc 410 Earth Remote Sensing Methods and Instrumentation
This course addresses the detection of electromagnetic radiation reflected, scattered, or emitted by components of the Earth system. Topics include the spectroscopy of remote sensing, the interpretation of received radiation via radiative transfer within a context of real measurements, the theory of instruments and detectors, and the comparison of real equipment to theoretical models. Prerequisite: Phys 192, Chem 106 (or AP Chem score of 4), Math 233, or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

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. Prerequisite: EPSc 201 or permission of instructor. Mandatory field trips. Credit 3 units. A&S IQ: NSM Arch: NSM 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. Exploitation of ground water systems. Prerequisite: EPSc 353; or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 437 Igneous & Metamorphic 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
The application of the principles of nuclear and physical chemistry to problems of the composition and differentiation of the Earth is addressed. This course includes an 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 106 (or AP Chem score of 4), or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 442 Aqueous Geochemistry
Introduction to the geochemistry of natural waters and the processes that alter their composition. Key principles of aqueous geochemistry are introduced and then used to describe the main controls of the chemistry of pristine and polluted soil, surface, and ground water environments. Topics covered include mineral solubility, complexion, acids and bases, carbonate chemistry, rock weathering and clay formation, adsorption and ion exchange, redox reactions, microbial energetics and redox
zonations, the geochemistry of iron, sulfur, trace elements, and radionuclides, and geochemical kinetics. Geochemical modeling will be introduced. Prerequisites: Chem 106 or 112A; EPS 201 or 202 are recommended.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

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 445 Organic Geochemistry
This course presents an introduction to the composition and analysis of organic material in the environment and geological record. It introduces a molecular- to global-level perspective of organic matter cycling, reactivity, and fluxes; the 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; an overview of analytical techniques, including both structural and isotopic aspects; oceanographic and paleoenvironmental applications of organic biomarkers; and contaminants and residue analysis. Prerequisites: EPSc 201 and Chem 106, or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: NSM Art: 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, isotope 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 Arch: 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. Prerequisites: EPSc 353 or permission of instructor.
Credit 3 units. A&S IQ: NSM Arch: 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 191, 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 Arch: 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
The landforms that surround us are being modified constantly by tectonic forces. Structural geology provides a framework for investigating, describing, and quantifying these changes. This course provides an introduction to the structures that form at all scales, from millimeter-sized fractures to plate-boundary-scale rifts. Topics include descriptive analysis of microscopic and macroscopic structures, field methods, the physical bases for rock deformation, and global tectonics. Prerequisites: EPS 352 and EPS 353, or permission of instructor. Three hours of lecture and one two-hour laboratory session are required each week.
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EPSc 473 Planetary Geology
Discussion of the evolution of the terrestrial planets and the outer-planets 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 Arch: NSM Art: NSM

L19 EPSc 486 Paleoclimatology
The history of Earth's changing climates and environments on timescales from decades to millions of years. Key concepts in paleoclimatology 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. EPSc-386 or EPSc-586 (or equivalent), or permission from the 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.