Earth and Environmental Sciences

Chair
• Charles "Tom" Foster Jr.

Undergraduate major: geoscience (B.A., B.S.)
Undergraduate minor: geoscience
Graduate degrees: M.S. in geoscience; Ph.D. in geoscience
Faculty: http://clas.uiowa.edu/ees/people
Web site: http://clas.uiowa.edu/ees/

Faculty and students in the Department of Earth and Environmental Sciences study the physical, chemical, and biological systems of Earth. Using modern observational, analytical, and computational methods, they examine how the planet's interior, surface, hydrosphere, biosphere, and atmosphere have evolved since Earth was born in the solar system 4.6 billion years ago. Topics commonly studied in the department include how plate movements cause earthquakes, volcanoes, and mountain building; global climate change and how climate change and catastrophic events cause changes in biodiversity; mass extinctions and patterns of evolution through Earth history; how and where economic resources are generated on Earth; and how these resources are located and used in modern society.

The earth and environmental sciences curriculum provides students with hands-on experience analyzing rocks, minerals, fossils, soils, and waters, generally in a small classroom setting. Much of this experience is obtained in laboratory and field courses. Field courses include travel to other states or countries to view Earth's materials and fossils in the context of their natural surroundings.

The master's degree in geoscience is regarded by most hiring agencies as the working degree, but an undergraduate degree is fully satisfactory in certain teaching, government, and industry situations. The doctoral degree is required for college and university faculty positions and for some research positions in industry.

Many of the University of Iowa's geoscience graduates find employment with resource companies, environmental corporations, and educational institutions. Others continue in graduate school or take jobs with government or conservation agencies. Some intend to enter law, business, or fields such as urban planning, environmental studies, engineering, archaeology, science education, or oceanography as advanced areas. Geoscience provides skills useful for all of these fields.

The department offers a variety of courses appropriate for nonmajors, including several approved for the Natural Sciences requirement of the General Education Program; see "Courses for Nonmajors" below.

Many of the department's faculty members are involved in the interdisciplinary Environmental Sciences Program, and a number of the department's courses satisfy requirements of the Certificate in Sustainability.

Undergraduate Programs of Study

• Major in geoscience (Bachelor of Arts, Bachelor of Science)
• Minor in geoscience

Students majoring in geoscience take at least an academic year's work in three allied scientific areas—physics, chemistry, and mathematics—and a semester of biology in addition to a course in each major area of geology.

Geoscience students may elect to pursue an additional major or a minor in a related discipline, usually chemistry, physics, biology, engineering, environmental sciences, or anthropology. See Majors, Minors, and Certificates under Current Students on the College of Liberal Arts and Sciences web site.

Bachelor of Science

The Bachelor of Science with a major in geoscience requires a minimum of 120 s.h., including at least 70 s.h. (19 courses) of work for the major (39 s.h. in earth and environmental sciences courses and at least 31 s.h. in supporting disciplines). Students must maintain a g.p.a. of at least 2.00 in all courses for the major and in all UI courses for the major. They also must complete the College of Liberal Arts and Sciences General Education Program. Transfer students must complete a minimum of 15 s.h. of course work in the Department of Earth and Environmental Sciences.

The geoscience major for the B.S. is designed to prepare students for immediate employment after graduation or to enter a graduate program in geology.

The department recommends that students fulfill the General Education Program's World Languages requirement with French, German, Russian, or Spanish and the Social Sciences requirement with approved course work in economics, geography, or anthropology.

The geoscience major for the Bachelor of Science requires the following course work.

EARTH AND ENVIRONMENTAL SCIENCES

One of these:
EES:1030 Introduction to Earth Science 4 s.h.
EES:1050 Introduction to Geology (preferred) 4 s.h.

All of these:
EES:1040 Evolution and the History of Life 4 s.h.
EES:2410 Mineralogy 4 s.h.
EES:2831 Geologic Field Methods 3 s.h.
EES:3300 Sedimentary Geology 4 s.h.
EES:3500 Igneous and Metamorphic Petrology 4 s.h.
EES:3840 Structural Geology 4 s.h.
EES:4832 Geologic Field Analysis 3 s.h.
At least two geoscience electives (see "Recommended Electives" below) 6-7 s.h.

One of these:
EES:3210 Principles of Paleontology 3 s.h.
EES:4490 Elements of Geochemistry 3 s.h.
EES:4630 Hydrogeology 3 s.h.
EES:4790 Engineering Geology 3 s.h.  
EES:4800 Solid Earth Geophysics 3 s.h.  

**MATHEMATICS**  
At least 8 s.h. of calculus, including one of these:  
MATH:1560 Engineering Mathematics II: 4 s.h.  
Multivariable Calculus  
MATH:1860 Calculus II 4 s.h.  
And:  
An additional course in mathematics, computer science, or statistics numbered MATH:2000 or above, or CS:1110 or above, or STAT:2010 or above  

**CHEMISTRY**  
B.S. students must complete at least 8 s.h. of college-level chemistry, including the following sequence or equivalent courses or more advanced courses. Chemistry courses numbered below CHEM:1110 Principles of Chemistry I do not count toward this requirement.  
CHEM:1110 & CHEM:1120 Principles of Chemistry I-II 8 s.h.  

**PHYSICS**  
B.S. students must complete at least 8 s.h. of college-level physics, as follows. Physics courses numbered below PHYS:1511 College Physics I do not count toward this requirement.  
One of these sequences:  
PHYS:1511-PHYS:1512 College Physics I-II 8 s.h.  
PHYS:1611-PHYS:1612 Introductory Physics I-II 8 s.h.  

**BIOLOGY**  
B.S. students must complete at least one biology course that includes a laboratory (4 s.h.). Students with an interest in paleontology are encouraged to take BIOL:1411 Foundations of Biology and BIOL:1412 Diversity of Form and Function.  

**RECOMMENDED ELECTIVES**  
All B.S. students should take elective courses from the following groups in order to broaden their undergraduate experience and prepare themselves for graduate study or professional employment. Students who have clear career goals are advised to take three or more elective courses from the group that fits their needs most closely. Students also may seek a broad education in geoscience by choosing elective courses from a number of groups.  

**Quaternary Geology**  
EES:3020 Earth Surface Processes 3 s.h.  
EES:3100 Introduction to Applied Remote Sensing 4 s.h.  
EES:3360 Soil Genesis and Geomorphology 3 s.h.  
EES:3380 Fluvial Geomorphology 3 s.h.  
EES:4490 Elements of Geochemistry 3 s.h.  
EES:4520 Isotope Geochemistry 3 s.h.  
EES:4620 Approaches to Geoarchaeology 3 s.h.  
EES:4630 Hydrogeology 3 s.h.  
EES:4720 Glacial and Pleistocene Geology 3 s.h.  

**Geochemistry**  
EES:4790 Engineering Geology 3 s.h.  
EES:4870 Applied Geostatistics 3 s.h.  

**Environmental Geology**  
EES:1400 Natural Disasters 3 s.h.  
EES:3070 Marine Ecosystems and Conservation 3 s.h.  
EES:3080 Introduction to Oceanography 2 s.h.  
EES:3100 Introduction to Applied Remote Sensing 4 s.h.  
EES:3380 Fluvial Geomorphology 3 s.h.  
EES:3390 Integrated Watershed Analysis 3 s.h.  
EES:4490 Elements of Geochemistry 3 s.h.  
EES:4520 Isotope Geochemistry 3 s.h.  
EES:4630 Hydrogeology 3 s.h.  
EES:4680 Field Methods in Hydrologic Science 3 s.h.  
EES:4790 Engineering Geology 3 s.h.  
EES:4800 Solid Earth Geophysics 3 s.h.  
EES:4870 Applied Geostatistics 3 s.h.  

**Sedimentary Geology**  
EES:3080 Introduction to Oceanography 2 s.h.  
EES:3300 Sedimentary Geology 4 s.h.  
EES:3380 Fluvial Geomorphology 3 s.h.  
EES:3770 Global Stratigraphy 3 s.h.  
EES:4490 Elements of Geochemistry 3 s.h.  
EES:4520 Isotope Geochemistry 3 s.h.  
EES:4750 Mineral and Petroleum Exploration Geology 3 s.h.  
EES:4800 Solid Earth Geophysics 3 s.h.  
EES:5820 Tectonics 3 s.h.  

**Tectonics/Petrology**  
EES:1400 Natural Disasters 3 s.h.  
EES:3410 Analytical Methods 2 s.h.  
EES:4490 Elements of Geochemistry 3 s.h.  
EES:4520 Isotope Geochemistry 3 s.h.  
EES:4630 Hydrogeology 3 s.h.  
EES:4870 Applied Geostatistics 3 s.h.  
EES:5820 Tectonics 3 s.h.  

**Paleobiology**  
EES:3070 Marine Ecosystems and Conservation 3 s.h.  
EES:3080 Introduction to Oceanography 2 s.h.  
EES:3210 Principles of Paleontology 3 s.h.  
EES:3220 Evolution of the Vertebrates 3 s.h.  
EES:3300 Sedimentary Geology 4 s.h.  
EES:3770 Global Stratigraphy 3 s.h.  
EES:4440 Vertebrate Osteology and Phylogeny 3 s.h.  
EES:4440 Phylogenetics and Biodiversity 3 s.h.  

**Paleontology**  
EES:3070 Marine Ecosystems and Conservation 3 s.h.  
EES:3080 Introduction to Oceanography 2 s.h.  
EES:3210 Principles of Paleontology 3 s.h.  
EES:3220 Evolution of the Vertebrates 3 s.h.  
EES:3300 Sedimentary Geology 4 s.h.  
EES:3770 Global Stratigraphy 3 s.h.  
EES:4300 Vertebrate Osteology and Phylogeny 3 s.h.  
EES:4440 Phylogenetics and Biodiversity 3 s.h.
EES:4450 Morphometrics 1-3 s.h.
EES:4490 Elements of Geochemistry 3 s.h.
EES:4520 Isotope Geochemistry 3 s.h.
EES:4700 Evolution of Ecosystems 3 s.h.
EES:4710 Evolution of Plants 3 s.h.
EES:5820 Tectonics 3 s.h.

**INDEPENDENT RESEARCH OPTION FOR GEOSCIENCE MAJORS**

A junior or senior who is ready to pursue independent research for credit in geoscience may assist a faculty member or graduate student with a current research project in EES:2190 Directed Study or may initiate a small-scale project involving a combination of field, laboratory, and library investigation in EES:3190 Directed Study. Independent study is encouraged and may lead to an honors thesis in EES:4999 Honors Thesis in Geoscience or a senior thesis in EES:4990 Senior Thesis in Geoscience that may be published subsequently.

**Bachelor of Arts**

The Bachelor of Arts with a major in geoscience requires a minimum of 120 s.h., including at least 51 s.h. of work for the major (at least 35 s.h. in earth and environmental sciences courses and at least 16 s.h. in supporting disciplines). Students must maintain a g.p.a. of at least 2.00 in all courses for the major and in all UI courses for the major. They also must complete the College of Liberal Arts and Sciences General Education Program.

Transfer students must complete a minimum of 15 s.h. of course work in the Department of Earth and Environmental Sciences.

The geoscience major for the B.A. is designed to provide students with a varied background in geology and a broader choice of electives than is practical in the Bachelor of Science program. The major for the Bachelor of Arts is intended for students who are interested in the fundamentals of geology or earth science teaching (see “B.A. or B.S. with Teacher Licensure” below).

Completing the minimum requirements for this degree may not adequately prepare a student for an entry-level professional job in geology.

The department recommends that students fulfill the General Education Program's World Languages requirement with French, German, Russian, or Spanish and the Social Sciences requirement with approved course work in economics, geography, or anthropology.

The geoscience major for the Bachelor of Arts requires the following course work.

**EARTH AND ENVIRONMENTAL SCIENCES**

This course:

EES:2410 Mineralogy 4 s.h.

One of these:

EES:1030 Introduction to Earth Science 4 s.h.
EES:1050 Introduction to Geology 4 s.h.

One or both of these:

EES:1040 Evolution and the History of Life 4 s.h.
EES:3210 Principles of Paleontology 3 s.h.

At least three of these:

EES:3300 Sedimentary Geology 4 s.h.
EES:3360 Soil Genesis and Geomorphology 3 s.h.
EES:3380 Fluvial Geomorphology 3 s.h.
EES:3500 Igneous and Metamorphic Petrology 4 s.h.
EES:3840 Structural Geology 4 s.h.
EES:4630 Hydrogeology 3 s.h.

And:

Geoscience electives 12 s.h.

**MATHEMATICS**

B.A. students must complete the following course work in mathematics.

College-level mathematics (may include computer science and statistics) 10 s.h.

**CHEMISTRY**

B.A. students must complete at least two college-level chemistry courses, as follows. Chemistry courses numbered below CHEM:1070 General Chemistry I do not count toward this requirement.

One of these sequences:

CHEM:1070 & CHEM:1080 General Chemistry I-II 6 s.h.
CHEM:1110 & CHEM:1120 Principles of Chemistry I-II 8 s.h.

**FIELD REQUIREMENT**

To complete the major, B.A. students must have field experience. They may take two semesters of EES:1180 Geology Field Trip: Selected National Parks, or two semesters of EES:3160 Field Trip, or one semester of each of the two courses. Or they may take one semester of EES:2831 Geologic Field Methods or the Iowa Lakeside Laboratory session.

EES:1180 Geology Field Trip: Selected National Parks 2 s.h.
EES:2831 Geologic Field Methods 3 s.h.
EES:3160 Field Trip 2 s.h.

One natural science session at Iowa Lakeside Laboratory for a minimum of 3 s.h.

**INDEPENDENT RESEARCH OPTION FOR GEOSCIENCE MAJORS**

A junior or senior who is ready to pursue independent research for credit in geoscience may assist a faculty member or graduate student with a current research project in EES:2190 Directed Study or may initiate a small-scale project involving a combination of field, laboratory, and library investigation in EES:3190 Directed Study. Independent study is encouraged and may lead to an honors thesis in EES:4999 Honors Thesis in Geoscience or a senior thesis in EES:4990 Senior Thesis in Geoscience that may be published subsequently.

**B.A. or B.S. with Teacher Licensure**

Geoscience majors interested in earning licensure to teach in elementary and/or secondary schools must complete the College of Education's Teacher Education Program (TEP) in addition to the requirements for the major and all requirements for graduation. The TEP requires several
College of Education courses and student teaching. Contact the Office of Education Services for details.

Students must satisfy all degree requirements and complete Teacher Education Program licensure before degree conferral.

Students with a strong interest in science teaching may complete a major offered by the Science Education Program. Students choose one of five emphases—biology, chemistry, earth science, physics, or all-science—and earn a Bachelor of Science degree. They may apply for admission to the Teacher Education Program. See Science Education in the Catalog.

Four-Year Graduation Plan

The following checkpoints list the minimum requirements students must complete by certain semesters in order to stay on the University's Four-Year Graduation Plan. (Courses in the major are those required to complete the major; they may be offered by departments other than the major department.)

Note: These checkpoints show the range of required course work; the major for the Bachelor of Arts requires a minimum of 17 courses; the major for the Bachelor of Science requires 19.

The geoscience major requires field trip experiences, many of which take place during breaks in or between semesters or during the summer session. These checkpoints do not include the field trip requirements.

Before the third semester begins: competence in math through trigonometry and the first required chemistry course

Before the fifth semester begins: three to five courses in the major, including the remainder of the chemistry requirement and continuation of the mathematics requirement

Before the seventh semester begins: 7-11 courses in the major and at least 90 s.h. earned toward the degree

Before the eighth semester begins: 10-14 courses in the major

During the eighth semester: enrollment in all remaining course work in the major, all remaining General Education courses, and a sufficient number of semester hours to graduate

Honors in the Major

Students majoring in geoscience have the opportunity to graduate with honors in the major. Departmental honors students must maintain a cumulative g.p.a. of at least 3.33 in all University of Iowa course work and in all geoscience courses. To graduate with honors in geoscience, students must complete a senior thesis, registering in EES:4999 Honors Thesis in Geoscience. They must obtain approval of their honors thesis contract from their advisor and the department's undergraduate committee, and they must earn a grade of B or higher in EES:4999.

In addition to honors in their majors, undergraduate students have a variety of opportunities for honors study and activities through membership in the University of Iowa Honors Program; visit Honors at Iowa to learn about the University's honors program.

Minor

The minor in geoscience requires a minimum of 15 s.h. in geoscience courses, including 12 s.h. in courses considered advanced for the minor offered by the Department of Earth and Environmental Sciences at the University of Iowa. Mineralogy [EES:2410], Geologic Field Methods [EES:2831], and all earth and environmental sciences courses numbered 3000 and above are considered advanced for the minor. Students must maintain a g.p.a. of at least 2.00 in all courses for the minor and in all UI courses for the minor. Course work in the minor may not be taken pass/nonpass.

College-level courses in mathematics, physics, chemistry, and biology usually are required as collateral work for geoscience students. Those seeking a minor in geoscience should be sufficiently prepared in the areas of supporting sciences before they take advanced courses in geoscience.

Recommended advanced courses in geoscience that deal with important areas of earth materials and earth processes are as follows.

<table>
<thead>
<tr>
<th>Course</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>EES:2410 Mineralogy</td>
<td>4 s.h.</td>
</tr>
<tr>
<td>EES:2831 Geologic Field Methods</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3020 Earth Surface Processes</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3070 Marine Ecosystems and Conservation</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3080 Introduction to Oceanography</td>
<td>2 s.h.</td>
</tr>
<tr>
<td>EES:3210 Principles of Paleontology</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3300 Sedimentary Geology</td>
<td>4 s.h.</td>
</tr>
<tr>
<td>EES:3360 Soil Genesis and Geomorphology</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3380 Fluvial Geomorphology</td>
<td>3 s.h.</td>
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<tr>
<td>EES:3390 Integrated Watershed Analysis</td>
<td>3 s.h.</td>
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<tr>
<td>EES:3500 Igneous and Metamorphic Petrology</td>
<td>4 s.h.</td>
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<tr>
<td>EES:3840 Structural Geology</td>
<td>4 s.h.</td>
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<tr>
<td>EES:4490 Elements of Geochemistry</td>
<td>3 s.h.</td>
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<tr>
<td>EES:4790 Engineering Geology</td>
<td>3 s.h.</td>
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<tr>
<td>EES:4800 Solid Earth Geophysics</td>
<td>3 s.h.</td>
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<tr>
<td>EES:5820 Tectonics</td>
<td>3 s.h.</td>
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</tbody>
</table>

Courses for Nonmajors

Each year more than 1,800 students enroll in Department of Earth and Environmental Sciences introductory courses that are approved for General Education; look for courses with the prefix EES under "Natural Sciences" in the General Education Program section of the Catalog.

The department also offers the following upper-level courses with few or no prerequisites.

<table>
<thead>
<tr>
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<th>Hours</th>
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<tbody>
<tr>
<td>EES:3020 Earth Surface Processes</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3070 Marine Ecosystems and Conservation</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>EES:3080 Introduction to Oceanography</td>
<td>2 s.h.</td>
</tr>
<tr>
<td>EES:3100 Introduction to Applied Remote Sensing</td>
<td>4 s.h.</td>
</tr>
<tr>
<td>EES:3210 Principles of Paleontology</td>
<td>3 s.h.</td>
</tr>
</tbody>
</table>

National Honor Society

The department sponsors a chapter of Sigma Gamma Epsilon National Honor Society for the Earth Sciences. Students with an overall g.p.a. of at least 2.80 and at least 3.20 in geoscience courses are considered for membership.
after they have completed a minimum of 16 s.h. of course work in geoscience. Consult the departmental honors advisor for more information.

Graduate Programs of Study

- Master of Science in geoscience
- Doctor of Philosophy in geoscience

The Master of Science program in geoscience prepares students for employment in industry or for doctoral study. The Doctor of Philosophy program is designed to prepare students for future employment in higher education or research and to bring them to the forefront of a specialized area of geoscience.

All geoscience graduate students must meet the admission and degree requirements of the Graduate College; see the Manual of Rules and Regulations of the Graduate College (particularly sections IX, X, and XII). They also should acquaint themselves with the University calendar, for deadline dates and so forth.

All entering graduate students are required to enroll in EES:5070 Geologic Orientation during the fall semester of their first year in the graduate program.

The department provides detailed information about current graduate degree requirements and timelines for making satisfactory progress toward a degree in the document "The University of Iowa Guidelines for Graduate Study in Earth and Environmental Sciences"; see Graduate Student Guidelines under Graduate Program on the Department of Earth and Environmental Sciences web site.

Throughout their graduate study, all M.S. and Ph.D. students must maintain a g.p.a. of at least 3.00 in all course work required for their degree and in all graduate-level geoscience course work. Students whose grade-point average drops below 3.00 are placed on academic probation.

Geoscience graduate students are encouraged to present their research at local, regional, national, or international meetings. The department provides partial funding for travel to such meetings.

Master of Science

The Master of Science degree in geoscience requires a minimum of 30 s.h. of graduate credit. The program is designed primarily to prepare students for employment in industry or for study toward a Ph.D. degree. M.S. students may count up to 8 s.h. of research credit toward the 30 s.h. required for the degree. They must earn at least 24 s.h. toward the degree in University of Iowa courses taken after they enroll in the program. M.S. students also must complete EES:5010 Geoscience Seminar Series each semester until they defend their thesis.

During the second semester of study, each M.S. student should propose an advisory committee of at least three faculty members to the department chair for approval. M.S. thesis students are responsible for obtaining their advisory committee's approval of a suitable program of course work and for satisfactory development of research plans as outlined in a thesis proposal, which should be completed and approved by the department chair before the end of the second semester of full-time study. The thesis typically has depth and breadth similar to those of a published research paper. Thesis students must deliver a half-hour public presentation of their thesis, followed by an oral defense. They also are required to present their research at a local, regional, national, or international meeting approved by the department chair before they may graduate.

Doctor of Philosophy

The Doctor of Philosophy degree in geoscience requires a minimum of 72 s.h. of graduate credit. The program is designed to prepare students for future employment in higher education or research and to bring them to the forefront of a specialized area of geoscience.

The Ph.D. requires a dissertation, which has the approximate research content of three published papers.

Ph.D. students usually enter the program with established fields of interest and a research advisor already selected. Under exceptional circumstances, a student may be admitted to the Ph.D. program without an established field of interest.

Entering Ph.D. students must consult with a research advisor or the department's director of graduate study before they enroll in courses. By the first month of their second semester of doctoral study, all Ph.D. students must select an advisor. Each student also must select a thesis topic and forward it to the department chair for approval by the end of the first month of the second semester of doctoral study.

Within broad limits, Ph.D. students should select courses that reflect their individual needs, interests, and talents; their advisor and advisory committee must approve their course selections.

During the second semester of doctoral study, each Ph.D. student should propose an advisory committee of at least five faculty members to the department chair for approval. Before the end of the second semester of doctoral study, each student must obtain his or her committee's approval of a suitable plan of study to be submitted to the department chair for approval. In consultation with the advisor and other faculty members, each doctoral candidate prepares a formal dissertation proposal approved by their committee and submitted to the department chair for approval by the end of the candidate's third semester of doctoral study.

Students are required to include in their plan of study at least 18 s.h. of regular course work taught by tenured or tenure-track faculty members of the Department of Earth and Environmental Sciences. Students must earn the 18 s.h. after being admitted to and enrolling in the Ph.D. program. Directed study and research credit do not count toward the required 18 s.h.

Ph.D. students must enroll in EES:5010 Geoscience Seminar Series each semester they are registered until they successfully defend their dissertation, or for two consecutive semesters after the semester in which they pass their comprehensive examination, whichever comes first.

After earning their first 24 s.h. of graduate credit, Ph.D. students must be enrolled at least two consecutive semesters in full-time study (at least 9 s.h. per semester) at the University of Iowa; or they must be enrolled three consecutive semesters for at least 6 s.h. per semester at the University, during which time they hold at least a one-quarter-time assistantship that is certified by the department as contributing to their doctoral program.
Students should complete most of their course work before taking the comprehensive examination, which consists of both written and oral portions and which must be passed before the end of the fourth semester of doctoral study.

Once Ph.D. candidates have passed the comprehensive examination, they are required to register each semester until they receive the degree. Candidates who have completed their plan of study may register for GRAD:6002 Doctoral Continuous Registration or GRAD:6003 Doctoral Final Registration.

Students must submit their written dissertation to the committee at least two weeks before the final examination. All Ph.D. candidates must deliver a one-hour public presentation associated with the dissertation defense. They also are required to submit a manuscript presenting the results of their graduate research to a refereed journal or other publication approved by the department chair before they may defend their dissertation.

Facilities

Resources and equipment available for research in the Department of Earth and Environmental Sciences include the following.

**Computer facilities:** three teaching classrooms with 10-12 networked PC workstations; a computing classroom with 20 PCs and 10 Mac workstations with GIS, GMS, remote sensing, image analysis, and specialized computational software packages; a student computer room with six PCs and two Macs; and a number of multiprocessor workstations in research laboratories.

**Electron microprobe:** JOEL JXA-8230 electron probe microanalyzer with five wavelength-dispersive spectrometers capable of quantitatively analyzing a full spectrum of elements in solid materials to a spot size as small as one micron.

**Environmental and Hydrogeology Laboratory:** permeameters and tensionometers; pumping and slug/bail test units with transducers and data-loggers; water-quality analysis facility; advanced groundwater modeling and geostatistics software; advanced data logging systems for field research; 3-D sensor arrays (wind and water systems); and facilities for field instrumentation design and construction.

**Environmental Instrumentation Laboratories:** storage, testing, and teaching facility focusing on field instrumentation; assembly, housing, and testing of climatic, meteorological, fluvial, water quality and associated environmental instrumentation data recording systems and sampling systems.

**Geomorphic Computing Laboratory:** high-end visualization, digitizing, remote sensing and GIS systems; and high-end multiprocessor workstations.

**Morphometric laboratories:** reflex microscope and microscribe for capturing 3-D data; high-resolution digital cameras and microscopes for 2-D image analysis; and laboratories for micro- and macro-fossil preparation.

**Paleontological Repository:** more than a million specimens, including some 25,000 type and referred specimens, with 6,000-7,000 primary types; invertebrate, vertebrate, and plant fossils of all geologic ages, and more than 90 percent Paleozoic invertebrates; the fifth-largest university collection in North America (CONARIP 1977).

**Petroleum and geochemistry laboratories:** laser-ablation inductively coupled plasma mass spectrometer (LA-ICPMS); clean laboratory for preparation of samples for elemental and isotopic analysis; alpha- and gamma-ray spectrometry laboratories; image analysis; petrographic microscopes; photo microscopy; wet-chemistry facilities; rock preparation and mineral separation; UNIX, Windows, and Mac workstations for data analysis and modeling; and one atm gas-mixing furnace for melt inclusion homogenization.

**Quaternary Materials Laboratory:** pipette grain-size analysis apparatus; chittick apparatus; Sedigraph 5100 X-ray particle-size analyzer; Horiba Camsizer L digital image particle analyzer; wet-chemistry facilities; C-H-N element analyzer; a Flotech flotation system; and a Giddings drill rig.

**Scanning Electron Microscope:** Hitachi S-3400N, a variable-pressure scanning electron microscope (SEM) equipped with a motorized stage, large chamber, and digital image capture; capable of imaging specimens with no metal coating, or specimens that are slightly hydrated or porous, as well as conventionally processed specimens; equipped with a Bruker AXS Quantax 400 X-ray microanalysis system; XFlash silicon drift detector with excellent energy resolution and light element detection; providing ultra-fast acquisition of line scans and elemental maps.

**Sedimentary geology laboratories:** water ion chromatograph; image analysis; Sedigraph X-ray particle-size analyzer; Horiba Camsizer L digital image particle analyzer; and a soil/sediment characterization laboratory.

**Thin-section and rock preparation laboratory:** diamond saws and specialized grinding equipment used to prepare ultrathin slices (30 microns thick) of rocks and fossils for microscopic and electron microprobe analysis.

Cooperative Activities

The department does collaborative work with the Iowa Geological Survey and the Office of the State Archaeologist of Iowa. Earth and environmental sciences students sometimes work on projects for the survey.

The Departments of Anthropology, Biology, Chemistry, Civil and Environmental Engineering, Earth and Environmental Sciences, and Geographical and Sustainability Sciences share services, expertise, joint instruction, and equipment. The Department of Earth and Environmental Sciences is an important participant in the Iowa Quaternary Studies group, an interdisciplinary program that promotes projects combining work in anthropology, biology, geography, geology, and statistics. Course work, degree programs, and facilities are shared among departments. The Department of Earth and Environmental Sciences and its faculty also support and actively participate in the interdisciplinary Environmental Sciences Program, which offers an undergraduate major and minor, and a number of the department's courses satisfy requirements of the undergraduate Certificate in Sustainability.
Field Trips

Field trips are integral parts of several courses in earth and environmental sciences. The geology of the Iowa City region is characterized by Quaternary glacial sediments on a largely Paleozoic sedimentary section a few hundred meters thick, overlying a Precambrian crystalline basement. Marine and terrestrial fossil assemblages, extensive reefs, and unique geode sites are located within a few hours' drive. Numerous Pleistocene glaciations are represented in Iowa, and field studies of landforms, exposures, and cores continue to yield information on sedimentology, stratigraphy, soil formation, paleopedology, and fossil biotas from both glacial and interglacial deposits.

Spring break and summer provide time for longer trips, which are open to all earth and environmental sciences students. In recent years, students have traveled to the southern Appalachians, Arizona, China, Death Valley, Dominican Republic, the Florida Keys, Hawaii, New Mexico, the Ozarks, Puerto Rico, and Texas. Advanced classes have visited California, Colorado, Kansas, Montana, Oklahoma, Wisconsin, and Ontario, Canada.

Courses

Not all courses are offered every year.

Lower-Level Undergraduate

EES:1000 First-Year Seminar 1-2 s.h.
Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities). Requirements: first- or second-semester standing.

EES:1020 Loess Hills Service Learning Trip 1 s.h.
Special topics, directed research.

EES:1021 Spring Break Service Learning Trip 1 s.h.
Special topics, directed research.

EES:1030 Introduction to Earth Science 3-4 s.h.
Relationships between plate tectonics, geologic time, and the rock cycle with volcanoes and igneous, sedimentary, metamorphic rocks; fossils; radioactive isotopes; landscape evolution; mountain building; natural resources; their impacts on civilization. GE: Natural Sciences without Lab; Natural Sciences with Lab. Same as CEE:1030.

EES:1040 Evolution and the History of Life 3-4 s.h.
Fossils over the past 3.5 billion years, origin and evolution of life, evolutionary radiations and mass extinctions, the invasion of land, dinosaurs, the age of mammals, relationship between biological systems and environmental change in earth history. Offered spring semesters. GE: Natural Sciences without Lab; Natural Sciences with Lab.

EES:1050 Introduction to Geology 4 s.h.
Minerals, rocks, and rock-forming processes (including volcanoes and sedimentary environments); surface processes (rivers, groundwater, glaciers, deserts, ocean shorelines), major earth processes (continental drift, plate tectonics, earthquakes, mountain building); impact on civilization. Offered fall semesters. GE: Natural Sciences with Lab.

EES:1060 Origins of Life in the Universe (Part 1) 3 s.h.
Fundamental questions (How old is the universe? What is the nature of life? How has life evolved on Earth? What are our human origins? Are there other habitable planets in the universe?) that revolve around understanding origins from different perspectives (i.e., astronomy, physics, geoscience, biology, chemistry, anthropology); work with faculty from several departments to investigate these questions; inquiry-based activities to build success in critical thinking, teamwork, effective written and oral communication; origin of the universe, biochemistry of life, and origin of life on Earth; first of a two-part sequence. Recommendations: first-year or sophomore standing. GE: Natural Sciences without Lab. Same as ASTR:1060, BIOL:1060.

EES:1061 Origins of Life in the Universe (Part 2) 4 s.h.
Fundamental questions (What is the nature of life? How is evolution and how has life evolved on Earth? What are our human origins? Are there other habitable planets in the universe?) that revolve around understanding origins from different perspectives (astronomy, physics, geoscience, biology, chemistry, anthropology); students work with faculty from several departments to investigate these questions; inquiry-based activities to build success in critical thinking, teamwork, and effective written and oral communication; second of a two-part sequence. GE: Natural Sciences with Lab. Same as ASTR:1061, BIOL:1061, ANTH:1061.

EES:1070 Age of Dinosaurs 4 s.h.
Origin and evolutionary history of dinosaurs; diversity of dinosaurian groups, their geographic distributions and paleoecology; origins of flight among dinosaurs; environmental context, including other animals and plants that lived alongside dinosaurs; the so-called extinction of dinosaurs and radiation of modern forms; the role dinosaurs play in the interaction between science and the popular media. Offered fall semesters. GE: Natural Sciences with Lab.

EES:1080 Introduction to Environmental Science 3-4 s.h.
Biological and physical character of the Earth; interaction of humans with the environment, including impacts on ecosystems, climate, natural processes, resources; alternative options, including sustainability, waste management, energy, land reform. GE: Natural Sciences without Lab; Natural Sciences with Lab. Same as ENVS:1080.

EES:1090 Introduction to Environmental Sciences Laboratory 1 s.h.
Laboratory component of EES:1080. Requirements: completion of 3 s.h. in EES:1080 or ENVS:1080; or 3 s.h. of transfer equivalent. GE: Natural Sciences Lab only. Same as ENVS:1090.

EES:1115 Energy and Society: History and Science of Oil 3 s.h.
History, politics, and science of oil and oil industry. GE: Historical Perspectives. Same as ENVS:1115, GEOG:1115, HIST:1115.

EES:1170 Geology of the U.S. National Parks 2 s.h.
Geologic features, geologic history, important biological and archaeological characteristics, with emphasis on features that caused certain areas to be included in national park system. Offered spring semesters.

EES:1180 Geology Field Trip: Selected National Parks 2 s.h.
Observation, interpretation of prominent geologic, geomorphic, biological features; semester-break or semester-end visits to different parks or groups of parks each year. Offered spring semesters.

EES:1290 Energy and the Environment 3 s.h.
Scientific concepts related to potentially significant energy sources of the 21st century; environmental impacts, positive and negative, of each energy source as well as geologic and geographical distributions and applications. GE: Natural Sciences without Lab.

EES:1400 Natural Disasters 3 s.h.
How earth-atmosphere-hydrosphere-space systems produce events catastrophic to humans on the scale of individual lives to civilizations; root causes of earthquakes, landslides, volcanic eruptions, floods, hurricanes, tsunami, tornadoes, and asteroid impact, and their local, national, and global impact; spatial and temporal occurrences of these hazards; methods and processes for hazard preparedness, response, and recovery; social, economic, and policy aspects that affect and compound the magnitude of disasters associated with natural phenomena; case studies drawn from contemporary and ancient societies. GE: Natural Sciences without Lab.

EES:2190 Directed Study 1-3 s.h.
Special topics, independent research.

EES:2310 Introduction to Climatology 3 s.h.
Introduction to fundamental physical science principles that govern climatic processes and patterns; emphasis on scientific thinking and practice through lecture, discussion, exercises; opportunities to explore real-world climatology applications and questions (What is climate change? How fast is the climate actually warming? What are the contributions from us and how much is natural variability? How is climate change going to affect our weather?). Recommendations: GEOG:1020 or similar earth systems science course. Same as GEOG:2310.

EES:2410 Mineralogy 4 s.h.
Physical, chemical, and optical properties of minerals; phase relations; structures; associations; diagnostic features for identification. Offered fall semesters. Prerequisites: (EES:1030 or EES:1050) and (CHEM:1070 or CHEM:1110) and (MATH:0100 or MATH:0300 or MATH:1010).

EES:2831 Geologic Field Methods 3 s.h.
Introduction to basic methods of geologic field work in southwest Montana using topographic maps and GPS to locate oneself, identifying geologic map units (including superficial deposits), recognizing geologic contacts, constructing stratigraphic sections, measuring planar structures, and making geologic maps complete with a legend and cross-section. Offered summer session. Prerequisites: EES:1030 or EES:1050 or EES:1080 or EES:1400.

Upper-Level Undergraduate and Graduate

EES:3000 Geologic Training Assignment 1-3 s.h.
Practical experience. Requirements: grade of C or higher in EES:3500 and geology g.p.a. of at least 3.00.

EES:3020 Earth Surface Processes 3 s.h.
Basic geomorphic and environmental processes that shape the earth's surface; emphasis on erosion, transport, deposition by land mass movement (creep, landslides, earth flow), fluid agents (wind, water, ice); methods used to study these processes. Prerequisites: EES:1030 or EES:1050 or EES:1080 or ENVS:1080 or GEOG:1020. Same as ENVS:3020, GEOG:3020.

EES:3040 Writing for the Earth and Environmental Sciences 1-3 s.h.
Practical methods of content creation across curriculum; effective communication to lay and academic audiences; methods of planning, drafting, revising, and editing everything from general articles of interest to scientific papers. Same as WRIT:3200.

EES:3050 Geology of Iowa 3 s.h.
Investigation of geologic history responsible for landscape, soil, rocks, fossils, and geologic resources of Iowa. Recommendations: previous geology course.

EES:3070 Marine Ecosystems and Conservation 3 s.h.
Introduction to ocean ecosystems, including coral reefs, mangroves, estuaries and salt marshes, sandy and rocky shores, seagrass and kelp beds, the deep sea, plankton; biodiversity of each ecosystem; interrelationship of biota and physical/chemical environment; interactions among organisms, including food webs and symbiosis; local and global threats such as overfishing, pollution, ocean acidification, global warming, sea level change; ongoing biodiversity crisis, solutions for conservation problems.

EES:3080 Introduction to Oceanography 2 s.h.
Descriptive, chemical, physical, biological, geological aspects of oceans; impact on weather, climate, shorelines, food supply, other aspects of civilization. Offered spring semesters. Recommendations: knowledge of basic chemistry, biology, physics, earth science.
EES:3090 Topics in Museum Studies  
1 s.h.  
Systematic and analytic methods used for research in physical collections; tutorials in collection building, curation, and preservation; designed by members of the University of Iowa Collections Coalition. Same as MUSM:3090.

EES:3100 Introduction to Applied Remote Sensing  
4 s.h.  
Remote sensing of the earth's surface from aircraft, satellites; aerial photograph interpretation; remote sensing systems, methods, data analysis using electromagnetic spectrum and digital processing techniques, including visible, infrared, microwave radiation; remote sensing applied to geologic and environmental problems. Prerequisites: EES:1030 or EES:1050 or EES:1080. Same as ENVS:3100.

EES:3110 Chemical Evolution of the Oceans  
3 s.h.  
Investigation of various physico-chemical states oceans have assumed over the past four billion years of Earth history; use of isotope geochemistry as a proxy for ancient ocean conditions; focus on integrated Earth system science, paleoceanographic and paleoclimate modeling, role of chemical stratigraphy in deciphering past climate states of ocean-atmosphere system; relationship between chemical changes in ocean/atmosphere and biological systems of the Earth. Same as ENVS:3110.

EES:3150 Sustainability Project  
arr.  
Individual or collective project related to sustainability under the direction and supervision of a faculty member; involves regularly scheduled meetings, data collection and interpretation, and a final project report.

EES:3160 Field Trip  
2 s.h.  
Field trip to an area of geologic interest, such as carbonate area of Florida, Grand Canyon (Arizona), Rio Grande Rift (New Mexico), Death Valley (California, Nevada), Appalachian Mountains (Virginia); preceded by weekly discussions of destination's geology. Offered spring semester.

EES:3190 Directed Study  
arr.  
Special topics, independent research.

EES:3200 Collection Care and Management  
3 s.h.  
How a museum's management policy relates to its administrative, legal, and ethical obligations to its collections; acquisitions, deaccessions, collection use, data standards, storage environment, health, safety, documentation. Same as MUSM:3200.

EES:3206 Seminar: Taphonomy  
3 s.h.  
Taphonomy (study of fossil record in paleontology and archaeology); processes for accumulation, modification, and deposition of remains in prehistory; instruction by archaeologist and paleontologist. Requirements: graduate standing. Same as ANTH:3206.

EES:3210 Principles of Paleontology  
3 s.h.  
Patterns of evolution in fossil record; species and analysis of their evolutionary relationships; paleoecology, paleocommunity evolution; evolutionary radiation and mass extinctions; large-scale relationships between biodiversity and climatic change. Offered fall semesters.

EES:3220 Evolution of the Vertebrates  
3 s.h.  
Evolutionary history of vertebrates revealed by fossils and information from living animals; biogeographic, stratigraphic, paleoecological aspects of selected groups, especially mammals and dinosaurs; transitions from aquatic to terrestrial life, origins of flight, major events in vertebrate history (including mass extinctions and explosive radiations). Requirements: introductory course in geoscience or bioscience.

EES:3260 Wetlands: Function, Geography, and Management  
3 s.h.  
Hydrological, geomorphological, and ecological processes and their interaction in wetlands; geographic differences in wetlands based on climate and hydrology; wetlands, lakes, and rivers; role of wetlands in drainage basin hydrology and flooding; values and valuation of wetlands; wetland law and wetland delineation; wetlands and water resources. Prerequisites: GEOG:2374 or EES:2310. Same as GEOG:3320.

EES:3300 Sedimentary Geology  
4 s.h.  
Basic concepts of sedimentology, stratigraphy, depositional environments, sedimentary petrology; hands-on analyses of sediments and sedimentary rocks, including thin-section petrography; lecture/laboratory. Offered fall semesters. Prerequisites: EES:1030 or EES:1050.

EES:3360 Soil Genesis and Geomorphology  
3 s.h.  
Introduction to soil genesis, soil geomorphology, and classification including the basics of soil profile description and soil-landscape, soil-vegetation, and soil-climate relationships; emphasis on study of soils as the interface between living and non-living Earth systems and the role of soils in sustaining ecosystems and human societies; short field excursions and a weekend field trip. Requirements: college earth science and chemistry. Same as GEOG:3360.

EES:3380 Fluvial Geomorphology  
3 s.h.  
Hydrologic principles, stream channel processes, and fluvial geomorphology within drainage basin systems; spatial and temporal variations in water distribution, analysis of hydrological data, flow mechanisms, sediment transport, forecasting procedures, hydrograph construction, modeling. Requirements: EES:3020 or another 3000-level geology or hydraulics course. Same as CEE:3328.

EES:3390 Integrated Watershed Analysis  
3 s.h.  
Integration of existing knowledge of physical, hydrological, and environmental processes with management issues and challenges in water resources and environmental management; aspects of water quantity and quality, water use and treatment; basin management issues related to forestry, agriculture, urbanization, floods, droughts.
EES:3410 Analytical Methods  2 s.h.
Theory and practice of analyzing the chemical, isotopic, and mineralogical compositions of rocks, organic materials, and waters; use of modern analytical instruments. Offered spring semesters. Prerequisites: EES:3500 and CHEM:1070 and (PHYS:1512 or PHYS:1702).

EES:3500 Igneous and Metamorphic Petrology  4 s.h.
Nature, origin, and petrography of igneous and metamorphic rocks in hand specimen and thin-section. Offered spring semesters. Prerequisites: (EES:1030 or EES:1050) and EES:2410 and (CHEM:1070 or CHEM:1110) and (MATH:0100 or MATH:0300 or MATH:1010).

EES:3770 Global Stratigraphy  3 s.h.
Types of stratigraphy (e.g., biostratigraphy, lithostratigraphy, sequence stratigraphy, chemostratigraphy, magnetostratigraphy, cyclostratigraphy, chronostratigraphy) that share a number of procedures and practices and how differences cloud understanding of Earth history; central role of stratigraphy in modern geoscience pursuits; issue of time in stratigraphic record as an organizing theme for investigation of comparative stratigraphy.

EES:3840 Structural Geology  4 s.h.
Rock deformation; description, classification of geologic structures such as faults and folds; processes that generate geologic structures; solution of structural problems; interpretation of geologic maps. Prerequisites: EES:1030 or EES:1050.

Microscopy methods for research; all aspects of research, from sample preparation to imaging to data analysis; when to use a particular microscopy procedure; theory, operation, and application of scanning electron microscopy, scanning probe microscopy, laser scanning microscopy, X-ray microanalysis. Requirements: a physical science course. Same as CBE:4156, ACB:4156.

EES:4200 Advanced Collection Care and Management  3 s.h.
Builds on MUSM:3200; types and materials of museum objects and their care; storage and preservation of paper, books, photographs, works of art, electronic media, textiles, furniture, archaeological artifacts, and natural history specimens; collections project and hands-on practice in preservation techniques, enclosures, and supports; for students planning museum careers or professions that require care of collections. Prerequisites: MUSM:3200 or EES:3200. Same as MUSM:4200.

EES:4230 Special Topics  1-3 s.h.
Contemporary issues in earth sciences.

EES:4420 Vertebrate Osteology and Phylogeny  3 s.h.
Anatomy of the vertebrate skeleton from developmental, functional, and phylogenetic perspectives; relationship between skeletal, muscular, and nervous systems; history of the skeleton through modern forms; lecture and laboratory. Prerequisites: EES:3220 or ANTH:3305.

EES:4440 Phylogenetics and Biodiversity  3 s.h.
Methods available for reconstructing evolutionary history and measuring biodiversity, including distance, parsimony, likelihood, and taxic approaches; applications to molecular and morphological systematics, historical biogeography, study of diversity through time. Prerequisites: (EES:1040 or EES:3210) or (BIOL:1411 and BIOL:1412).

EES:4450 Morphometrics  1-3 s.h.
Quantitative methods for collection and analysis of morphologic data, including 2-D and 3-D geometric morphometrics and use of multivariate statistical methods to study size and shape; applications of morphometric techniques to study development, adaptation, variation within and among species, related topics in paleontology and evolutionary biology. Offered alternate years. Prerequisites: EES:1040 or EES:3210.

EES:4490 Elements of Geochemistry  3 s.h.
Introduction to application of chemical principles to solution of geologic problems concerning earth and environmental processes; origin of elements, chemical differentiation of Earth and the solar system, geochronology, application of radiogenic and stable isotopes, chemical equilibrium, elementary thermodynamics and kinetics, carbonate and silicate stability relationships, chemical weathering, adsorption, trace element behavior, oxidation-reduction reactions, characterization of surface and ground waters, and ocean chemistry. Prerequisites: EES:1050 and CHEM:1080.

EES:4520 Isotope Geochemistry  3 s.h.
Radiogenic and stable isotope systematics, applications to geological, cosmological, and environmental problems.

EES:4620 Approaches to Geoarchaeology  3 s.h.
Geoarchaeology as multidisciplinary contextual framework for human paleoecology; natural processes that create the archaeological record, approaches to reconstructing landscapes of the past as a context for archaeological deposits; weekend field trip. Prerequisites: EES:3360 or EES:4720 or ANTH:3205 or ANTH:4205. Same as ANTH:4620.

EES:4630 Hydrogeology  3 s.h.
Role of groundwater in water cycle, subsurface water profile, aquifers and aquitards, basic principles and laws of physical and chemical processes of groundwater flow and contaminant transport in geological formations for sustainable development and protection of groundwater resources; groundwater geology and hydrology, regional aquifer systems, well hydraulics, slug/bail and pumping test and their analyses, groundwater contamination and remediation, management and sustainability of groundwater resources.

EES:4660 Groundwater Modeling  3 s.h.
Groundwater flow and contaminant transport modeling; numerical methods, applications of groundwater modeling to water supply, groundwater resources evaluation, remediation design using software; GMS (MODFLOW, MODPATH, and MT3D). Prerequisites: (EES:4630 or CEE:4103) and MATH:1860. Same as CEE:4104.

EES:4680 Field Methods in Hydrologic Science  3 s.h.
Collection and interpretation of physical hydrology and hydraulics field measurements; basic data quality assurance and quality control; hands-on experience with field equipment and data collection. Prerequisites: EES:2831 or EES:3020 or EES:3300 or EES:3360 or EES:3380 or EES:3390 or EES:4630 or EES:4720 or EES:4790 or EES:4800 or CEE:3371 or ENGR:2510 or ENVS:3020.

EES:4700 Evolution of Ecosystems 3 s.h.
Evolutionary history of terrestrial and marine ecosystems; ecological processes from population to ecosystem levels; community assembly, trophic levels, networks, biodiversity dynamics; practical aspects of paleoecological data collection, statistical analysis, modeling. Requirements: two courses in geoscience, biology, environmental sciences, anthropology, or geography. Same as ENVS:4700.

EES:4710 Evolution of Plants 3 s.h.
Evolutionary history of plants over geologic time: relationships, morphology, and fossil record of major plant lineages; patterns and processes in evolution of plant morphology and diversity; ecological innovations and evolution of terrestrial ecosystems; relationships between biotic and environmental change; paleobotanical tools in stratigraphy, paleoclimatology, sedimentology; practical aspects of paleobotanical data collection, statistical analysis, modeling; field trip. Requirements: two courses in geoscience, anthropology, biology, environmental science, or geography.

EES:4720 Glacial and Pleistocene Geology 3 s.h.
Introduction to glaciers and glacial and interglacial Earth systems; linkages among glacial, oceanic, and atmospheric systems and their effects on landscapes and biota over the past two million years; how oceans, atmosphere, and glaciers interact and landscape effects of past glacial and interglacial cycles. Requirements: physical geology or physical geography or anthropology.

EES:4750 Mineral and Petroleum Exploration Geology 3 s.h.
Fundamentals of resource exploration philosophy and methods, with project-based presentation of techniques and strategies for mineral exploration and petroleum exploration; integration and evaluation of geological, geochemical, and geophysical techniques for mineral exploration; hydrocarbon systems and seismic interpretation for petroleum exploration. Corequisites: EES:3500 and EES:3840.

EES:4790 Engineering Geology 3 s.h.
Application of geology, water, and earth processes to civil and environmental engineering practice; physical properties of rock and soil, geologic mapping and surveying, groundwater supplies and wells, stream engineering, watershed management, site investigations for environmental assessment, and geologic hazards. Prerequisites: EES:1030 or EES:1050 or EES:1080.

EES:4800 Solid Earth Geophysics 3 s.h.
Geophysical methods used to address geological and engineering problems (e.g., finding petroleum and mineral deposits, studying groundwater resources, tracing contaminant plumes, evaluating archaeological sites); methods including gravity, magnetics, radiometrics, refraction and reflection seismography, geophysical well logging, and geoelectrical methods (direct current, frequency- and time-domain electromagnetics, induced polarization, magnetic resonance surveying, ground-penetrating radar); capabilities, drawbacks, costs; planning and budgeting surveys, processing the resulting digital data. Requirements: introductory geology or physics.

EES:4832 Geologic Field Analysis 3 s.h.
Structural, stratigraphic, and regional analysis of geology in the Rocky Mountains of Montana; emphasis on making reasonable geologic interpretations from field relationships; mapping projects in vicinity of Dillon, Montana that build on experience gained in EES:2831; capstone experience dedicated to synthesizing the geology of a fold-and-thrust belt near Glacier National Park. Offered summer session. Prerequisites: EES:2831 and EES:3840.

EES:4870 Applied Geostatistics 3 s.h.
Applications of geostatistical methods to geology, geography, hydrology, environmental sciences, and engineering; variogram, Kriging, analysis of spatial-varied data with varied computer software in participants' specialties. Same as GEOG:4870.

EES:4990 Senior Thesis in Geoscience arr.
Independent research resulting in a senior thesis. Requirements: senior standing.

EES:4999 Honors Thesis in Geoscience arr.
Independent research resulting in an honors thesis. Requirements: honors standing.

Graduate

EES:5010 Geoscience Seminar Series 1 s.h.
Scholarly work and research in geoscience.

EES:5015 American Association of Petroleum Geologists Fall Field Trip 1 s.h.
Resource-related topics in mineral and hydrocarbon exploration; joint field trip with Iowa State University. Requirements: AAPG student chapter member or graduate standing, and basic understanding of mineralogy, petrology, and structural geology.

EES:5070 Geologic Orientation 1 s.h.
Department degree requirements, programs; field survey of local geology; tips for TAs; introduction to specialized facilities; for new graduate students.

EES:5120 Global Change Seminar 1-2 s.h.
Current global change issues, including climate change, ecosystem changes and conservation, energy; seminar format with student presentations.

EES:5250 Environmental Seminar 1 s.h.
Environmental topics selected by student and instructor.
EES:5330 Carbonate Petrology 2 s.h.
Identification of constituents and interpretation of genesis, structures, environments of formation, and patterns and processes of diagenesis in limestones; laboratory-based.
Requirements: familiarity with optical microscope and sedimentation principles.

EES:5350 Depositional Environments 3-4 s.h.
Modern patterns of sedimentation; emphasis on interpreting depositional environments of ancient sedimentary rocks and deciphering resulting stratigraphic patterns. Requirements: knowledge of basic sedimentary geology and paleontology.

EES:5380 Process Geomorphology Seminar 1-3 s.h.
Topics in process geomorphology ranging from fluvial dynamics to mass movement to sediment transport and related environmental processes.

EES:5530 Geochronology 3 s.h.
How to evaluate published ages, and assumptions/errors involved; how to select and sample suitable materials for dating, and choose a suitable dating method and analytical technique; opportunity to develop skills for research and professional careers. Prerequisites: EES:4490 or EES:4520.

EES:5550 Metamorphic Petrology 3 s.h.
Interpretation of metamorphic rocks using hand specimens, thin sections, field relationships, mineralogical composition, texture, geochronology, isotope geochemistry, thermodynamics, kinetics, and tectonic setting; phase equilibria in pelitic, mafic, and carbonate rocks; thermobarometry, petrogenetic grids, P-T-X relationships, and pseudosections; kinetic models of metamorphic textures, heat-flow modeling, P-T-t paths, and tectonic evolution of metamorphic rocks.
Prerequisites: EES:3500.

EES:5820 Tectonics 3 s.h.
Dynamic processes responsible for crustal genesis, plate movements, mountain building; plate boundary zones; sedimentologic, structural, petrologic, geophysical characteristics of major tectonic settings; multidisciplinary approach; week-long field trip.
Prerequisites: EES:3840.

EES:6250 Paleontology Seminar 1-3 s.h.
Current controversial issues in paleontology.
Recommendations: EES:3210.

EES:6390 Advanced Watershed Analysis Seminar 1-3 s.h.
Integration of existing knowledge of physical, hydrological, and environmental processes with management issues and challenges in water resources and environmental management; aspects of water quantity and quality, water use and treatment, and basin management issues related to forestry, agriculture, urbanization, floods, droughts.

EES:6570 Tectonics and Petrology Seminar 1-2 s.h.
Topics in tectonics, structural geology, petrology.

EES:6920 Advanced Structural Geology 3 s.h.
Kinematic and dynamic analysis of deformed rocks; microstructural analysis; strain analysis, field investigations of highly deformed rocks. Prerequisites: EES:3840.

EES:7990 Research: Geoscience arr.
Independent research related to theses or dissertations in geoscience.