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: https://clas.uiowa.edu/ees/people
Website: https://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 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.

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.

- EES:3020 Earth Surface Processes 3
- EES:3070 Marine Ecosystems and Conservation 3
- EES:3080 Introduction to Oceanography 2
- EES:3100 Introduction to Applied Remote Sensing 4
- EES:3210 Principles of Paleontology 3

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.

Programs

Undergraduate Programs of Study

Majors
- Major in Geoscience (Bachelor of Arts)
- Major in Geoscience (Bachelor of Science)

Minor
- Minor in Geoscience

Graduate Programs of Study

Majors
- Master of Science in Geoscience
- Doctor of Philosophy in Geoscience
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.

Mineral Separation and Geochronology Preparation Facility: jaw crushers, disk pulverizer, shaker table, electromagnetic separators and heavy liquid separation equipment for mineral separation; core drill apparatus and saws for removing grains from thin sections and slabs; microscopes and digital imaging for grain selection and characterization; polishing equipment for slabs, thin section stubs, and grain mounts; natural standards for co-mounting with unknowns prior to analysis at a variety of geochronology facilities.

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; one of the largest university collections in North America.

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-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; and a Gatan ChromaCL cathodoluminescence detector system for imaging grain textures.

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.

Courses

Not all courses are offered every year.

Earth and Environmental Sciences Courses

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: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 with Lab; Natural Sciences without Lab. Same as CEE:1030.

EES:1031 Introduction to Earth Science Laboratory 1 s.h.
Laboratory component of EES:1030. Requirements: completion of 3 s.h. in EES:1030 or CEE:1030. Same as CEE:1031.

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 with Lab; Natural Sciences without 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 Big Ideas: Origins of the Universe, Earth, and Life 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 ENVS:1080. Same as ENVS:2200.

EES:1061 Big Ideas: Evolution of Life on Earth and the Search for Life in the Universe 4 s.h.
How has life evolved on Earth? What are our human origins? Are there other habitable planets in the universe? These fundamental questions revolve around understanding the origins of life from different perspectives—astronomy and physics, geoscience, biology, chemistry, and anthropology; students will work together with faculty from across four different departments to investigate these questions using inquiry-based activities to build success in critical thinking, teamwork, and effective written and oral communication; second half of the origins sequence (though either course also may be taken alone). GE: Natural Sciences with Lab. Same as ANTH:1061, ASTR:1061, BIOL: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 with Lab; Natural Sciences without Lab. Same as ENVIS:1080.

EES:1085 Fundamentals of Environmental Science 4 s.h.
Interdisciplinary study of how Earth's natural systems interact, how these systems affect society, and how they respond to human activity; how environmental problems can be solved and avoided by drawing upon knowledge in disciplines as diverse as ecology, anthropology, economics, chemistry, and political science; blended instructional environment, including traditional lectures, discussions in TILE classrooms, laboratory, online learning, peer-reviewed writing exercises, and service learning. Offered fall semesters. GE: Natural Sciences with Lab. Same as ENVIS:1085.

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 Big Ideas: The History and Science of Oil 3 s.h.
Historical perspective on business, science, geology, technology, politics, environment, and culture of the global oil industry; the rise of oil as the most influential international business of the last 150 years, the material foundation of economies, a major force in world politics, a shaper of daily life, and a guide to understanding Earth's deep history. Offered fall semesters. GE: Historical Perspectives. Same as ENVIS: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.

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:2001 Second-Year Field Trip for Earth and Environmental Sciences 1 s.h.
Opportunity for students to begin developing an appreciation of earth system and earth history scales; application of classroom learning to field-based inquiry; real-world examples of introductory course material in an outdoor classroom setting. Prerequisites: EES:1030 or EES:1050 or EES:1080 or ENVS:1080. Requirements: geoscience or environmental sciences major. Same as ENVIS:2001.

EES:2190 Directed Study arr.
Special topics, independent research.

EES:2200 Historical Geology 4 s.h.
Framework of earth history that is essential to understand how the earth system works; investigation of physical, biological, atmospheric, oceanographic, and chemical history of the earth to prepare for further earth and environmental science courses. Prerequisites: EES:1030 or EES:1050 or EES:1080 or ENVS:1080. Same as ENVIS:2200.
EES:2310 Introduction to Climatology 3 s.h.
Introduction to atmospheric processes that determine weather and climate; flow of energy through the atmosphere, distribution and movement of moisture and air, and atmospheric disturbances such as cyclones, hurricanes and tornadoes, and climate change. Recommendations: GEOG:1020 or similar earth systems science course. Same as ENVS: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: (CHEM:1110 or CHEM:1070) and (EES:1050 or EES:1030).

EES:2831 Geologic Field Methods 3 s.h.
Introduction to basic methods of geologic field work in southwestern 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:1400 or EES:1080 or EES:1030 or EES:1050.

EES:3000 Geologic Training Assignment 1-3 s.h.
Practical experience.

EES:3001 Third-Year Field Trip for Earth and Environmental Sciences 1 s.h.
Opportunity for students to apply their major course work to real-world problems; field trip to visit parks, mines, and/or quarries in Missouri and Arkansas that illustrate many of the lessons learned in EES:2410 and EES:3500. Prerequisites: EES:1030 or EES:1050 or EES:1080 or ENVS:1080 or EES:2410. Requirements: geoscience or environmental sciences major, and junior standing. Same as ENV:3001.

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:1080 or EES:1050 or EES:1080 or GEOG:1020. Same as ENV: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 2 s.h.
Exploration of the geologic history responsible for landscape, soil, rocks, fossils, water, and natural resources of Iowa; background of Iowa's natural history; preparation for K-12 educators to deliver earth and environmental science content in their own classrooms utilizing natural landscapes in Iowa.

EES:3051 Geology of Iowa Field Trip 1 s.h.
Exploration of the geologic history responsible for landscape, soil, rocks, fossils, water, and natural resources of Iowa; field-based examples of Iowa's natural history; preparation for K-12 educators to deliver earth and environmental science content in their own classrooms utilizing the natural landscapes in Iowa. Recommendations: EES:3050. Same as ENVS:3051.

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:1050 or EES:1080 or EES:1030. Same as ENVS:3100.

EES:3110 Chemical Evolution of the Oceans 3 s.h.
Investigation of various physicochemical 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:3130 Career Path Planning for Earth and Environmental Sciences 1 s.h.
Opportunity to cultivate a sense of what employers deem as important skills beyond the technical requirements, develop a set of polished application materials and practice interviewing skills, and investigate a wide variety of potential career paths through interaction with department alumni.

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 1-3 s.h.
Field trip to an area of geologic interest, such as localities in the Midwest, Hawaii, Grand Canyon (Arizona), Rio Grande Rift (New Mexico), Death Valley (California, Nevada), Appalachian Mountains (Virginia), as well as international destinations such as the Caribbean and China; preceded by weekly discussions of destination's geology.

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: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:2310 or GEOG:2374. 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.

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 2-3 s.h.
Theory and practice of analyzing chemical, isotopic, and mineralogical compositions of rocks, organic materials, and waters; use of modern analytical instruments. Offered spring semesters. Prerequisites: EES:3500 and (PHYS:1512 or PHYS:1702) and CHEM:1070.

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: (MATH:1010 or MATH:0300 or MATH:0100) and (EES:1050 or EES:1030) and (CHEM:1110 or CHEM:1070) and EES:2410.

EES:3770 Global Stratigraphy 3 s.h.
Types of stratigraphy (e.g., biostratigraphy, lithostratigraphy, sequence stratigraphy, chronostratigraphy, 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.

EES:4001 Fourth-Year Field Trip for Earth and Environmental Sciences 2 s.h.
Application of core course learning to real-world examples; students develop a broader understanding of interrelated aspects of earth and environmental sciences as truly integrated scientific endeavors; field trip to Big Bend National Park to highlight a wide range of geoscience and environmental science studies and provide students an opportunity to apply all aspects of their training to the amazing geologic landscape of southwest Texas; capstone field experience for students heading into their senior year. Prerequisites: EES:2831. Requirements: geoscience or environmental sciences major, and senior standing. Same as ENVS:4001.

EES:4156 Scanning Electron Microscopy and X-Ray Microanalysis 2-3 s.h.
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 ACB:4156, CBE:4156.

EES:4200 Advanced Collection Care 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. Same as MUSM:4200.

EES:4230 Special Topics 1-3 s.h.
Contemporary issues in earth sciences.
Earth and Environmental 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 constructing 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 (BIOL:1411 and BIOL:1412) or EES:3210.

**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.

**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:1030 or EES:1050) and (CHEM:1070 or CHEM:1110).

**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 paleoeconomy; 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:4205. Same as ANTH:4205.

**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: MATH:1860 and (EES:4630 or CEE:4103). 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:4720 or EES:2831 or EES:3020 or EES:3160 or EES:3300 or EES:3380 or ENGR:2510 or EES:4800 or EES:4630 or CEE:3371 or EES:4790 or EES:3390 or EES: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 paleocological data collection, statistical analysis, modeling. Requirements: two courses in geoscience, biology, environmental sciences, anthropology, or geography. Same as ENV: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:1080 or EES:1050.

**EES:4800 Solid Earth Geophysics**  3 s.h.
Geophysics is the broad geoscience field interested in discovering the unseen characteristics of the Earth and other planets, including the internal structure of the Earth, the current motions of tectonic plates, the sources and causes of geological disasters, and the locations of economic resources; methods to accomplish these goals include seismology, gravity and magnetic studies, geodesy, and measurements of heat; course offers a broad introduction to these topics that is rooted in current and growing fields of active research. Requirements: introductory geology or physics.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>EES:4832</td>
<td>Geologic Field Analysis</td>
<td>3</td>
<td>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.</td>
</tr>
<tr>
<td>EES:4870</td>
<td>Applied Geostatistics</td>
<td>3</td>
<td>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.</td>
</tr>
<tr>
<td>EES:5010</td>
<td>Geoscience Seminar Series</td>
<td>1</td>
<td>Scholarly work and research in geoscience.</td>
</tr>
<tr>
<td>EES:5015</td>
<td>American Association of Petroleum</td>
<td>1</td>
<td>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.</td>
</tr>
<tr>
<td>EES:5070</td>
<td>Geologic Orientation</td>
<td>arr.</td>
<td>Department degree requirements, programs; field survey of local geology; tips for TAs; introduction to specialized facilities; for new graduate students.</td>
</tr>
<tr>
<td>EES:5120</td>
<td>Global Change Seminar</td>
<td>1-2</td>
<td>Current global change issues, including climate change, ecosystem changes and conservation, energy; seminar format with student presentations.</td>
</tr>
<tr>
<td>EES:5250</td>
<td>Environmental Seminar</td>
<td>1</td>
<td>Environmental topics selected by student and instructor.</td>
</tr>
<tr>
<td>EES:5330</td>
<td>Carbonate Petrology</td>
<td>2</td>
<td>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.</td>
</tr>
<tr>
<td>EES:5350</td>
<td>Depositional Environments</td>
<td>3-4</td>
<td>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.</td>
</tr>
<tr>
<td>EES:5380</td>
<td>Process Geomorphology Seminar</td>
<td>1-3</td>
<td>Topics in process geomorphology ranging from fluvial dynamics to mass movement to sediment transport and related environmental processes.</td>
</tr>
<tr>
<td>EES:5550</td>
<td>Metamorphic Petrology</td>
<td>3</td>
<td>Interpretation of metamorphic rocks using hand specimens, thin sections, field relationships, mineralogical composition, texture, geochronology, isotopic geochmistry, thermodynamics, kinetics, and tectonic setting; phase equilibria in pelitic, mafic, and carbonate rocks; thermobarometry, petrogenetic grids, P-T-X relationships, and psuedosections; kinetic models of metamorphic textures, heat-flow modeling, P-T-t paths, and tectonic evolution of metamorphic rocks. Prerequisites: EES:3500.</td>
</tr>
<tr>
<td>EES:5820</td>
<td>Tectonics</td>
<td>3</td>
<td>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.</td>
</tr>
<tr>
<td>EES:6390</td>
<td>Advanced Watershed Analysis Seminar</td>
<td>1-3</td>
<td>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.</td>
</tr>
<tr>
<td>EES:6570</td>
<td>Tectonics and Petrology Seminar</td>
<td>1-2</td>
<td>Topics in tectonics, structural geology, petrology.</td>
</tr>
<tr>
<td>EES:6920</td>
<td>Advanced Structural Geology</td>
<td>3</td>
<td>Kinematic and dynamic analysis of deformed rocks; microstructural analysis; strain analysis, field investigations of highly deformed rocks. Prerequisites: EES:3840.</td>
</tr>
<tr>
<td>EES:7604</td>
<td>Principles of Scholarly Integrity</td>
<td>0</td>
<td>Training in responsible conduct of research and scholarly activities; student/mentor responsibilities, authorship, plagiarism/falsification/fabrication of data, intellectual property, conflict of interest; fiscal, institutional, and societal; data handling. Requirements: postdoctoral standing in geoscience.</td>
</tr>
<tr>
<td>EES:7990</td>
<td>Research: Geoscience</td>
<td>arr.</td>
<td>Independent research related to theses or dissertations in geoscience.</td>
</tr>
</tbody>
</table>