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Samantha Hopkins, associate professor (paleontology). See Robert Donald Clark Honors College.

Eugene D. Humphreys, professor (seismology, regional tectonics). BS, 1974, MS, 1978, California, Riverside; PhD, 1985, California Institute of Technology. (1985)


Mark H. Reed, professor (mineral deposits, aqueous geochemistry). BA, 1971, Carleton; MS, 1974, PhD, 1977, California, Berkeley. (1979)

The date in parentheses at the end of each entry is the first year on the University of Oregon faculty.

- Bachelor of Arts in Earth Sciences
- Bachelor of Science in Earth Sciences
- Minor in Earth Sciences

Undergraduate Studies

The undergraduate program in the Department of Earth Sciences provides an understanding of the materials that constitute the earth and the processes that have shaped the earth from deep in its interior to the surface environment—geology. Geology applies all the basic sciences—biology, chemistry, mathematics, and physics—to understanding earth processes in the historical context of geologic time. It is a science that explores problems by combining field investigations with laboratory experiments and theoretical studies.

Geology also addresses many natural hazards—earthquakes, flooding, and volcanic eruptions—that affect humans. It addresses the impact of humans on the earth’s surface environment, where we pollute rivers and ground water, cause rapid erosion and landslides, or attempt to re-engineer rivers and shorelines.

Preparation

High school students planning to major in geological sciences should include in their high school program as much mathematics and science (physics, chemistry, biology, or earth science) as possible.

Students who transfer to the department after two years of college work elsewhere should have completed a year of general chemistry, a year of general physics, and two quarters or a semester of calculus. A year of general geology with laboratory is recommended.

Careers

Students with a degree in earth sciences are qualified for employment in a broad range of careers: geotechnical and environmental consultants; K–12 school teachers (with an additional teaching certificate); laboratory technicians; professional geologists, geophysicists, or geochemists; and positions in the petroleum and mining industries or in state and federal agencies such as the United States Geological Survey or the Environmental Protection Agency. The current climate for employment in the earth sciences is good. Geoscience jobs require skills in critical thinking and problem solving, quantitative analysis, oral and written communication, and team work. The Department of Earth Sciences curriculum emphasizes these skills.

Earth Sciences Curriculum

The Department of Earth Sciences offers a bachelor of science (BS) or a bachelor of arts (BA) degree with a major in earth sciences.

Major Tracks

Earth science is an unusually broad subject. It addresses everything from the chemical processes that make rocks and minerals to the physics behind plate tectonics and the travel of earthquake waves through the planet. It explores the history of the evolution of life revealed in fossils, and it probes the earth processes that affect how humans can survive on the surface of the planet. To address this breadth, the department offers four curricular tracks for a major in earth sciences: geology, geophysics, environmental geoscience, and paleontology.

All of the tracks require a common core of general chemistry, calculus, general geology, and physics, except that paleontology- and environmental geoscience-track students may take two terms of biology in place of two terms of physics. Beyond the core, each track requires certain additional courses and a selection of electives.

Undergraduate Research

As many as 4 credits of research can be counted toward electives in any of the tracks. To receive such credit, students must

- submit a short letter, approved by the faculty research advisor and addressed to the head undergraduate advisor in earth sciences, stating the nature of the research and asserting that there is faculty supervision
- submit a final written report to the faculty advisor describing the results of the research

Students may earn credit in this category by registering for any of the following:

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<td>ERTH 406</td>
<td>Practicum: [Topic]</td>
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<td>ERTH 408</td>
<td>Laboratory Projects: [Topic]</td>
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</table>

Students who complete an honors thesis may not apply this option toward elective credits.

Grade Options and Standards

Undergraduate majors must take for letter grades (the pass/no pass option is not acceptable) all the courses required in their degree program. Required courses must be completed with grades of C– or better. Exceptions for honors students are noted under Honors in Earth Sciences.

Honors in Earth Sciences

Application for graduation with honors in earth sciences must be made no later than spring term of the student’s junior year. To be eligible for graduation with honors, a student must

- maintain a grade point average (GPA) of 3.50 or better in geological sciences courses or a 3.00 or better in all science courses
- submit and orally present an acceptable honors thesis written under the supervision of a department faculty member and evaluated by a committee consisting of three faculty members including the supervisor. The thesis should be presented no later than three weeks before final examinations during the term the student plans to graduate

Honors students may register for 3 credits of Research: [Topic] (ERTH 401) the term before they intend to graduate, and 3 credits of Thesis (ERTH 403) the term of graduation. These credits may be applied toward electives.

Group Requirements

Fourteen earth sciences courses satisfy university science group requirements. See the Group Requirements section of this catalog under Registration and Academic Policies.
Kindergarten through Secondary Teaching Careers

Students who complete a degree with a major in earth sciences are eligible to apply to the College of Education’s fifth-year licensure program in middle-secondary teaching or the fifth-year licensure program in elementary teaching. More information is available in the College of Education (http://catalog.uoregon.edu/education/) section of this catalog.

Four-Year Degree Plan

The degree plan shown is only a sample of how students may complete their degrees in four years. There are alternative ways. Students should consult their advisor to determine the best path for them.

- Geology Track (p. 3)
- Geophysics Track (p. 4)
- Environmental Geoscience Track (p. 5)
- Paleontology Track (p. 6)

Bachelor of Science in Earth Sciences: Geology Track

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| Total Credits | 42-47 |

**Bachelor of Science in Earth Sciences: Geophysics Track**

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| Total Credits | 48 |

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**Bachelor of Science in Earth Sciences: Environmental Geoscience Track**

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Bachelor of Science in Earth Sciences: Paleontology Track

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<td>CH 223</td>
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<td>PHYS 202</td>
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<td>ERTH 315</td>
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<td>ERTH 332</td>
<td>Introduction to Petrology</td>
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Earth Sciences

General-education, multicultural, or other group-satisfying course 4

Spring
PHYS 203 General Physics 4
ERTH 318 Introduction to Field Methods 3
General-education, multicultural, or other group-satisfying course 8

Credits 17

Total Credits 15

Course Title Credits Milestones

Summer
ERTH 406 Practicum: [Topic] (12 credits) 1-6

Credits 1-6

Total Credits 62-67

Course Title Credits Milestones

Fourth Year
Fall
General-education, multicultural, or other group-satisfying courses 8
Geology or other science elective 8

Credits 16

Winter
General-education, multicultural, or other group-satisfying courses 8
Geology or other science elective 8

Credits 16

Spring
General-education, multicultural, or other group-satisfying courses 12
Geology or other science elective 4

Credits 48

Total Credits 48

Master’s Degrees in Earth Sciences (http://catalog.uoregon.edu/arts_sciences/geologicalsciences/GRearth/#maandmstext)
Ph.D. in Earth Sciences (http://catalog.uoregon.edu/arts_sciences/geologicalsciences/GRearth/#doctoraltext)

Graduate Studies

The Department of Earth Sciences offers programs of graduate study leading to master of science (MS), master of arts (MA), and doctor of philosophy (PhD) degrees with opportunity for research in a wide variety of specialty fields. Course work is designed to meet individual needs, and students may pursue independent research in geobiology, geochemistry, geodesy, geomechanics, geomorphology, geophysics, mineralogy, petrology, volcanology, paleontology, stratigraphy, sedimentary petrology, structural geology, and ore deposit geology. The master’s degree program requires two years or more for completion.

Admission to the graduate program is competitive and based on academic records, scores on the Graduate Record Examinations (GRE), and letters of recommendation. Nonnative speakers of English must also submit scores for the Test of English as a Foreign Language (TOEFL) and the Test of Spoken English (TSE). Applications are welcome from students who are interested in using their background in related fields, such as physics, chemistry, and biology, to solve geologic or geophysical problems.

Graduate students are advised by a guidance committee consisting of three faculty members. This committee meets with each student shortly after he or she arrives on campus and as often thereafter as necessary for planning purposes.

Requirements

Basic university requirements for graduate degrees are described in the Graduate School (http://catalog.uoregon.edu/graduate/) section of this catalog. The department sets additional examination, course
work, seminar, and thesis requirements. Applicants should read the Guide to Graduate Study on the department website (http://earthsciences.oregon.edu/graduate-program/) or write to the Department of Earth Sciences for details.

Programs
Graduate study in earth sciences is offered in five broad areas:

1. volcanology-petrology-geochemistry
2. stratigraphy–surface processes
3. paleontology-paleopedology-geobiology
4. structural geology–geophysics
5. economic geology (mineral deposits)

Volcanology-Petrology-Geochemistry
The department has excellent analytical and other research facilities for studies in these subdisciplines, and the volcanic and metamorphic terrane of the Northwest offers unsurpassed opportunities for field studies. Active research programs are diverse and include studies of eruption dynamics, magma volatile inventories, and magma rheology; experimental studies of igneous phase equilibria and trace element partitioning; calculations of multicomponent equilibria in aqueous systems and volcanic gases; and studies of igneous protogenesis.

Stratigraphy–Surface Processes
The stratigraphic record of tectonically active sedimentary basins indicates the dynamic interactions among basin subsidence, sediment input from eroding sources, evolution of depositional systems, and active faulting and folding that govern these processes. Research in this area combines field-based stratigraphic, sedimentologic, and geomorphic analysis with provenance studies and concepts derived from theoretical models to decipher the complex structural and climatic controls on the filling histories of active basins.

Surface processes regulate how tectonics and climate affect landscape evolution. Field observations, numerical simulations, topographic analyses, and experimental facilities are used to study sediment transport processes over a range of spatial and temporal scales. Projects incorporate links between active tectonics and structural geology, biology, geomorphics, and surface processes to address problems such as landsliding and hill-slope evolution, biological contributions to soil creep and landscape lowering, and the geomorphic implications of seismic-induced landsliding.

Paleontology-Paleopedology-Geobiology
Studies of fossil soils, plants, and vertebrates aim to reconstruct life on land and its role in global change. Global changes of interest include Neogene paleoclimate and paleoenvironment of ape and human evolution in East Africa, environmental effects of terminal Cretaceous impact and dinosaur extinction in Montana, consequence of mass extinction and methane clathrate degassing at the Permian-Triassic boundary, and the effect of early land plants and forest on weathering and atmospheric composition during the early Paleozoic.

Geobiology focuses on the interaction of microorganisms with the geologic environment and the ways life forms affect geological processes, such as weathering and mineralization.

Structural Geology–Geophysics
Graduate work in the structural geology–geophysics area involves the study of the earth's dynamic processes.

Seismic imaging techniques using regional arrays provide tools for understanding regional tectonics. Studies of upper-mantle and lithospheric structure beneath the Rocky Mountains and in the Pacific Northwest subduction zone are providing essential constraints, unavailable from surface geology, for detailed dynamical models of plate-lithospheric deformation.

Structural geology focuses on applying modern field and analytical techniques to solving problems in Cenozoic tectonics and active faulting. Detailed field mapping, trench logging, and geomorphic analysis are combined with seismic array data, land- and space-based geodetic data, and theoretical modeling to address problems including Oregon's Basin and Range province and coastal deformation, active tectonics of the San Andreas Fault system, and seismic risk along the Pacific margin of the United States and southeast and central Asia.

Geophysical experiments conducted at sea investigate the nature of sea-floor spreading including the segregation, transport, and storage of melt; the riftimg of oceanic lithosphere; and the spatial and temporal connectivity between magmatic, tectonic, and hydrothermal processes.

Mineral Deposits
Current research on ore deposits includes studies of porphyry copper deposits, epithermal veins, and active geothermal systems. These projects combine field mapping, petrography, and chemical analyses with theoretical chemical modeling of processes of ore fluid generation, alteration, and mineralization.

Related Research Activities
The Condon Collection of Fossils at the Museum of Natural and Cultural History maintains strong ties to the Department of Earth Sciences. Two geology professors are curators of the collection, and paleontology graduate and undergraduate students are often employed as assistants. The Condon Collection contains 60,000 specimens, including invertebrate and vertebrate fossils, paleobotanical remains, and an extensive collection of modern animals that are available to interested researchers for study.

Research Facilities
Students may use a variety of analytical facilities and equipment including a three-component broadband (0.03–50Hz) seismic array, an electron microprobe, a scanning electron microscope with image analysis, x-ray diffraction, FTIR spectroscopy, stable isotope mass spectroscopy, and a geochemistry laboratory.

An experimental petrology laboratory covers a range of crustal temperatures and pressures and includes equipment for doing experiments in controlled atmospheres. Two piston-cylinder apparatus with pressure-temperature capability to 35 kilobars and 1,500°C may be used to study crystalline, partially molten, and molten silicates under mantle-like conditions.

Computers are used for much of the research in the department including acquisition and processing of seismic and gravity data and numerical modeling of geophysical processes and geochemical reactions. A geochemistry laboratory is equipped with sophisticated computer programs for thermodynamic calculations of gas-liquid-solid equilibria and reaction processes important in metamorphic, volcanic gas,
hydrothermal, and diagenetic systems. The Internet can be accessed through the UONet fiber-optic link. A student computer facility, equipped with PC and Macintosh computers and laser printers, is also connected to the networks.

The sedimentological and paleontological laboratories have, in addition to standard laboratory equipment, an electronic particle-size analyzer, an x-radiography unit, photomicroscopes, a Leitz Aristophot unit, a fully maintained catalog of foraminifera, an acid room, and a conodont-processing laboratory.

Financial Aid for Graduate Students
Most of the department's graduate students are fully supported through teaching and research assistantships. More information about financial assistance and department policies for awarding and renewing teaching and research fellowships may be obtained by reading the Guide to Graduate Study on the department website (http://earthsciences.uoregon.edu/graduate-program/) or by writing to the department.

Courses

ERTH 101. Exploring Planet Earth. 4 Credits.
Plate tectonics, mantle flow, and magmatism. Volcanoes, earthquakes, mountain building, generation of Earth's crust; rocks and minerals; Earth's internal structure. Comparison with other planets. Laboratory, lecture.

ERTH 102. Exploring Earth's Environment. 4 Credits.
Landforms, surface processes, and interactions between humans and the environment. Weathering, erosion, sedimentation, ground water, streams, glaciers, deserts, oceans, and coastlines; geologic hazards. Laboratory, lecture. Roering.

ERTH 103. Exploring Earth History. 4 Credits.
History of the Earth. Geologic time, sedimentary environments; oceans, mountains, and climate through time; stratigraphic history of North America; evolution of plants and animals. Laboratory, lecture.

ERTH 104. Exploring Earth's Geology and Society. 4 Credits.
Investigation of topics in geology, ecology, and anthropology relevant to contemporary global energy debates; current energy policy issues investigated through term projects.

ERTH 105. Exploring Earth's Resources and Environment. 4 Credits.
Survey of the geological processes that both create and destroy mountain ranges around the world, and an introduction to geological science.

ERTH 156M. Scientific Revolutions. 4 Credits.
Surveys several major revolutions in our views of the natural and technological world, focusing on scientific concepts and methodological aspects. For nonscience majors. Multilisted with PHYS 156M.

ERTH 198. Laboratory Projects: [Topic]. 1-12 Credits.
Repeatable.

ERTH 199. Special Studies: [Topic]. 1-6 Credits.
Repeatable. Studies of geologic topics combine background lectures with guided field trips to areas of geologic interest.

ERTH 201. Dynamic Planet Earth. 4 Credits.
Processes that cause earthquakes, volcanism, mountain building, and plate tectonics. Includes Earth's origin and internal structure, rocks and minerals, gravity and magnetics. Weekly lectures, two-hour laboratory.

ERTH 202. Earth's Surface and Environment. 4 Credits.
Earth materials, the rock record, human interactions with surface environment. Sedimentary rocks and environments, chemical and physical weathering, mineral and energy resources, hydrogeology, ground-water contamination, surface processes, human impacts. Weekly lectures, two-hour laboratory.

ERTH 203. History of Life. 4 Credits.
Origin, history, and physical evolution of the Earth; geologic time scales, development of the global stratigraphic section. Weekly lectures, two-hour laboratory.

ERTH 213. Geology of National Parks. 4 Credits.
Examines selected geologic features in United States national parks and the processes that form them. Focuses on parks in the western United States.

ERTH 304. The Fossil Record. 4 Credits.
Origin of life in Precambrian; evolution of plants and invertebrate animals; evolution of early chordates, fish, amphibians, reptiles, dinosaurs, birds, and mammals; speciation and extinction. Intended for junior and senior nonmajors but also open to geological sciences majors.

ERTH 305. Dinosaurs. 4 Credits.
Overview of the past and present biodiversity of vertebrate animals, including ourselves, dinosaurs, and what ruled the ocean when dinosaurs roamed the land.

ERTH 306. Soils and Soils. 4 Credits.
Mechanisms that cause earthquakes and volcanoes, relation to plate tectonics, associated hazards, examples in Oregon and the western United States.

ERTH 307. Oceanography. 4 Credits.
Characteristics and physical, chemical, and biological processes of the world's oceans. Includes sections on origin of the oceans, plate tectonics, and human use and misuse of oceans.

ERTH 308. Geology of Oregon and the Pacific Northwest. 4 Credits.
The region's geologic and tectonic history and the plate tectonic processes responsible for its evolution.

ERTH 316. Introduction to Hydrogeology. 4 Credits.
Examines the role of water in geologic and environmental processes. Topics include water cycle, groundwater flow, and contaminant transport.
Pre- or coreq: MATH 252, PHYS 201.
ERTH 318. Introduction to Field Methods. 3 Credits.
Introduction to geologic mapping and related field skills, rock descriptions, cross sections, and structures. Lectures, laboratories, mandatory field trips.
Prereq: ERTH 101–ERTH 103 or ERTH 201–ERTH 203.

ERTH 319. Cascade Volcanoes - Field Studies. 4 Credits.
Two-week summer course. Physical processes that cause volcanic activity, and an introduction to geological science. Examines recent volcanic activity in the Cascades, impacts of volcanism on people, infrastructure, and natural resources, and volcano monitoring and hazard assessment.

ERTH 331. Mineralogy. 5 Credits.
Crystal chemistry, systematic study of rock-forming silicate, and selected other minerals, mineral optics, and x-ray diffraction. Lab work with hand samples and petrographic microscopes.
Prereq: ERTH 201, ERTH 202 or ERTH 101, ERTH 102; coreq: CH 221 or CH 224.

ERTH 332. Introduction to Petrology. 5 Credits.
Origin and classification of igneous, metamorphic, and sedimentary rocks. Microscopic study of rocks in thin section.
Prereq: ERTH 331.

ERTH 333. Sedimentology and Stratigraphy. 4 Credits.
Sedimentary processes; characteristic properties of sedimentary rocks and their use in interpreting depositional environments; principles of lithostratigraphy and sequence stratigraphy.
Prereq: ERTH 101–ERTH 103 or ERTH 201–ERTH 203; pre- or coreq: ERTH 311 or ERTH 332.

ERTH 337. Introduction to Physical Oceanography. 4 Credits.
Introduction to the physical processes that occur in the ocean. These processes control the movement of sediment, pollution, nutrients, and biota, as well as heat and freshwater. Topics might include waves, global ocean circulation, sediment transport, estuarine circulation, and biological oceanography.
Prereq: ERTH 101 and ERTH 102 or ERTH 201 and ERTH 202; PHYS 101 and PHYS 102 or PHYS 201 and PHYS 202 or PHYS 251 and PHYS 252.

ERTH 350. Structural Geology. 3 Credits.
Description, analysis, and origin of geologic structures including faults, folds, and tectonites. Focus on kinematic and dynamic analysis of deformation of earth materials.
Prereq: ERTH 318; ERTH 311 or ERTH 332.

ERTH 351. Structural Geology Problems. 1 Credit.
Exercises in solving structural geology problems using orthographic and stereographic projection techniques. Problems emphasize calculating stress and strain from structural markers.
Coreq: ERTH 350.

ERTH 352. Structural Geology Laboratory and Field. 1 Credit.
Collection and interpretation of field and map data for structural analysis. Includes field trips, map and cross-section generation, and some computer-based exercises.
Coreq: ERTH 350.

ERTH 353. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society’s attempt to mitigate them.
Prereq: ERTH 101 or ERTH 201.

ERTH 354. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 355. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 356. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

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Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

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Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 359. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 360. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 361. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 362. Geologic Hazards. 4 Credits.
Examines geologic hazards, including both the physical processes that cause them and society's attempt to mitigate them.

ERTH 363. Computational Tools for Earth Sciences. 4 Credits.
Introduction to computational tools vital to the work of Earth scientists, including data management and analysis, algorithms, basic programming, computational environments, and visualization.
Prereq: MATH 251.

ERTH 399. Special Studies. 1-5 Credits.
Repeatable.

ERTH 400M. Temporary Multilisted Course. 1-5 Credits.
Repeatable.

ERTH 401. Research: [Topic]. 1-21 Credits.
Repeatable.

ERTH 403. Thesis. 1-6 Credits.
Repeatable thrice for maximum of 6 credits.
Prereq: earth sciences honors or senior thesis students only.

ERTH 405. Reading and Conference: [Topic]. 1-21 Credits.
Repeatable.

ERTH 406. Practicum: [Topic]. 1-6 Credits.
Repeatable once.

ERTH 407. Seminar: [Topic]. 1-5 Credits.
Repeatable.

ERTH 408. Laboratory Projects: [Topic]. 1-12 Credits.
Repeatable.

ERTH 409. Terminal Project. 1-12 Credits.
Repeatable.

ERTH 410. Experimental Course: [Topic]. 1-5 Credits.
Repeatable.

ERTH 410L. Experimental Course: [Topic]. 1-5 Credits.
Repeatable.

ERTH 414. Igneous and Metamorphic Petrology. 4 Credits.
Advanced principles of igneous and metamorphic petrogenesis. Gibbs phase rule, phase diagrams, mineral thermodynamics; magma geochemistry and rheology; metamorphic facies, geothermometry and geobarometry. Johnston.
Prereq: ERTH 332; CH 223 or CH 226H.

ERTH 415. Field Geophysics. 4 Credits.
Introduction to geophysical methods for subsurface investigation, useful for exploration, geotechnical engineering, and characterization of subsurface groundwater and environmental conditions.
Prereq: MATH 112 or PHYS 201.

ERTH 416. Geophysical and Environmental Sensors. 4 Credits.
This experiential course will provide students an introduction to sensors, microcontrollers, automation, data collection and programming from the perspective of sensing the Earth and the environment.
Prereq: MATH 252, ERTH 363 or CS 122.

ERTH 418. Earth and Environmental Data Analysis. 4 Credits.
Tools-based instruction in data analysis for earth and environmental scientists. Topics include descriptive statistics, visualization, uncertainty analysis, hypothesis testing, regression, time series, and directional data.
Prereq: MATH 246 or MATH 251.

ERTH 420. Geocommunication. 3 Credits.
Scientific writing and presentations for the geological sciences. Focus on writing scientific papers and proposals, preparing oral and visual presentations.

ERTH 420M. Temporary Multilisted Course. 1-5 Credits.
Repeatable.
ERTH 423M. Introduction to Space Physics. 4 Credits.
Course explores the interaction of the solar wind with the Earth's magnetosphere using fundamental plasma physics supported and motivated by spacecraft observations. Students will gain an understanding of the physics governing the interaction building from single particle plasma motion to specific observation supported examples. Prereq: PHYS 253, MATH 282.

ERTH 425. Geology of Ore Deposits. 5 Credits.
Porphyry copper-molybdenum, epithermal, massive sulfides in volcanic rocks, and base and precious metals in sedimentary rocks. Geologic setting, alteration and ore mineral assemblages, and geochemistry of ore formation. Prereq: CH 223; ERTH 332.

ERTH 433. Paleobotany. 4 Credits.
Evolution and ecology of plants and microorganisms from the origin of life to global warming. Laboratory exercises and field trip to collect plant fossils. Pre- or coreq: ERTH 103 or ERTH 203.

ERTH 434. Vertebrate Paleontology. 4 Credits.
Evolution of vertebrates, including ourselves, based on fossil evidence. Physical and other evolutionary constraints are addressed, and lab exercises provide practical experience. Prereq: ERTH 103 or ERTH 203.

ERTH 435. Paleopedology. 4 Credits.
Soil formation; mapping and naming fossil soils; features of soils in hand specimens and petrographic thin sections; interpretations of ancient environments from features of fossil soils. Prereq: ERTH 311 or ERTH 332.

ERTH 436. Paleoecology and Functional Morphology. 4 Credits.
Ecological methods for the study of fossil organisms, both terrestrial and marine. Covers a range of methods from those that reconstruct the ecology of individual species to those that deal with whole communities and ecosystems. Laboratory offers practical and analytical experience in the methods. Prereq: ERTH 103, ERTH 203, or BI 213.

ERTH 438. Geobiology. 4 Credits.
Studies how microorganisms interact with geological environments at scales from enzymes to global element cycles.

ERTH 440. Sedimentary Basin Analysis. 4 Credits.

ERTH 441. Hillslope Geomorphology. 4 Credits.
Hillslope processes and landforms; includes hillslope hydrology, overland flow erosion, weathering and soil formation, soil creep, landslides and related hazards, glacial and periglacial processes, effects of land-use practices and fire, and landscape evolution.

ERTH 451. Hydrogeology. 4 Credits.
Study of the origin, motion, and physical and chemical properties of ground water. Emphasizes quantitative analysis of flow and interaction with geologic materials. Prereq: CH 222 or CH 225H; ERTH 316.

ERTH 452. Neotectonics and Quaternary Geology. 4 Credits.
Interpretation of active structures from deformed quaternary sediments and surfaces using case histories. Field project uses air photos and field techniques. Repeatable once for maximum of 8 credits. Prereq: ERTH 334, ERTH 350.

ERTH 453. Tectonics. 3 Credits.
Tectonic processes and examples. Global kinematics of plates and the forces that drive them. Continental deformation in compressional, shear, and extensional settings. Prereq: ERTH 350 and calculus.

ERTH 454. Fluid Dynamics. 4 Credits.
Introduction to the continuum theory of fluid dynamics, focusing on the Navier-Stokes equations of motion including common simplified limits and extensions. Applications are drawn from Earth and Planetary Science, Biology, and Physics. Prereq: PHYS 252, MATH 252.

ERTH 455. Mechanical Earth. 4 Credits.
Introduction to continuum mechanics. Includes stress and strain, friction, elasticity, viscous fluids, constitutive laws, equations of motion, and deformation of the Earth. Prereq: ERTH 315, PHYS 202, or equivalent; MATH 256.

ERTH 456. Signal Processing. 4 Credits.
A theoretical and hands-on introduction to signal processing techniques that are widely used in geophysical, geological, and related fields. Prereq: MATH 252 or ERTH 363.

ERTH 458. Earth Monitoring. 4 Credits.
Learn hands-on applications of tools used to monitor the solid earth and its changes through time (deformation, gravity, etc.). Address problems related to natural hazards (earthquakes, landslides, volcanoes) and natural resources (climate change). Prereq: ERTH 101 or ERTH 201, PHYS 201 or MATH 252.

ERTH 462. Environmental Geomechanics. 4 Credits.
Application of fluid and solid mechanics to understanding processes in the earth and environmental sciences. Offered alternate years. Prereq: ERTH 455.

ERTH 463. Computational Earth Science. 4 Credits.
Practical techniques for scientific computing. Topics include root finding, curve fitting, interpolation, integration and differentiation, optimization, differential equations. Prereq: MATH 253; ERTH 363 or equivalent.

ERTH 466. Geodynamics. 4 Credits.
Introduction to the process of the earth's physical workings. Includes rheology, bending of lithosphere, viscous flow, and heat transport. Prereq: MATH 256 or equivalent; ERTH 455.

ERTH 467. Fault Mechanics. 4 Credits.
The physics of faulting throughout the earthquake cycle. Topics include fault friction, seismic rupture, earthquake triggering, and other fault zone processes. Offered alternate years. Prereq: ERTH 315, MATH 253.

ERTH 468. Introduction to Seismology. 4 Credits.
Introduction to observational, theoretical, and computational seismology. Includes review of earth structure, source representation, ray theory, and seismic wave phenomena. Prereq: MATH 256, ERTH 455.

ERTH 471. Thermodynamic Geochemistry. 4 Credits.
Introduction to geologic application of classical chemical thermodynamics. Gibbs free energy and its temperature, pressure, and composition derivatives; fugacity, activity, and chemical potential. Solutions, ideal and nonideal. Prereq: ERTH 311 or ERTH 332, CH 223, MATH 253.
ERTH 472. Aqueous-Mineral-Gas Equilibria. 4 Credits.
Aqueous chemistry applied to natural waters (geothermal, diagenetic, continental brines). Equilibrium calculations applied to aqueous-mineral-gas systems.
Prereq: CH 223; MATH 252.

ERTH 473. Isotope Geochemistry. 4 Credits.
Introduction to nuclear physics and isotope systematics; techniques of isotope analysis; applications of stable and radioactive isotopes in geochronology and as tracers of geological processes.

ERTH 474. Soil and Environmental Chemistry. 4 Credits.
Understanding the flow and cycling of chemicals in soils is vital for addressing many pressing societal issues, including mitigating climate change, growing abundant and safe food, and protecting water quality. This class will describe fundamental soil chemical principles and consider their broader applications.
Prereq: ENVS 477, CH 222.

ERTH 480. Volcanology. 4 Credits.
Products and processes of volcanism, transport of magma in the conduit and into the atmosphere, eruptive mechanisms, volcanic hazards.
Prereq: ERTH 201, PHYS 201 or PHYS 251, and MATH 251 or MATH 246.

ERTH 500M. Temp Multilist Course. 1-5 Credits.
Repeatable.

ERTH 503. Thesis. 1-16 Credits.
Repeatable.

ERTH 507. Seminar: [Topic]. 1-5 Credits.
Repeatable.

ERTH 508. Laboratory Projects: [Topic]. 1-12 Credits.
Repeatable.

ERTH 510. Experimental Course: [Topic]. 1-5 Credits.
Repeatable.

ERTH 514. Igneous and Metamorphic Petrology. 4 Credits.
Advanced principles of igneous and metamorphic petrogenesis. Gibbs phase rule, phase diagrams, mineral thermodynamics; magma geochemistry and rheology; metamorphic facies, geothermometry and geobarometry. Johnston.

ERTH 515. Field Geophysics. 4 Credits.
Introduction to geophysical methods for subsurface investigation, useful for exploration, geotechnical engineering, and characterization of subsurface groundwater and environmental conditions.

ERTH 516. Geophysical and Environmental Sensors. 4 Credits.
This experiential course will provide students an introduction to sensors, microcontrollers, automation, data collection and programming from the perspective of sensing the Earth and the environment.

ERTH 518. Earth and Environmental Data Analysis. 4 Credits.
Tools-based instruction in data analysis for earth and environmental scientists. Topics include descriptive statistics, visualization, uncertainty analysis, hypothesis testing, regression, time series, and directional data.
Prereq: MATH 246 or MATH 251.

ERTH 520. Geocommunication. 3 Credits.
Scientific writing and presentations for the geological sciences. Focus on writing scientific papers and proposals, preparing oral and visual presentations.

ERTH 523M. Introduction to Space Physics. 4 Credits.
Course explores the interaction of the solar wind with the Earth’s magnetosphere using fundamental plasma physics supported and motivated by spacecraft observations. Students will gain an understanding of the physics governing the interaction building from single particle plasma motion to specific observation supported examples.

ERTH 525. Geology of Ore Deposits. 5 Credits.
Porphyry copper-molybdenum, epithermal, massive sulfides in volcanic rocks, and base and precious metals in sedimentary rocks. Geologic setting, alteration and ore mineral assemblages, and geochemistry of ore formation.

ERTH 533. Paleobotany. 4 Credits.
Evolution and ecology of plants and microbes from the origin of life to global warming. Laboratory exercises and field trip to collect plant fossils.

ERTH 534. Vertebrate Paleontology. 4 Credits.
Evolution of vertebrates, including ourselves, based on fossil evidence. Physical and other evolutionary constraints are addressed, and lab exercises provide practical experience.

ERTH 535. Paleopedology. 4 Credits.
Soil formation; mapping and naming fossil soils; features of soils in hand specimens and petrographic thin sections; interpretations of ancient environments from features of fossil soils.

ERTH 536. Paleoecology and Functional Morphology. 4 Credits.
Ecological methods for the study of fossil organisms, both terrestrial and marine. Covers a range of methods from those that reconstruct the ecology of individual species to those that deal with whole communities and ecosystems. Laboratory offers practical and analytical experience in the methods.

ERTH 538. Geobiology. 4 Credits.
Studies how microorganisms interact with geological environments at scales from enzymes to global element cycles.

ERTH 540. Sedimentary Basin Analysis. 4 Credits.
Evolution of sedimentary basins, emphasizing tectonic controls on basin formation and filling. Interpretation of subsidence mechanisms and sedimentary processes through analysis of the stratigraphic record.

ERTH 541. Hillslope Geomorphology. 4 Credits.
Hillslope processes and landforms; includes hillslope hydrology, overland flow erosion, weathering and soil formation, soil creep, landslides and related hazards, glacial and periglacial processes, effects of land-use practices and fire, and landscape evolution.

ERTH 551. Hydrogeology. 4 Credits.
Study of the origin, motion, and physical and chemical properties of ground water. Emphasizes quantitative analysis of flow and interaction with geologic materials.

ERTH 552. Neotectonics and Quaternary Geology. 4 Credits.
Interpretation of active structures from deformed quaternary sediments and surfaces using case histories. Field project uses air photos and field techniques. Repeatable once for maximum of 8 credits.

ERTH 553. Paleobotany. 4 Credits.
Evolution and ecology of plants and microbes from the origin of life to global warming. Laboratory exercises and field trip to collect plant fossils.

ERTH 554. Fluid Dynamics. 4 Credits.
Introduction to the continuum theory of fluid dynamics, focusing on the Navier-Stokes equations of motion including common simplified limits and extensions. Applications are drawn from Earth and Planetary Science, Biology, and Physics.

ERTH 554M. Introduction to Space Physics. 4 Credits.
Course explores the interaction of the solar wind with the Earth’s magnetosphere using fundamental plasma physics supported and motivated by spacecraft observations. Students will gain an understanding of the physics governing the interaction building from single particle plasma motion to specific observation supported examples.
ERTH 555. Mechanical Earth. 4 Credits.
Introduction to continuum mechanics. Includes stress and strain, friction, elasticity, viscous fluids, constitutive laws, equations of motion, and deformation of the earth.

ERTH 556. Signal Processing. 4 Credits.
A theoretical and hands-on introduction to signal processing techniques that are widely used in geophysical, geological, and related fields.

ERTH 558. Earth Monitoring. 4 Credits.
Learn hands-on applications of tools used to monitor the solid earth and its changes through time (deformation, gravity, etc.). Address problems related to natural hazards (earthquakes, landslides, volcanoes) and natural resources (climate change).

ERTH 559. Environmental Geomechanics. 4 Credits.
Application of fluid and solid mechanics to understanding processes in the earth and environmental sciences. Offered alternate years.

ERTH 562. Geodynamics. 4 Credits.
Introduction to the process of the earth's physical workings. Includes rheology, bending of lithosphere, viscous flow, and heat transport.

ERTH 563. Fault Mechanics. 4 Credits.
The physics of faulting throughout the earthquake cycle. Topics include fault friction, seismic rupture, earthquake triggering, and other fault zone processes. Offered alternate years.

ERTH 564. Introduction to Seismology. 4 Credits.
Introduction to observational, theoretical, and computational seismology. Includes review of earth structure, source representation, ray theory, and seismic wave phenomena.

ERTH 566. Thermodynamic Geochemistry. 4 Credits.
Introduction to geologic application of classical chemical thermodynamics. Gibbs free energy and its temperature, pressure, and composition derivatives; fugacity, activity, and chemical potential. Solutions, ideal and nonideal.

ERTH 567. Aqueous-Mineral-Gas Equilibria. 4 Credits.
Aqueous chemistry applied to natural waters (geothermal, diagenetic, continental brines). Equilibrium calculations applied to aqueous-mineral-gas systems.
Prereq: CH 223; MATH 252.

ERTH 568. Isotope Geochemistry. 4 Credits.
Introduction to nuclear physics and isotope systematics; techniques of isotope analysis; applications of stable and radioactive isotopes in geochronology and as tracers of geological processes.

ERTH 569. Soil and Environmental Chemistry. 4 Credits.
Understanding the flow and cycling of chemicals in soils is vital for addressing many pressing societal issues, including mitigating climate change, growing abundant and safe food, and protecting water quality. This class will describe fundamental soil chemical principles and consider their broader applications.

ERTH 570. Volcanology. 4 Credits.
Products and processes of volcanism, transport of magma in the conduit and into the atmosphere, eruptive mechanisms, volcanic hazards.

ERTH 601. Research: [Topic]. 1-16 Credits.
Repeatable.

ERTH 602. Supervised College Teaching. 1-16 Credits.
Repeatable.

ERTH 603. Dissertation. 1-16 Credits.
Repeatable.

ERTH 605. Reading and Conference: [Topic]. 1-16 Credits.
Repeatable.

ERTH 606. Practicum: [Topic]. 1-16 Credits.
Repeatable.

ERTH 607. Seminar: [Topic]. 1-5 Credits.
Repeatable.

ERTH 608. Laboratory Projects: [Topic]. 1-16 Credits.
Repeatable.

ERTH 609. Terminal Project. 1-16 Credits.
Repeatable.

ERTH 610. Experimental Course: [Topic]. 1-5 Credits.
Repeatable.

ERTH 620. Advanced Igneous Petrology. 3 Credits.
Ingeous rocks of the ocean basins, continental margins, and stable continental interior including basalts, calcalkaline series, and granites. Content varies according to research interests.
Prereq: ERTH 514, 571, or equivalent.

ERTH 692. Advanced Volcanology. 4 Credits.
This course introduces students to concepts of heat and mass transfer to understand the transport of magma in the subsurface and the physical processes involved in volcanic eruptions.
Prereq: ERTH 480, ERTH 580.