

Earth Sciences

OFFICE: Galbraith Hall, Room 188

Revelle College

<http://earthsciences.ucsd.edu>

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The Earth Sciences Program

The earth sciences encompass broad scientific study of the origin and evolution of the earth system and its life forms. Instruction in the Earth Sciences Program at UCSD embraces a wide range of topics, including the physical and chemical evolution of the planet, the evolution of life, the causes of earthquakes and volcanic eruptions, earth-surface processes, the origin and behavior of oceans and atmosphere, and the impact of humans on the environment. The program offers instruction on several different levels, including introductory classes for nonscience majors, and upper-division courses for earth science majors, students interested in the major, students who have a specialization or minor in earth sciences, and students with majors in other related fields. Earth science investigations are increasingly quantitative and experimental, and thus most upper-division courses require a strong foundation in chemistry, physics, and mathematics. For students interested in pursuing careers in the earth sciences, the program offers a B.S. degree and a contiguous B.S./M.S. degree. In addition, students may follow a chemistry/earth sciences major, a physics major with a specialization in earth sciences, or an environmental systems/earth sciences major (see the "Chemistry," "Physics," or "Environmental Systems" sections of the catalog for details). The program also offers an academic minor in earth sciences.

The Earth Sciences Program takes advantage of the unique opportunities offered by UCSD, in particular through the Scripps Institution of Oceanography. Faculty and researchers at Scripps teach most of the earth sciences courses. Classes beyond introductory level are usually small, permitting personalized instruction. Field trips are an important part of the instructional program. Earth sciences students are encouraged to consult with their instructors about incorporating appropriate courses and research opportunities at the Scripps Institution of Oceanography into their undergraduate curriculum.

A degree in earth sciences is an appropriate start for a broad range of career and graduate school opportunities in various areas, including research, government, state and federal survey jobs, environmental management, the petroleum and mining industries, consulting, ocean sciences, industrial institutions, elementary or secondary

education, environmental policy, or environmental law. Program advisers and faculty can provide additional information on career and graduate school opportunities.

Majors in Earth Sciences

Three tracks with slightly different course requirements are presently offered through the UCSD Interdisciplinary Earth Sciences Undergraduate Program. These are the *ERTH/Geology*, *ERTH/Geochemistry*, and *ERTH/Geophysics* majors.

It is strongly recommended that all earth science majors meet regularly with the Earth Science Program academic advising staff and a faculty adviser to discuss and update curriculum choices.

Lower-division requirements are designed to provide the foundations in mathematics, physics, chemistry, and biology that are essential in modern quantitative earth science disciplines. In addition, there are four upper-division courses introducing basic concepts, EARTH 100, EARTH 102, EARTH 103, and EARTH 104. EARTH 100, EARTH 102, and EARTH 103 should be taken during the sophomore year to provide the appropriate background for other upper-division courses.

A grade-point average of 2.0 or higher in the upper-division major program is required for graduation. Students must receive a grade of C- or better in any course to be counted toward fulfillment of the major requirements. In exceptional cases, students with a grade-point average in the major of 2.5 or greater may petition to have one grade of D accepted. All courses (lower- and upper-division) required for the major must be taken for a letter grade.

Special Studies Courses

Special studies in the earth sciences are offered as the courses EARTH 198 and EARTH 199. These courses are subject to consent of the instructor and approval by the earth sciences faculty adviser. They are open to students who have accrued at least ninety quarter-units and have a GPA of at least 3.0. No more than two quarters of earth sciences special studies may be counted toward any earth sciences major.

ERTH/Geology

The geology ERTH major is designed to allow students maximum flexibility in tailoring the curriculum to their interests, within the constraints of obtaining the necessary background in physical, biological, and earth sciences. Compared to the ERTH/Geochemistry and ERTH/Geophysics tracks, it requires more earth science and fewer non-earth science courses.

Lower-Division Requirements

Math 20A-B-C (may allow Math. 10A-B-C by petition) **AND Math. 20D**

Physics 2A-B-C (may allow Physics 1A-B-C by petition)

Chemistry 6A-B-C

Biology 3

ERTH 50

Earth Science Upper-Division Core Requirements

ERTH 100. Introduction to Field Methods

ERTH 102. Introduction to Geochemistry

ERTH 103. Introduction to Geophysics

ERTH 104. Geobiology

Upper-Division Earth Science Requirements

ERTH 105. Sedimentology and Stratigraphy

ERTH 120. Mineralogy

ERTH 152. Petrology and Petrography

ERTH 160. Introduction to Tectonics

ERTH 162. Structural Geology

ERTH 182A-B. Applied Geophysics

Upper-division restricted electives: at least four courses from:

Chem. 173. Atmospheric Chemistry

ERTH 110. Introduction to GIS for Earth and Environmental Scientists

ERTH 112. Urban Landscapes

ERTH 135. Satellite Remote Sensing

ERTH 142. Atmospheric Chemistry

ERTH 144. Introduction to Isotope Geochemistry

ERTH 155. Petrology and Geochemistry of the Solid Earth

ERTH 170. Introduction to Volcanology (summer session)

ERTH 185. Applied Complexity

ERTH 195. Methods of Teaching Earth Sciences

ERTH 197. Earth Science Internship

ERTH 198. Directed Group Study

ERTH 199. Independent Study

SIO 210. Physical Oceanography

SIO 226. Introduction to Marine Geophysics

SIO 240. Marine Geology

SIO 247. Rock Magnetism and Paleomagnetism

SIO 250. Earth History

SIO 260. Marine Chemistry

SIO 280. Biological Oceanography

An example schedule is outlined below:

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 20C
Chem. 6A	Chem. 6B	Chem. 6C
ERTH 50	Phys. 2A	Phys. 2B
SOPHOMORE YEAR		
Math. 20D	ERTH 102	ERTH 104
Phys. 2C	ERTH 162	
ERTH 100	BILD 3	
JUNIOR YEAR		
ERTH 105	ERTH 120	ERTH 152
ERTH 103	ERTH 182A	ERTH 182B
SENIOR YEAR		
ERTH Elect.	ERTH Elect.	ERTH Elect.
	ERTH Elect.	ERTH 160

ERTH/Geochemistry Major

This specialization focuses on the Earth as a chemical system, and on its evolution. Emphasis is placed on the fundamental observations that allow geoscientists to understand better the past history of the planet, the energetics of its evolution, and the major "cycles" (e.g., water, carbon) that characterize and control planetary-scale changes on a broad range of time scales. The major is appropriate for students interested in modern geochemistry, in "global change" studies, and in global and local environmental problems, including biochemical and anthropogenic effects.

Lower-Division Requirements

Math 20A-B-C-D

Physics 2A-B-C (2D recommended)

Chemistry 6A-B-C and Chem 6BL

Biology 3

Earth Sciences 50

Earth Science Upper-Division Core Requirements

ERTH 100. Introduction to Field Methods

ERTH 102. Introduction to Geochemistry

ERTH 103. Introduction to Geophysics

ERTH 104. Geobiology

Upper-Division Earth Science Requirements

ERTH 120. Mineralogy

ERTH 144. Introduction to Isotope Geochemistry

ERTH 152. Petrology and Petrography

Upper-Division Chemistry Requirements

Chemistry 120A. Inorganic Chemistry

Chemistry 131. Physical Chemistry or Chemistry 127

Chemistry 140A. Organic Chemistry

Chemistry restricted electives, at least two courses from:

Chemistry 149A-B. Environmental Chemistry

Chemistry 173. Atmospheric Chemistry

Upper-division restricted electives: at least three courses from:

ERTH 105. Sedimentology and Stratigraphy

ERTH 110. Introduction to GIS for Earth and Environmental Scientists

ERTH 112. Urban Landscapes

ERTH 135. Satellite Remote Sensing

ERTH 142. Atmospheric Chemistry and Biochemical Cycles

ERTH 155. Petrology and Geochemistry of the Solid Earth

ERTH 160. Introduction to Tectonics

ERTH 162. Structural Geology

ERTH 170. Introduction to Volcanology (summer session)

ERTH 182A-B. Applied Geophysics

ERTH 185. Applied Complexity

ERTH 195. Methods of Teaching Earth Sciences

ERTH 197. Earth Science Internship

ERTH 198. Directed Group Study

ERTH 199. Independent Study

SIO 226. Introduction to Marine Geophysics

SIO 240. Marine Geology

SIO 247. Rock Magnetism and Paleomagnetism

SIO 250. Earth History

SIO 260. Marine Chemistry

SIO 263. Aqueous Chemistry

An example schedule is outlined below.

FALL	WINTER	SPRING
FRESHMAN YEAR		
Chem. 6A	Chem. 6B	Chem. 6C
Math. 20A	Chem. 6BL	Math. 20C
ERTH 50	Math. 20B	
SOPHOMORE YEAR		
Phys. 2A	Phys. 2B	Phys. 2C
Math. 20D	ERTH 102	BILD 3
ERTH 100		
JUNIOR YEAR		
ERTH 103	ERTH 120	ERTH 104
Chem. 140A	ERTH 144	ERTH 152
	Chem. 127 or 131	
SENIOR YEAR		
Chem. 120A	ERTH Elect.	ERTH Elect.
Chem. Elect.	ERTH Elect.	Chem. Elect.

ERTH/Geophysics Major

This specialization focuses on the mechanical, dynamical, and thermodynamical aspects of the Earth. Emphasis is placed on a solid background of fundamental physics, from mechanics and electromagnetism to continuum- and quantum mechanics, and on the necessary mathematical skills. The major introduces basic techniques used to investigate the internal structure of the Earth, from seismology to the study of potential fields, and space geodesy. Elementary geodynamics, including the physics of simple convective systems, introductory rock mechanics, and plate kinematics are among topics introduced. At the same time, a "hands on" exposure to field problems and techniques will be accessible through an Applied Geophysics sequence.

Lower-Division Requirements

Math 20A-B-C-D-E-F
 Physics 4A-B-C-D or Physics 2A-B-C (Physics 4 sequence recommended)
 Chemistry 6A-B-C
 Biology 3
 ERTH 50

Earth Science Upper-Division Core Requirements

ERTH 100. Introduction to Field Methods
 ERTH 102. Introduction to Geochemistry
 ERTH 103. Introduction to Geophysics
 ERTH 104. Geobiology

Upper-Division Earth Sciences Requirements

ERTH 130. Geodynamics of Terrestrial Planets
 or ERTH 160. Introduction to Tectonics
 ERTH 182A-B. Applied Geophysics

Upper-Division Physics Requirements

Physics 100A-B-C. Electromagnetism
 Physics 110A-B. Mechanics

Physics restricted electives: at least one course from:

Physics 105A. Mathematical and Computational Physics
 Physics 121. Experimental Techniques
 Physics 140A-B. Statistical and Thermal Physics
 MAE 131A. Solid Mechanics I
 MAE 180A. Space Science and Engineering

Upper-division restricted electives: at least two courses from:

ERTH 105. Sedimentology and Stratigraphy
 ERTH 110. Introduction to GIS for Earth and Environmental Scientists
 ERTH 112. Urban Landscapes
 ERTH 120. Mineralogy
 ERTH 130. Geodynamics of Terrestrial Planets
 ERTH 135. Satellite Remote Sensing
 ERTH 142. Atmospheric Chemistry and Biochemical Cycles
 ERTH 144. Introduction to Isotope Chemistry
 ERTH 152. Petrology and Petrography
 ERTH 155. Petrology and Geochemistry of the Solid Earth
 ERTH 160. Introduction to Tectonics
 ERTH 162. Structural Geology
 ERTH 170. Introduction to Volcanology (summer session)
 ERTH 185. Applied Complexity
 ERTH 195. Methods of Teaching Earth Sciences
 ERTH 197. Earth Science Internship
 ERTH 198. Directed Group Study
 ERTH 199. Independent Study
 SIO 223. Geophysical Data Analysis
 SIO 226. Introduction to Marine Geophysics
 SIO 227A. Introduction to Seismology
 SIO 250. Earth History

An example schedule is outlined below.

FALL	WINTER	SPRING
FRESHMAN YEAR		
Chem. 6A	Chem. 6B	Chem. 6C
Math. 20A	Math. 20B	Math. 20C

ERTH 50	Phys. 4A	Phys. 4B
SOPHOMORE YEAR		
Math. 20D	Math. 20E	Math. 20F
Phys. 4C	Phys. 4D	BILD 3
ERTH 100	ERTH 102	
JUNIOR YEAR		
Phys. 100A	Phys. 100B	Phys. 100C
Phys. 110A	Phys. 110B	ERTH 104
ERTH 103	ERTH 182A	ERTH 182B
SENIOR YEAR		
ERTH 130 OR 160	Phys. Elect. ERTH Elect.	ERTH Elect.

Earth Sciences Minor

A minor in earth sciences consists of twenty-eight units of earth science courses, at least twenty of which must be upper-division, focused on geology, geochemistry, or geophysics. Courses required by a student's major may not be applied toward a minor and neither can ERTH 198 nor ERTH 199. Courses for the minor may be taken on a Pass/Not Pass basis if the student's college permits.

Honors Program

The Earth Sciences Program offers an Honors Program for a limited number of students who have demonstrated excellence in the major. Students are eligible for admission to the program when they have:

1. Completed ninety units of courses including twelve units of earth science courses.
2. Achieved a GPA of 3.3 overall and 3.5 in earth science courses.
3. Submitted to the Earth Science Steering Committee, and had approved, an honors thesis research proposal.

Successful completion of the Honors Program requires:

1. Maintenance of a GPA of 3.3 overall and 3.5 in earth science courses.
2. Completion, with a B grade or higher, of a minimum of eight units of ERTH 196 related to the honors thesis research, distributed over at least two quarters. These units must be in addition to the ordinary major requirements. However, students who subsequently fail to

complete the Honors Program may apply up to four of these 196 units to their major.

3. Acceptance of a written honors thesis report by a committee of not fewer than three faculty members.
4. Satisfactory presentation of an oral report on the thesis research, preferably at a public undergraduate research conference on campus, or at an earth science conference. Alternatively, the oral report may be given at a seminar involving honors students and at least three faculty members.

Students who successfully complete the Honors Program will graduate with "high distinction."

Students who are interested in the Honors Program should contact the program adviser in Galbraith Hall, room 188, Revelle College.

Study Abroad

Study abroad through the **Education Abroad Program** (<http://programsabroad.ucsd.edu>) or **Opportunities Abroad Program** can enhance a student's major, particularly as an opportunity for diverse field experiences. However, careful planning is important to meet all major requirements. Please contact the Earth Sciences Office as early as possible if you are planning to study abroad.

Careers in Education

Students interested in a teaching career should be aware that the earth sciences major, because of its broad course requirements in the sciences, fulfills many of the subject requirements for obtaining a California Teaching Credential through UCSD's Teacher Education Program (TEP). The projected high demand over the next decade for well-trained teachers, particularly in the sciences, makes this an attractive option for many students. Students who wish to take advantage of this opportunity may wish to complete a minor in education. Please contact the TEP office directly for further details.

Contiguous Bachelor's/ Master's Degree Program

The integrated program leading to a bachelor of science and a master of science degree in earth sciences is offered to undergraduate students

who are enrolled in the earth sciences major, and to qualified students who are completing a specialization or minor in earth sciences. It is open only to UCSD undergraduates, and entails participation in research in an area of the earth sciences to be determined jointly by the student and a committee of faculty members from the Earth Sciences Program. Applications will only be accepted during the final quarter of the applicant's junior year, or the first or second quarter of the senior year. A minimum undergraduate GPA of 3.0 overall and 3.3 in upper-division earth sciences courses is required for admission. Applications must include a written statement of purpose, a summary of the research proposal, and a letter of support from the potential M.S. thesis adviser. Students must complete requirements for the B.S. degree before they are enrolled in the M.S. program, and are expected to meet the requirements for the M.S. degree within three consecutive academic quarters after obtaining the B.S. Students may be dropped from the program if breaks in enrollment occur. The Earth Sciences Program does not have financial aid available for students enrolled in the program. Please contact the Earth Sciences Office in Galbraith Hall, room 188, Revelle College for information.

Earth Sciences Graduate Program

Other graduate degrees in the earth sciences are offered through the graduate department of the Scripps Institution of Oceanography. See listings under "Scripps Institution of Oceanography" for detailed information.

COURSES

For course descriptions not found in the 2006–2007 General Catalog, please contact the department for more information.

NOTE: The program will endeavor to offer the courses outlined below. However, unforeseen circumstances (particularly changes in ship schedules) sometimes mandate a change of scheduled offerings, especially the quarter offered (F,W,S). Students are strongly advised to check the Schedule of Classes or to contact the Earth Sciences Program Office (Galbraith

Hall, Room 188, Revelle College, 858-534-8157) to obtain up-to-date information.

LOWER-DIVISION

ERTH 1. The Planets

Space exploration has revealed an astonishing diversity among the planets and moons in our solar system. The planets and their histories will be compared to gain insight and a new perspective on planet Earth. *Prerequisite: none.* (S)

ERTH 10. The Earth (4)

A basic introduction to geology for students with little previous science background. The course stresses understanding of the concepts of the structure of the Earth and the processes which have formed it and continue to modify it. The course emphasizes material which every educated citizen should know for appreciation and enjoyment of the world around us, for understanding geological events as reported in the news, and for participating in making intelligent decisions regarding the future of our environment. Three-hour lecture plus optional local field trips. *Prerequisite: none.* (W)

ERTH 12. History of the Earth and Evolution (4)

Evolution of the Earth from its origin in the early solar system to formation of continents and ocean basins, and how the planet became habitable. It examines the geologic record of evolution, extinction, plate tectonics, and climate changes through time. Three-hour lecture. *Prerequisite: none.* (S)

ERTH 15. Natural Disasters

An introduction to environmental perils and their impact on everyday life. Geological and meteorological processes are explored, including earthquakes, volcanic activity, large storms, global climate change, mass extinctions throughout Earth's history, and human activity that causes and prevents natural disasters. *Prerequisite: none.* (F)

ERTH 16. Geology of the National Parks (4)

An introduction to fundamental concepts of geology and environmental science through the lens of the national park system. Topics covered include the geologic time scale; plate tectonics; igneous, metamorphic, and sedimentary processes; geomorphology; climate change; and environmental degradation. *Prerequisite: none.* (W)

ERTH 20. The Atmosphere (4)

Descriptive introduction to meteorology and climate studies. Topics include global and continental wind and precipitation patterns, weather forecasting, present climate and past climate changes (including droughts, El Niño events), man-made modification of climate, including CO₂ and other "greenhouse" gases effects, ozone destruction, "little ice ages," acid rain. Three-hour lecture. *Prerequisites: some high school physics and chemistry background recommended.* (W)

ERTH 30. The Oceans (4)

Presents modern ideas and descriptions of the physical, chemical, biological, and geological aspects of oceanography, and considers the interactions between these aspects. Intended for students interested in the oceans, but who do not necessarily intend to become professional scientists. Three-hour lecture, one-hour discussion. *Prerequisite: some background in high school chemistry recommended.* (F)

ERTH 35. Water (4)

This course will examine the properties of water that make it unique and vital to living things. Origin of water

on Earth and neighboring planets will be explored. Socially relevant issues concerning water use and contamination will be covered. *Prerequisite: none.* (S)

ERTH 40. The Biosphere (4)

Explores life on earth and its relationship to the environment—past, present, and future. Topics include origins of life, earth history, elemental cycles, global climate variability, and human impacts on our environment. *Prerequisite: none.* (F)

ERTH 50. Introduction to Earth and Environmental Sciences (5)

This course is an introduction to how our planet works, focusing on the formation and evolution of the solid earth, and the processes affecting both its surface and interior. Laboratories and field trips complement and extend the lecture material. *Prerequisite: none.* (F)

ERTH 90. Undergraduate Seminar (1)

Provides an introduction to earth sciences. Faculty members from departments in natural sciences, geosciences, and marine sciences will offer perspectives in these areas.

ERTH 96. Frontiers in the Earth Sciences (2)

An introduction to current research in the earth sciences. Background in science not required, but may be useful for some topics. Areas covered vary from year to year. (S)

ERTH 99. Independent Study (2-4)

Independent reading or research on a problem by special arrangement with a faculty member. *Prerequisite: completion of at least 30 units of undergraduate study with a minimum GPA of at least 3.0.*

UPPER-DIVISION

ERTH 100. Introduction to Field Methods (4)

Mapping and interpretation of geologic units. Field work is done locally and the data are analyzed in the laboratory. There will be one mandatory weekend field trip to Anza Borrego State Park. *Prerequisite: EARTH 50, or consent of instructor.* (F)

ERTH 102. Introduction to Geochemistry (4)

A broad introduction to the chemical composition and evolution of the Earth and the solar system. This course explores applications of chemical methods to elucidate the origin and geologic history of the Earth and the planets, the evolution of the oceans and atmosphere, and the impact of humankind on the environment. *Prerequisites: EARTH 50, Chemistry 6A-B-C or equivalent, first-year, mathematics, and physics, or consent of instructor.* (W)

ERTH 103. Introduction to Geophysics (4)

An introduction to the structure and composition of the solid earth. Topics include seismology, the gravity and magnetic fields, high-pressure geophysics, and concepts in geodynamics. Emphasis is on global geophysics, i.e., on the structure and evolution of the planet. *Prerequisites: Math. 20A-B-C-D and Physics 2 sequence, EARTH 50, or consent of instructor. EARTH 160 recommended.* (F)

ERTH 104. Geobiology (5)

Introduction to the major biological transitions in earth history from the origins of metabolism and cells to the evolution of complex societies. The nature and limitations of the fossil record, patterns of adaptation and diversity, and the tempo and mode of biological

and environmental change. Laboratories and field trips complement and extend the lecture material. *Prerequisites: EARTH 50, BILD 3 or equivalent, or consent of instructor.* (S)

ERTH 105. Sedimentology and Stratigraphy (4)

This course will examine sedimentary environments from the mountain tops to the deep sea across a variety of time scales. The focus will be to understand how depositional processes form the stratigraphic record. The central goal of the course is to develop the skills to interpret stratigraphy and read the history of the earth that it records. *Prerequisites: EARTH 50 and EARTH 100.* (F)

ERTH 110. Introduction to GIS for Earth and Environmental Scientists (4)

A hands-on introduction to geological and environmental applications of geographic information systems (GIS). Students acquire data through field surveys and digitization, design and construct GIS using ESRI's ArcGIS software, analyze spatial data, and present the finished products as maps. *Prerequisites: EARTH 50 or ESYS 102 or the equivalent, or consent of instructor.* (S)

ERTH 112. Urban Landscapes (4)

Introduction to scientific principles, such as conservation of mass and energy and pattern formation, that govern the development of urban centers as complex systems. Contrasts between natural and urban landscapes will be highlighted, with examples including water routing and disease transmission. *Prerequisite: upper-division standing.* (S)

ERTH 120. Introduction to Mineralogy (4)

This course focuses on the symmetry, crystal structure, chemical, and physical properties of minerals with special emphasis on the common rock-forming minerals, and highlights the applications of mineralogical and X-ray crystallographic techniques to a spectrum of important problems in the earth sciences. The laboratory will introduce the students to the polarizing microscope and X-ray powder diffraction methods for the study of rock-forming minerals. *Prerequisites: EARTH 50, EARTH 102.* (W)

ERTH 130. Geodynamics of Terrestrial Planets (4)

Planetary differentiation through geodynamical processes is the fundamental agent controlling the evolution of the planet on geological time scales. Similarities and differences between the Earth, Venus, Mars, and other terrestrial planets and satellites teach us about the processes which shape a planet's formation and evolution. The course includes a computer-oriented lab. *Prerequisites: Math. 20A-B-C-D and Physics 2 sequence, or consent of instructors.* (F)

ERTH 135. Satellite Remote Sensing (4)

Satellite remote sensing provides global observations of Earth to monitor changes in the environment of land, oceans, and ice. This course is an overview of the physical principles of remote sensing including orbits, electromagnetic radiation, diffraction, electro-optical, and microwave systems. *Prerequisites: Physics 2A-B or Physics 4A-B-C.* (S)

ERTH 142. Atmospheric Chemistry and the Biochemical Cycles of Atmospheric Trace Gases (4)

Evolution of the Earth's atmosphere, from the earliest days of the planet to the present, and into the future. The atmospheres of other terrestrial planets are discussed to provide a planetary perspective. Discussions will include effects of "greenhouse" gases such as H₂O, CO₂, and CH₄ in climate modification, and other

influences of civilization's byproducts on atmospheric chemistry, e.g., the destruction of the ozone layer. The biogeochemical cycles of the radioactively important trace gases will be examined. *Prerequisites: Chemistry 6 sequence or equivalent, or consent of instructor.* Not offered every year. SIO staff. (W)

ERTH 144/SIO 252A. Introduction to Isotope Geochemistry (4)

Radioactive and stable isotope studies in geology and geochemistry, including geochronology, isotopes as tracers of magnetic processes, cosmic-ray produced isotopes as tracers in the crust and weathering cycle, isotopic evolution of the crust and mantle. At the graduate level, oral presentations are required and the final exam is more rigorous. Offered in alternate years. *Prerequisites: Graduates: SIO entrance requirements or consent of instructor. Undergraduates: EARTH 50, EARTH 102, EARTH 120, or equivalent.* (W)

ERTH 152. Petrology and Petrography (4)

Mineralogical, chemical, textural, and structural properties of igneous, metamorphic, and sedimentary rocks; their origin and relations to evolution of the Earth's crust and mantle. Includes rocks of both the continents and ocean basins. The laboratory emphasizes both hand specimens and microscopic studies of rocks in thin sections. *Prerequisites: EARTH 50, EARTH 102, and EARTH 120 or their equivalents.* (S)

ERTH 155/SIO 251. Petrology and Geochemistry of the Solid Earth (4)

Overview of the Earth from a geochemical and petrogenetic point of view. The formation and chemical differentiation of material in the solar system, the formation and differentiation of the Earth into core, mantle, crust and atmosphere/hydrosphere, the generation of magma in a variety of plate tectonic settings, and isotope and trace element geochemistry of igneous and metamorphic rocks. Literature readings will be assigned and discussion is expected of everyone. *Prerequisite: EARTH 152 or consent of instructors.* (W)

ERTH 160. Introduction to Tectonics (4)

The theory of plate tectonics attempts to explain how forces within the earth give rise to continents, ocean basins, mountain ranges, earthquake belts and most volcanoes. In this course we will learn how plate tectonics works. *Prerequisite: EARTH 50.* (S)

ERTH 162/SIO 256L. Structural Geology (4)

Principles of stratigraphy and structural geology applicable to field geologic studies. Discussion and laboratory exercises. Two to three field trips required. Graduate students, additionally, will complete an in-depth, literature-based, focused study consisting of a written report and a 45-minute seminar on topics related to structural geology. *Prerequisites: EARTH 50 and EARTH 100, or consent of instructor. Graduate students enroll with consent of instructor.* (W)

ERTH 170. Introduction to Volcanology (4)

This course teaches fundamental aspects of physical and chemical volcanology with a major field study component on an active volcano on Hawaii. Subjects are introduced in lectures and reinforced and expanded in field exercises. *Prerequisites: EARTH 50, Chem. 6A, upper-division standing or consent of instructor; eighteen years or older and ability to walk up to fifteen miles a day over rough terrain.* (Offered summer session only)

ERTH 182A. Applied Geophysics (4)

Introduction to design and execution of simple geophysical field experiments, including seismic, gravimetric, geoelectrical, and geodetic techniques. The focus is on a simple geological problem that can be solved by geophysical experiments. Computer-aided data analysis and interpretation. *Prerequisite: EARTH 103.* (W)

ERTH 182B. Applied Geophysics (4)

Design and execution of simple geophysical field experiments, including seismic, gravimetric, geoelectrical, and geodetic techniques. The focus is on a simple geological problem that can be solved by geophysical experiments. Computer-aided data analysis and interpretation. *Prerequisite: EARTH 182A.* (S)

ERTH 185. Applied Complexity (4)

Techniques from the study of complex systems, including genetic algorithms, neural networks, forecasting, artificial life and agent-based modeling, are introduced and applied to problems in geology, physics, engineering, biology, and economics. *Prerequisites: Math 20A-B-C-D or equivalent, MATLAB recommended.* (S)

ERTH 190. Special Topics in Earth Sciences (2-4)

A seminar course designed to treat emerging or topical subjects in the earth sciences. Involved reading from the literature and student participation in discussion. Topics vary from year to year.

ERTH 194. Research Seminar in Washington, D.C. (4)

Course attached to six-unit internship taken by students participating in the UCDC program. Involves weekly seminar meetings with faculty and teaching assistant and substantial research paper. *Prerequisites: departmental approval, participation in UCDC Program.*

ERTH 195. Methods of Teaching Earth Sciences (4)

Introduction to teaching earth sciences class section in a lower-division class, hold office hours, assist with examinations. This course counts only once towards the major. *Prerequisites: junior or senior earth sciences major with GPA of 3.0 or an A in the course and consent of instructor, plus department stamp.*

ERTH 196. Honors Thesis Research (4)

Independent reading or research on a problem. By special arrangement with a faculty member. (Letter grade only.)

ERTH 197. Earth Science Internship (2-4)

The Earth Science Internship program is designed to complement the program's academic curriculum with practical field experience. *Prerequisites: consent of instructor, upper-division standing, minimum GPA of 2.0, department stamp.*

ERTH 198. Directed Group Study (2-4)

This course covers a variety of directed group studies in areas not covered by formal EARTH courses (P/NP grades only.) *Prerequisite: consent of instructor.*

ERTH 199. Independent Study for Undergraduates (4)

Independent reading or research on a problem. By special arrangement with a faculty member. (P/NP grades only.)

ERTH 211. Research Seminar (2)

A three quarter required sequence for BS/MS Earth Sciences students to prepare students for thesis writing. (F,W,S)