Earth Sciences

Joshua J. Roering, Department Head
541-346-5574
541-346-4692 fax
100 Cascade Hall
1272 University of Oregon
Eugene, Oregon 97403-1272

Faculty

Ilya N. Bindeman, professor (stable isotope geochemistry, volcanology). BS, 1988, Moscow; PhD, 1998, Chicago. (2004)

Edward B. Davis, associate professor (vertebrate paleontology). BS, 1999, Tennessee, Knoxville; PhD, 2005, California, Berkeley. (2013)

Rebecca J. Dorsey, professor (sedimentology, basin analysis). BS, 1983, Vermont; MA, 1986, PhD, 1989, Princeton. (1997)

Josef Dufek, professor (volcanology). BS, 2000, Chicago; MS, 2004, PhD, 2006, Washington (Seattle). (2017)

Brittany Erickson, assistant professor (computational science). PhD, 2010, Santa Barbara (2018)

Thomas Giachetti, assistant professor (volcanology). MS, 2006, PhD, 2010, Université Blaise Pascal, Clermont-Ferrand. (2015)

Emilie Hooft Toomey, associate professor (marine geophysics). BSc, 1990, Trinity College, Toronto; PhD, 1997, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. (1999)

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)

Qusheng Jin, associate professor (biogeoscience). BS, 1994, Nanjing; MS, 1997, Chinese Academy of Sciences; PhD, 2003, Illinois, Urbana-Champaign. (2005)

Leif A. Karlstrom, assistant professor (volcanology, geomorphology, fluid mechanics). BS, 2006, Oregon; PhD, 2011, California, Berkeley. (2011)

Diego Melgar, assistant professor (earthquake seismology, tsunamis, geodetic imaging). BEng., 2009, Universidad Nacional Autonoma de Mexico; MS, 2010, PhD, 2014, Scripps College. (2017)

Marli B. Miller, senior instructor (structural geology). BA, 1982, Colorado College; MS, 1987, PhD, 1992, Washington (Seattle). (1997)

Matthew Polizzotto, associate professor (soil and environmental hydrogeochemistry). BS, BA, 2001, Rochester; PhD, 2007, Stanford. (2016)

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

Alan W. Rempel, professor (geomechanics and applied mathematics). BASc, 1991, MSc, 1995, British Columbia; PhD, 2001, Cambridge. (2004)

Gregory J. Retallack, professor (paleobotany, paleosols). BA, 1973, Macquarie; PhD, 1978, New England University, Australia. (1981)

Joshua J. Roering, professor (surface processes, geomorphology). BS, 1994, MS, 1995, Stanford; PhD, 2000, California, Berkeley. (2000)

Valerie Sahakian, assistant professor (tectonics, ground seismology, marine geophysics). BS, 2009, Rhode Island; MS, 2010, PhD, 2015, Scripps College. (2018)

David A. Sutherland, associate professor (physical oceanography). BA, 2001, North Carolina, Wilmington; PhD, 2008, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. (2011)

Amanda M. Thomas, associate professor (earthquake seismology and fault mechanics). BS, 2007, Georgia Institute of Technology; PhD, 2012, California, Berkeley. (2015)

Douglas R. Toomey, professor (seismology, tectonics, midocean ridges). BS, 1981, Pennsylvania State; PhD, 1987, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. (1990)

Meredith Townsend, assistant professor (volcanology). BS, 2011, Washington and Lee, PhD, 2017, Stanford (2019)

Paul J. Wallace, professor (igneous petrology, volcanology, geochemistry). BS, 1986, George Washington University; PhD, 1991, California, Berkeley. (2001)

James M. Watkins, associate professor (experimental petrology, geochemistry, volcanology). BS, 2005, Wisconsin, Eau Claire; PhD, 2010, Cailfornia, Berkeley. (2012)

Ray J. Weldon, professor (neotectonics, structural and quaternary geology). BA, 1977, Pomona; PhD, 1986, California Institute of Technology. (1987)

Research Staff

Andrew Hadlock, research assistant. BS, 2018, Florida (2019)

Sara Meyer, field technician. BS, 2010, California, Santa Cruz; IT specialist certification, 2015, Alaska, Fairbanks. (2017)

Leland O'Driscoll, seismic field technician. PhD, 2012, Oregon (2015)

James Palandri, research associate. PhD, 2000, Oregon. (2001)

Silas Thoms, research assistant. BS, 2019, Oregon State (2019)

Lucy Walsh, research assistant. MS, 2012, Oregon. (2017)

Emeriti

A. Dana Johnston, professor (experimental petrology, geochemistry). BS, 1976, Bates; MS, 1978, PhD, 1983, Minnesota. (1986)

M. Allan Kays, professor emeritus. BA, 1956, Southern Illinois; MA, 1958, PhD, 1960, Washington (St. Louis). (1961)

William N. Orr, professor emeritus. BS, 1961, Oklahoma; MA, 1963, California, Riverside and Los Angeles; PhD, 1967, Michigan State. (1967)

Jack M. Rice, professor emeritus. AB, 1970, Dartmouth College; MS, 1972, PhD, 1975, Washington (Seattle). (1977)

Norman M. Savage, professor emeritus. BSc, 1959, Bristol; PhD, 1968, Sydney. (1971)

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:

Code	Title	Credits
ERTH 401	Research: [Topic]	1-21
ERTH 406	Field Studies: [Topic]	1-6
ERTH 408	Laboratory Projects: [Topic]	1-6

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/archive/2021-2022/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

Course	Title	Credits	Milestones
First Year			
Fall			
MATH 111	College Algebra	4	
WR 121	College Composition I	4	
CH 221 or CH 224H	General Chemistry I or Advanced General Chemistry I	4	
ERTH 101 or ERTH 201	Exploring Planet Earth or Dynamic Planet Earth	4	
	Credits	**16**	
Winter			
ERTH 102 or ERTH 202	Exploring Earth's Environment or Earth's Surface and Environment	4	
MATH 112	Elementary Functions	4	
CH 222 or CH 225H	General Chemistry II or Advanced General Chemistry II	4	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**16**	
Spring			
ERTH 103 or ERTH 203	Exploring Earth History or History of Life	4	
WR 122 or WR 123	College Composition II or College Composition III	4	
MATH 246 or MATH 251	Calculus for the Biological Sciences I or Calculus I	4	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**16**	
	Total Credits	**48**	

Course	Title	Credits	Milestones
Second Year			
Fall			
PHYS 201 or PHYS 251	General Physics or Foundations of Physics I	4	
MATH 247 or MATH 252	Calculus for the Biological Sciences II or Calculus II	4	
ERTH 331	Mineralogy	5	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**17**	
Winter			
PHYS 202 or PHYS 252	General Physics or Foundations of Physics I	4	
ERTH 315	Earth Physics	4	
ERTH 332	Introduction to Petrology	5	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**17**	
Spring			
PHYS 203 or PHYS 253 or CH 223 or CH 226H	General Physics or Foundations of Physics I or General Chemistry III or Advanced General Chemistry III	4	
ERTH 318	Introduction to Field Methods	3	
ERTH 316	Introduction to Hydrogeology	4	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**15**	
	Total Credits	**49**	

Course	Title	Credits	Milestones
Third Year			
Fall			
ERTH 418 or MATH 253 or MATH 343 or MATH 425 or PHYS 481	Earth and Environmental Data Analysis or Calculus III or Statistical Models and Methods or Statistical Methods I or Design of Experiments	4	
General-education, multicultural, or other group-satisfying courses		8	

Geology elective		4
	Credits	**16**
Winter		
General-education, multicultural, or other group-satisfying courses		8
Geology elective		4
	Credits	**12**
Spring		
ERTH 334	Sedimentology and Stratigraphy	4
ERTH 350	Structural Geology	3
ERTH 351	Structural Geology Problems	1
ERTH 352	Structural Geology Laboratory and Field	1
General-education, multicultural, or other group-satisfying course		4
	Credits	**13**
Summer		
ERTH 406	Field Studies: [Topic] (12 Credits)	1-6
	Credits	**1-6**
	Total Credits	**42-47**

Course	Title	Credits Milestones
Fourth Year		
Fall		
General-education, multicultural, or other group-satisfying courses		8
Geology or other science elective		4
	Credits	**12**
Winter		
General-education, multicultural, or other group-satisfying courses		8
Geology or other science elective		4
	Credits	**12**
Spring		
General-education, multicultural, or other group-satisfying courses		8
Geology or other science elective		4
	Credits	**12**
	Total Credits	**36**

Bachelor of Science in Earth Sciences: Geophysics Track

Course	Title	Credits Milestones
First Year		
Fall		
ERTH 101 or ERTH 102	Exploring Planet Earth or Exploring Earth’s Environment	4
MATH 111	College Algebra	4
WR 121	College Composition I	4
CH 221 or CH 224H	General Chemistry I or Advanced General Chemistry I	4
	Credits	**16**
Winter		
ERTH 102 or ERTH 202	Exploring Earth’s Environment or Earth's Surface and Environment	4
MATH 112	Elementary Functions	4
CH 222 or CH 225H	General Chemistry II or Advanced General Chemistry II	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**16**
Spring		
WR 122 or WR 123	College Composition II or College Composition III	4
MATH 246 or MATH 251	Calculus for the Biological Sciences I or Calculus I	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**12**
	Total Credits	**44**

Course	Title	Credits Milestones
Second Year		
Fall		
PHYS 251	Foundations of Physics I	4
MATH 252	Calculus II	4
ERTH 318	Introduction to Field Methods	3
General-education, multicultural, or other group-satisfying course		4
	Credits	**15**
Winter		
PHYS 252	Foundations of Physics I	4
MATH 253	Calculus III	4
ERTH 315	Earth Physics	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**16**
Spring		
PHYS 253	Foundations of Physics I	4
ERTH 311	Earth Materials	5
ERTH 316	Introduction to Hydrogeology	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**17**
	Total Credits	**48**

Course	Title	Credits Milestones
Third Year		
Fall		
MATH 256	Introduction to Differential Equations	4

PHYS 351	Foundations of Physics II	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**12**
Winter		
MATH 281	Several-Variable Calculus I	4
PHYS 352	Foundations of Physics II	4
ERTH 455	Mechanical Earth	4
	Credits	**12**
Spring		
MATH 282	Several-Variable Calculus II	4
PHYS 353	Foundations of Physics II	4
Geology or other science elective		4
	Credits	**12**
	Total Credits	**36**

Course	Title	Credits Milestones
Fourth Year		
Fall		
General-education, multicultural, or other group-satisfying courses		4
Geology or other science elective		8
	Credits	**12**
Winter		
General-education, multicultural, or other group-satisfying courses		8
Geology or other science elective		4
	Credits	**12**
Spring		
General-education, multicultural, or other group-satisfying courses		8
Geology or other science elective		4
	Credits	**12**
	Total Credits	**36**

Bachelor of Science in Earth Sciences: Environmental Geoscience Track

Course	Title	Credits Milestones
First Year		
Fall		
ERTH 101 or ERTH 102	Exploring Planet Earth or Exploring Earth's Environment	4
MATH 111	College Algebra	4
WR 121	College Composition I	4
CH 221 or CH 224H	General Chemistry I or Advanced General Chemistry I	4
	Credits	**16**
Winter		
ERTH 102 or ERTH 202	Exploring Earth's Environment or Earth's Surface and Environment	4
MATH 112	Elementary Functions	4
CH 222 or CH 225H	General Chemistry II or Advanced General Chemistry II	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**16**
Spring		
ERTH 103 or ERTH 203	Exploring Earth History or History of Life	4
WR 122 or WR 123	College Composition II or College Composition III	4
MATH 246 or MATH 251	Calculus for the Biological Sciences I or Calculus I	4
General-education, multicultural, or other group-satisfying course		4
	Credits	**16**
	Total Credits	**48**

Course	Title	Credits Milestones
Second Year		
Fall		
PHYS 201 or PHYS 251	General Physics or Foundations of Physics I	4
MATH 247 or MATH 252	Calculus for the Biological Sciences II or Calculus II	4
ERTH 311	Earth Materials	5
Geology elective		4
	Credits	**17**
Winter		
PHYS 202 or BI 211	General Physics or General Biology I: Cells	4
ERTH 315	Earth Physics	4
ERTH 332	Introduction to Petrology	5
General-education, multicultural, or other group-satisfying course		4
	Credits	**17**
Spring		
PHYS 203 or PHYS 253 or BI 212 or BI 213 or CH 223 or CH 226H	General Physics or Foundations of Physics I or General Biology II: Organisms or General Biology III: Populations or General Chemistry III or Advanced General Chemistry III	4
ERTH 311	Earth Materials	5
ERTH 316	Introduction to Hydrogeology	4

General-education, multicultural, or other group-satisfying course		4
	Credits	**17**
	Total Credits	**51**

Course	Title	Credits	Milestones
Third Year			
Fall			
ERTH 310	Earth Resources and the Environment	4	
ERTH 318	Introduction to Field Methods	3	
General-education, multicultural, or other group-satisfying courses		8	
	Credits	**15**	
Winter			
ERTH 353	Geologic Hazards	4	
ERTH 451	Hydrogeology	4	
ERTH 418	Earth and Environmental Data Analysis	4	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**16**	
Spring			
ERTH 334	Sedimentology and Stratigraphy	4	
GEOG 323	Biogeography	4	
General-education, multicultural, or other group-satisfying course		4	
Geology elective		4	
	Credits	**16**	
	Total Credits	**47**	

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	**16**	
	Total Credits	**48**	

Bachelor of Science in Earth Sciences: Paleontology Track

Course	Title	Credits	Milestones
First Year			
Fall			
ERTH 101 or ERTH 201	Exploring Planet Earth or Dynamic Planet Earth	4	
MATH 111	College Algebra	4	
WR 121	College Composition I	4	
CH 221 or CH 224H	General Chemistry I or Advanced General Chemistry I	4	
	Credits	**16**	
Winter			
ERTH 102 or ERTH 202	Exploring Earth's Environment or Earth's Surface and Environment	4	
MATH 112	Elementary Functions	4	
CH 222 or CH 225H	General Chemistry II or Advanced General Chemistry II	4	
General-education, multicultural, or other group-satisfying course		4	
	Credits	**16**	
Spring			
ERTH 103 or ERTH 203	Exploring Earth History or History of Life	4	
WR 122 or WR 123	College Composition II or College Composition III	4	
CH 223 or CH 226H	General Chemistry III or Advanced General Chemistry III	4	
MATH 251	Calculus I	4	
	Credits	**16**	
	Total Credits	**48**	

Course	Title	Credits	Milestones
Second Year			
Fall			
PHYS 201 or PHYS 251	General Physics or Foundations of Physics I	4	
BI 211	General Biology I: Cells	4	
MATH 252	Calculus II	4	
ERTH 331	Mineralogy	5	
	Credits	**17**	
Winter			
PHYS 202	General Physics	4	
ERTH 315	Earth Physics	4	
ERTH 332	Introduction to Petrology	5	

General-education, multicultural, or other group-satisfying course		4
	Credits	**17**
Spring		
PHYS 203	General Physics	4
ERTH 318	Introduction to Field Methods	3
General-education, multicultural, or other group-satisfying course		8
	Credits	**15**
	Total Credits	**49**

Course	Title	Credits Milestones
Third Year		
Fall		
Choose one from the following:		4
ERTH 433	Paleobotany	4
ERTH 434	Vertebrate Paleontology	4
ERTH 435	Paleopedology	4
General-education, multicultural, or other group-satisfying courses		4
Geology or other science elective		4
These courses are typically offered in alternate years, so enrollment is necessary in the third or fourth year according to availability.		
Contact advisor or department office for scheduling of these courses.		
	Credits	**24**
Winter		
Choose one from the following:		4
ERTH 433	Paleobotany	4
ERTH 434	Vertebrate Paleontology	4
ERTH 435	Paleopedology	4
General-education, multicultural, or other group-satisfying courses		4
Geology or other science course		4
These courses are typically offered in alternate years, so enrollment is necessary in the third or fourth year according to availability.		
Contact advisor or department office for scheduling of these courses.		
	Credits	**24**
Spring		
ERTH 334	Sedimentology and Stratigraphy	4
ERTH 350	Structural Geology	3
ERTH 351	Structural Geology Problems	1
ERTH 352	Structural Geology Laboratory and Field	1
General-education, multicultural, or other group-satisfying course		4
	Credits	**13**
Summer		
ERTH 406	Field Studies: [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	**16**
	Total Credits	**48**

Master's Degrees in Earth Sciences **(**http://catalog.uoregon.edu/archive/2021-2022/arts_sciences/geologicalsciences/GRearth/#maandmstext**)**

Ph.D. in Earth Sciences **(**http://catalog.uoregon.edu/archive/2021-2022/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/archive/2021-2022/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.uoregon.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, geomechanics, 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, consequences of mass extinction and methane clathrate degassing at the Permian-Triassic boundary, and the effect of early land plants and forests 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 rifting 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 undergraduate and graduate 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 geobiology 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 mantlelike 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 110. People, Rocks, and Fire. 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 137. Mountains and Glaciers. 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]. 1-5 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 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. Volcanoes and Earthquakes. 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 310. Earth Resources and the Environment. 4 Credits.
Geology of energy, mineral, and water resources and environmental issues related to their use. Topics include fossil fuels, metals, nuclear waste disposal, and water pollution.

ERTH 311. Earth Materials. 5 Credits.
Chemical and mineralogical composition of rocks, sediment, and soil. Properties of common minerals; origin of rocks; microscopic study of rock textures; environmental issues.
Prereq: ERTH 101, 102 or 201, 202; coreq CH 221 or 224.

ERTH 315. Earth Physics. 4 Credits.
Physics of basic Earth processes; application of physics to plate tectonics and lithospheric deformation. Topics include forces, deformation, gravity, and seismology. Taught once or more per academic year.
Prereq: MATH 252, PHYS 201.

ERTH 316. Introduction to Hydrogeology. 4 Credits.
Examines the role of water in geologic and environmental processes. Topics include the 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 101–103 or ERTH 201–203.

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, 202 or ERTH 101, 102; coreq: CH 221 or 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 334. 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 101–103 or ERTH 201–203; pre- or coreq: ERTH 311 or 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 201.

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: [Topic]. 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. Field Studies: [Topic]. 1-6 Credits.
Repeatable.

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

ERTH 408. Laboratory Projects: [Topic]. 1-6 Credits.
Repeatable.

ERTH 409. Practicum: [Topic]. 1-6 Credits.
Repeatable once.

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 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 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 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 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 microbes from the origin of life to global warming. Laboratory exercises and field trip to collect plant fossils.
Pre- or coreq: ERTH 103 or 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 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 332.

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.
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.
Prereq: ERTH 334, ERTH 350.

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 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 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 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]. 1-6 Credits.
Repeatable.

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

ERTH 510L. 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 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 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 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 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. 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.

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

ERTH 563. Computational Earth Science. 4 Credits.
Practical techniques for scientific computing. Topics include root finding, curve fitting, interpolation, integration and differentiation, optimization, differential equations.

ERTH 566. Geodynamics. 4 Credits.
Introduction to the process of the earth's physical workings. Includes rheology, bending of lithosphere, viscous flow, and heat transport.

ERTH 567. 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 568. 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 571. 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 572. 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 573. 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 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. Field Studies: [Topic]. 1-6 Credits.
Repeatable. Geologic fieldwork principally in connection with graduate thesis or dissertation. Emphasis on individual problems.

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

ERTH 608. Laboratory Projects: [Topic]. 1-3 Credits.
Repeatable.

ERTH 609. Practicum: [Topic]. 1-3 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 414/514, 471/571 or equivalent.

ERTH 692. Volcanology. 3 Credits.
Products and processes of volcanism, origin of magmas, eruptive mechanisms, and relation of volcanism to orogeny and tectonic processes.