

# Department of Geology

## College of Science

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**Degrees offered:** Bachelor of Science (BS), Bachelor of Arts (BA), and Master of Science (MS) in Geology; BS in Composite Teaching in Earth Science

**Undergraduate emphases:** *BS in Geology*—Hydrogeology-Engineering Geology and Geoarchaeology; **Graduate Specializations:** *MS in Geology*—Hydrogeology, Igneous Petrology, Paleoecology, Sedimentary Geology, Structural Geology, Tectonics, and Geomorphology

## Undergraduate Programs

### Objectives

Geology is the study of the planet Earth, the materials of which it is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin. Geology considers the physical forces that act within and on the Earth, the chemistry of its constituent materials, and the biology of its past inhabitants as revealed by fossil evidence. Geologists integrate biology, chemistry, engineering, mathematics, and physics in the study of our natural surroundings. The knowledge thus obtained is used by geologists to explore for energy, mineral, and water resources; to identify geologically stable sites for major structures; and to provide foreknowledge of some of the dangers associated with the mobile forces of a dynamic Earth. Geologists provide fundamental information required by modern society to plan for cultural and industrial development, reduce geological hazards, identify potential resources, and assist in the design of waste-disposal facilities.

The Department of Geology prepares students for professional careers in the geosciences and provides the background required for advanced studies. The department offers three options of study to meet the growing demand for geoscientists with training in general geology (BS in geology without an emphasis), hydrogeol-

ogy-engineering geology, or geoarchaeology. All options provide exposure to the sciences and an appreciation of our physical surroundings. The BS program in Geology meets the curriculum standards established by the American Institute of Professional Geologists.

The department also offers the Composite Teaching Major in Earth Science to prepare teachers of earth science at the secondary school level. Requirements for this major meet or exceed the standards of the National Science Teachers Association. Those students who major in earth science should be aware that state licensure is required of secondary education teachers. The Composite Teaching Major in Earth Science fulfills the requirements that provide eligibility for licensure. Licensure requirements vary from state to state, and students should investigate the requirements for the states in which they intend to seek employment. Advising for the Secondary Teacher Education Program (STEP) and State of Utah secondary education licensure is provided by the USU Department of Secondary Education.

The Department of Geology is housed within the Geology Building, which is located at the northeast corner of the Old Main Quad. The Geology Building provides spacious, well-equipped teaching labs, classrooms, and facilities, including a display and study area for students, computer access, document room, map room, preparation facilities, and research labs.

## General College of Science Requirements

All general College of Science requirements are embedded within the various major requirements listed below. No extra coursework is required to fulfill the general college requirements.

### Requirements

**Departmental Admission Requirements.** New freshmen admitted to USU in good standing qualify for admission to this major. Transfer students from other institutions need a 2.2 GPA, and students transferring from other USU majors need a 2.0 GPA for admission to this major in good standing. Students seeking admission to the Composite Teaching Major in Earth Science should be aware that a 2.75 minimum GPA is required for admission to the Secondary Teacher Education Program (STEP) in the Department of Secondary Education. Students in the Hydrogeology-Engineering Geology emphasis must meet all College of Engineering GPA standards appropriate for the courses to be taken having either the Engr or CEE prefix.

**Field Trips and Labs.** Most Geology courses have required laboratories and/or field trips. Those enrolled are expected to dress properly for the conditions and observe safety precautions issued by the instructors. Most courses require modest lab fees.

**Bachelor of Arts Degree.** For a BA in Geology, the foreign-language requirement must be satisfied in addition to the Bachelor of Science in Geology requirements.

**Bachelor of Science Degree in Geology.** Three options of study are available for a BS in Geology: General Geology (BS in Geology without an emphasis), Hydrogeology-Engineering Geology Emphasis, and Geoarchaeology Emphasis. For a **BS in Geology (General Geology option)**, the following courses are required: Geol 1150, 3200, 3500, 3520, 3550, 3600, 3700, 4500, 4700, 5200; Chem 1210, 1220, 1230, 1240; Phyx 2210, 2220; Math 1210; Stat 3000; CS 1050 or CS 1700 or CEE 5190 or AWER 4930; 12-20 credits of Geology electives; and up to 8 electives in approved, science-related areas. For a list of approved courses, students should see the current major requirement sheet or consult their geology advisor.

For a **BS in Geology (Hydrogeology-Engineering Geology Emphasis)**, the following courses are required: Geol 1150, 3200, 3500, 3550, 3600, 3700, 4700, 5200, 5510, 5600; Chem 1210, 1220, 1230, 1240; Phyx 2210, 2220; Math 1210, 1220, 2250; Engr 2000, 2040, 2200; CEE 3030, 3500; CEE 3430 or 4300; Soil 3000 or 5130.

For a **BS in Geology (Geoarchaeology Emphasis)**, the following courses are required: Geol 1150, 3200, 3500, 3550, 3600, 3700, 4700, 5430, 5680; Chem 1210, 1220, 1230, 1240; Biol 1210, 1220; Math 1210; Stat 3000; CS 1050 or CS 1700 or CEE 5190 or AWER 4930; Anth 1030, 3250, 3300, 4250, 4350, 4360, 5300; Soil 3000 or 5130.

**Bachelor of Science Degree in Composite Teaching—Earth Science.** For the BS in Composite Teaching—Earth Science, the following courses are required: Geol 1150, 2500, 3200, 3500, 3550, 3600, 3700, 4700; Chem 1210, 1220, 1230, 1240; Phyx 1020, 2210, 2220; Math 1210; Stat 3000; CS 1050 or 1700; Phyx

3010 or 3030; EnvS 5110 or FRWS 2200; Bmet 2000; AWER 3000 or Geol 3300; Sci 4300; InsT 5200; ScEd 3100, 3210, 3300, 3400, 4200, 4210, 4300, 4400, 5300, 5500, 5600; SpEd 4000.

**Geology Minor.** A minimum of 18 credits is required for an approved minor in Geology. Required courses are Geol 1100 or 1150; and Geol 3200. Elective geology courses must be numbered 3500 or higher.

**Senior Thesis.** Geology majors in good academic standing may elect to complete a senior thesis. This is an endeavor which normally spans a year in its preparation and presentation. Senior thesis credits may be applied toward the elective requirements in the General Geology option. For further information, students should contact their geology advisor or the geology department head.

**Geology Honors.** Geology majors with a minimum GPA of 3.30 may elect to complete the requirements for the Geology Honors degree option. This is a departmental recognition which is separate from the University Honors program. For further information, students should contact their geology advisor or the geology department head.

## Graduate Programs

### Admission Requirements

See general admission requirements on pages 72-73. In addition, applicants must have acceptable GRE scores. Minimum scores of 40th percentile on the Verbal section and 40th percentile on the Quantitative section and a combined minimum of 1,000 are required. A member of the Geology faculty must agree to serve as the major professor for the applicant prior to acceptance.

Applications will be considered throughout the year, but program entry in fall semester is preferred. Students who wish to be considered for assistantships or other financial aid must have complete applications on file no later than February 15 for entry into the program the following fall semester.

### Prerequisites for Matriculation

Completion of a BS or BA in geology, biology, physics, chemistry, or engineering is required for matriculated status. Suggested prerequisite courses include: Chem 1210, 1220, 1230, 1240; Phyx 2210, 2220; Math 1210; Stat 3000; and CS 1050 or CS 1700 or CEE 5190 or AWER 4930. Deficiencies in geology are determined based on current USU undergraduate degree requirements for either the Geology or Hydrogeology-Engineering Geology option, as appropriate. The following geology courses or their equivalents are expected: Geol 1150, 3200, 3500, 3550, 3600, 3700, 4700, and 5200. It is expected that any deficiencies will be made up before the end of the first year of study.

### Degree Program

**Master of Science Degree.** The department offers advanced study and research opportunities leading to the MS degree in Geology. Although many research specialties require advanced courses selected primarily from Geology offerings, additional

courses may be selected from other departments on campus, such as Civil and Environmental Engineering; Plants, Soils, and Biometeorology; Biology; Mathematics and Statistics; Aquatic, Watershed, and Earth Resources; Environment and Society; and Forest, Range, and Wildlife Sciences.

### **Specializations**

Fields of specialization for graduate research include the following: hydrogeology, igneous petrology, paleoecology (including invertebrate paleontology), sedimentary geology (including petrology, basin analysis, sedimentation, stratigraphy, and petroleum geology), process geomorphology, Quaternary geology, structural geology, and regional tectonics.

### **Degree Requirements**

Only the Plan A thesis option is allowed for the MS degree in Geology. The recommended distribution is 20 credits of coursework and 10 credits of thesis to obtain the required 30 credits for the MS degree. A minimum of five 6000-level geology courses (other than Geol 6800) is recommended for the degree program. Only two grades of less than *B* (*C* to *B-*) will be accepted as part of the required degree program as listed on the "Program of Study for Master's Degree." A 3.0 grade point average must be obtained in required coursework as listed on the Program of Study. Thesis credits will be graded *P-F* only (i.e., no letter grade will be given). Geology graduate students using department or University facilities and/or under geology faculty supervision must register for a minimum of 3 credits every semester, up to and including the semester in which the thesis is cleared by the School of Graduate Studies. Registration may not be required during the summer.

### **Research**

There are six broad areas of research emphasis within the department: (1) sedimentary geology, (2) structural geology (3) regional tectonics, (4) igneous petrology and geochemistry, (5) geomorphology, and (6) hydrogeology.

Research in **sedimentary geology** is diverse: sedimentation and development of coral reefs and associated carbonate environments during Pleistocene and Holocene times, changes in shallow-water carbonate environments through early Paleozoic time, nonmarine siliciclastic depositional systems and petroleum reservoirs, geochemical provenance methods, and large-scale architecture of Mesozoic-Cenozoic intracontinental basins in Asia. Research activities are dominantly field-oriented, and often have a subsurface component. Studies are ongoing in the western United States, Mexico, the Caribbean, China, and west Africa.

Research in **structural geology** includes the examination of the mechanical and chemical evolution of fault zones, the development of fold-and-thrust structures in Idaho, Montana, Wyoming, and Utah, and the characterization of fluid-flow properties in fractured crystalline rocks.

Research in **regional and global tectonics** examines the structural and tectonic development of extensional structures in the Great Basin and Salton Trough, collisional and accretionary tectonics in Pakistan and the southern Appalachians, the relationship of ophiolites to active margin processes, and the application of ba-

sin analysis to the tectonics of basin formation and large scale crustal structures in China, Mongolia, Pakistan, and west Africa.

Research in **igneous petrology and geochemistry** focuses on the origin and evolution of basic to intermediate magmatic systems, and their relationship to global tectonic processes. Current projects include plume-related volcanism and its interaction with continental lithosphere in the Snake River Plain, Idaho, the origin and tectonic evolution of accreted arc terranes, the multi-stage origin of ophiolites, especially the Coast Range ophiolite of California, and the formation and evolution of lunar highlands crust.

**Geomorphology** research includes the study of climate and anthropogenic controls on landscape change and sedimentation; controls on alluvial stratigraphy; hillslope processes; numerical modeling of climate controls on basin stratigraphy; Quaternary landscape evolution of the Grand Canyon; and the integration and evolution of the Colorado River.

Research activity in **hydrogeology** includes wellhead protection in confined to semiconfined aquifers, the relationships between stream losses and water table depths, and the identification and geochemical characterization of groundwater recharge to surface streams.

Geology faculty members commonly interact with the faculty and staff of the Utah Water Research Laboratory; the College of Natural Resources; the Department of Plants, Soils, and Biometeorology; and the Department of Civil and Environmental Engineering.

### **Financial Assistance**

Departmental financial support for incoming graduate students consists primarily of graduate teaching assistantships, which are awarded on a competitive basis. There is often other financial support available, such as research assistantships, resulting from grants or other external funding. Students requesting financial support should apply directly to the department no later than February 15. Admission to the MS program does not guarantee financial assistance.

### **Additional Information**

Additional information on the research activities of faculty and graduate students may be obtained directly from the Department of Geology's website at <http://www.usu.edu/geoldept>.

## **Geology Courses (Geol)**

**Geol 1100 (BPS). Exploring the Changing Earth: Introduction to Geology.** Presents basic principles of geology using a framework of plate tectonics, the central unifying theory of geology. Introduction to earth materials (minerals and various kinds of rocks) and earth processes, both internal and external. Emphasizes the continuum of interrelated events and the various cycles existing both in and on our planet. Three lectures per week (even weeks); two lectures and one lab (odd weeks). (3 cr) (F,Sp,Su) ©

**Geol 1150 (BPS). The Dynamic Earth: Physical Geology.** Physical processes, both internal and external, shaping the Earth. Igneous, metamorphic, and sedimentary environments and products. Emphasizes geology as an applied science, relying on other basic sciences as tools for interpretation and understanding. Three lectures and one two-hour lab per week. (4 cr) (F,Sp)

**Geol 2250. Introductory Internship/Co-op.** Introductory educational work experience. (1-4 cr) (F,Sp,Su) ©

**Geol 2500. Geology Field Excursions.** Geologic features and processes observed in the field. Prerequisite: Geol 1100 or 1150. (1 cr) (F,Sp) ©

**\*Geol 3050 (DSC). Ecology of Logan Canyon and Vicinity.** Examines natural and human-caused changes in biological and physical features in the local landscape through time. Emphasizes how ecological knowledge and a sense of place can help people to better understand local environmental issues. Also taught as FRWS 3050. (3 cr)

**Geol 3100 (DSC). Natural Disasters.** Hazardous geologic processes affecting humans. Cause, prediction, avoidance, and frequency of natural disasters, including earthquakes, volcanic eruptions, tsunamis, landslides, floods, subsidence, meteorite impacts, and global changes. Topics discussed in the context of earth systems and cycles. Three lectures per week. Prerequisite: One Breadth Physical Sciences (BPS) course. (3 cr) (Sp)

**Geol 3110. Natural Disasters Laboratory.** Laboratory exercises and field trips highlighting the relation between humans and local geologic problems. One two-hour lab per week. Prerequisite: Geol 3100 (may be taken concurrently). (1 cr) (Sp)

**Geol 3200 (DSC). The Earth Through Time.** Investigates dynamic nature of Earth's physical and biological processes, and how these processes have shaped Earth's 4.5 billion-year history. Emphasis on interpretation of the story of the geologic record (rocks and landforms) and Earth's sequential physical and biological changes. Three lectures and one two-hour lab per week. Prerequisite: Geol 1100 or 1150. (4 cr) (Sp) ©

**Geol 3300 (DSC). Geology of the World's Oceans.** Geologic evidence for the development of ocean basins and continental margins through plate tectonic processes. Also, the interaction of the geo- and biospheres and their effect on the evolution of the oceans and atmosphere. Discussion of shoreline and marine environments, the organisms inhabiting them, and the physical and chemical processes in operation therein. Three lectures per week. Prerequisite: One Breadth Physical Sciences (BPS) course. (3 cr) (Sp)

**Geol 3500. Mineralogy and Crystallography.** Introduction to crystallography, crystal chemistry, and descriptive mineralogy. Three lectures and one three-hour lab per week. Prerequisites: Chem 1210 and Geol 1150. (4 cr) (Sp)

**Geol 3520. Optical Mineralogy and Petrography.** Introduction to the theory of optical crystallography. Determination of minerals using the petrographic microscope. One lecture and one lab per week. Prerequisite: Geol 3500. (2 cr) (F)

**Geol 3550 (CI). Sedimentation and Stratigraphy.** Classification and analysis of sedimentary rocks and structures, with an emphasis on the interpretation of ancient sedimentary environments. Controls on sedimentary processes over time. Principles of stratigraphic correlation. Three lectures and one lab per week. Prerequisite: Geol 3200. (4 cr) (F)

**Geol 3600. Geomorphology.** Geomorphic processes, origin of landforms and surficial deposits. Emphasizes fluvial and hillslope landscape elements, and surficial geologic mapping. Three one-hour lectures and one three-hour lab per week. Prerequisite: Geol 1100 or 1150 or Geog 1130. Also taught as AWER 3600. (4 cr) (F)

**Geol 3700. Structural Geology.** Examines the mechanisms, mechanics, and geometrics of deformed rocks. Basic principles of rock deformation, stress and strain, fault and fold classifications, and the mechanisms by which rocks deform. Lab presents applications and techniques important for accurately describing and representing deformed rocks in maps and cross-sections, and how to interpret and present data on rock structures. Three lectures and one three-hour lab per week. Prerequisites: Geol 3550 and Phyx 2210. (4 cr) (Sp)

**Geol 4250. Advanced Internship/Co-op.** Advanced educational work experience. (1-4 cr) (F,Sp,Su) ©

**\*Geol 4500. Igneous and Metamorphic Petrology.** Origin, processes of formation, classification, and identification of igneous and metamorphic rocks. Study of igneous and metamorphic rocks in hand specimens and thin sections. Three lectures and one three-hour lab per week. Prerequisite: Geol 3500; corequisite: Geol 3520. (4 cr) (F)

**Geol 4700 (CI). Geologic Field Methods.** Collection, recording, and interpretation of geologic data requiring written reports, graphical formats, and oral presentations. Variety of field techniques used to examine variety of geologic deposits, features, and processes. Two extended labs per week. Half semester, early fall; may be paired with Geol 5630. Prerequisite: Geol 3700. (2 cr) (F)

**Geol 4900. Special Problems.** Directed study of selected topics. Written report required. Prerequisite: Permission of instructor. (1-4 cr) (F,Sp) ©

**Geol 5150 (d6150).<sup>1</sup> Fluvial Geomorphology.** Focuses on physical processes in streams that control their shape, plan form, slope, bed material, and distribution of channel bars. Emphasizes field analysis of these topics, and application of geomorphology to aquatic ecology and environmental restoration. Prerequisite: Geol/AWER 3600. Also taught as AWER 5150/6150. (4 cr) (F)

**\*Geol 5160 (d6160). Hillslope and Landscape Geomorphology.** Includes basics of hillslope weathering, transport, and hydrologic processes. Surveys classic and recent literature on hillslope-scale and landscape-scale geomorphic research. Three lectures and several Saturday field trips. Prerequisite: Geol/AWER 3600. Also taught as AWER 5160/6160. (3 cr) (Sp)

**\*Geol 5200. Geology Field Camp.** Integrative approach to examining geologic relationships in the field, deciphering geologic evolution of map regions, and interpreting the structure and distribution of rocks. Results presented in reports, maps, cross-sections, and graphical formats. Requires 40-45 hours of lab per week for 3.5-4.0 weeks. Prerequisites: Geol 3500, 3550, 3600, 3700, 4700. (5 cr) (Su)

**\*Geol 5410 (d6410). Introduction to Clay Mineralogy.** Introduction to and application of techniques, such as x-ray diffraction, differential thermal analysis, and chemical analysis, to study of clay minerals. Examination of the effects of clay mineral structures on physical and chemical properties. Three lectures and one lab per week; half semester. Prerequisite: Geol 3500. (2 cr) (Sp)

**\*Geol 5420. Metallic Mineral Deposits.** Origin and occurrence of metallic mineral deposits, study of representative ore suites, and field trips to active mines. Three lectures and one lab per week. Prerequisite: Geol 4500. (4 cr) (Sp)

**\*Geol 5430. Paleontology.** Survey of prominent microfossil and invertebrate taxa, including their diagnostic morphologic features, stratigraphic ranges, and environmental tolerances. Equips students with the necessary information and techniques to enable them to recognize and utilize fossils in stratigraphic and paleoenvironmental interpretation. Three lectures and one lab per week. Half semester; may be paired with Geol 5440. Prerequisite: Geol 3200. (2 cr) (F)

**\*Geol 5440 (CI) (d6440). Paleocology.** Interrelationships between various organisms and between organisms and their environment. Provides field, laboratory, and quantitative techniques for the interpretation of ancient environments and the analysis of past biotic interrelationships. Three lectures and one lab per week. Half semester; may be paired with Geol 5430. Prerequisite: Geol 5430. (2 cr) (F)

**\*Geol 5460 (d6460). Interpretation of Sedimentary Rocks I.** Detailed interpretation of sedimentary rocks, based on petrography and sedimentary characteristics. Source terranes, tectonic settings, depositional environments, and diagenetic changes during burial. Three lectures and two labs per week. Half semester; may be paired with Geol 5470. Prerequisites: Geol 3500 and 3550. (3 cr)

**\*Geol 5470 (d6470). Interpretation of Sedimentary Rocks II.** Application of field observations, hand-sample, thin-section, and x-ray diffraction analyses to the interpretation of chemical sedimentary rocks. Emphasizes determination of depositional environment and evaluation of diagenetic changes. Three lectures and one lab per week. Half semester; may be paired with Geol 5460. Prerequisites: Geol 3500 and 3550. (2 cr)

**Geol 5480 (d6480). Sedimentary Basin Analysis.** Detailed coverage of techniques of sedimentary basin analysis, including depositional systems, provenance, basin modeling, and fluid and heat flow history. Survey of types of sedimentary basins worldwide. Prerequisites: Geol 3500 and 3550. (3 cr) (F)

**\*Geol 5500 (d6500). Advanced Igneous Petrology.** Advanced concepts in the origin and evolution of magmatic systems, effects of different tectono thermal regimes on magma genesis, magma dynamics, and phase equilibria in magmatic systems. Concepts illustrated by rock suites from classic locations. Three lectures and three laboratory hours each week. Prerequisite: Geol 4500 or equivalent. (4 cr) (F)

**Geol 5510 (QI). Groundwater Geology.** Provides graduate students and senior undergraduates with understanding of fundamental principles of groundwater geology and hydrology, and helps prepare them for careers in hydrogeology or environmental geology. Three lectures per week. Prerequisites: Geol 1150 and Math 1210 or permission of instructor; Geol/AWER 3600 recommended. (3 cr) (F)

**Geol 5520 (CI) (d6520). Hydrogeologic Field Methods.** Methods of collection and analysis of field data for groundwater studies. Three lectures per week. Prerequisite: Geol 5510 or permission of instructor. (3 cr) (Sp)

**Geol 5530 (QI). Exploration Geophysics and Petroleum Exploration.** Applications of gravity, magnetics, electrical/electromagnetic methods, seismic reflection and refraction, borehole logging, and organic geochemistry in exploration for petroleum, groundwater, and ore bodies, and in amelioration of pollution. Three lectures and one two-hour lab per week. Prerequisites: Geol 3550, 3700, and Phyx 2220, or permission of instructor. (4 cr) (Sp)

**\*Geol 5540 (QI) (d6540). Quantitative Methods in Geology.** Application of various quantitative methodologies to geologic problems. Two lectures and one lab per week. (3 cr) (F)

**\*Geol 5550 (d6550). Geochemical Application of Electron Microprobe and X-Ray Fluorescence Analysis.** Theory and application of X-ray fluorescence spectrometry and the electron microprobe to problems in geochemistry and materials analysis. Two hours lecture and six hours laboratory per week. Prerequisite: Chem 1210 or equivalent, or permission of instructor. (4 cr) (Sp)

**Geol 5600. Geochemistry.** Application of thermodynamics, solution chemistry, phase diagrams, and both radioactive and stable isotopes to the understanding of earth processes. Three lectures per week. Prerequisite: Geol 3500. (3 cr) (F)

**\*Geol 5610 (d6610). Tectonic Evolution of North America.** Survey of tectonic styles and processes along plate margins, using the tectonic evolution of western North America as the prime example. Two lectures and one lab per week. Prerequisite: Geol 3700. (3 cr)

**\*Geol 5620 (QI) (d6620). Global Geophysics.** Application of physics to understanding geologic processes, the earth's interior, and the theory of plate tectonics. Two lectures and one two-hour lab per week. Prerequisites: Geol 3700 and Phyx 2220. (3 cr)

**\*Geol 5630. Photogeology.** Interpretation of geologic features on aerial photographs. Three two-hour labs per week. Half semester; may be paired with Geol 4700. Prerequisites: Geol 3600, 3700. (2 cr)

**Geol 5650. Senior Thesis.** Prerequisite: Permission of instructor. (1-4 cr) (F,Sp) ®

**\*Geol 5680 (d6680). Paleoclimatology.** Covers climate through the past four billion years of geologic time. Explores driving forces behind climate changes. Examines data and methods used in paleoclimate research. Includes discussion of literature and stresses local paleoclimate records. Three lectures per week, along with field trips. Prerequisite: Geol/AWER 3600 or permission of instructor. Also taught as AWER 5680/6680. (3 cr) (Sp)

**Geol 5900. Topics for Teachers.** Special topics in geology for elementary and secondary science teachers to provide an understanding of the geology of Utah and the

Western United States. Emphasis on field and lab activities. Prerequisite: Introductory geology course or permission of instructor. (1-4 cr) ®

**Geol 6150 (d5150). Fluvial Geomorphology.** Focuses on physical processes in streams that control their shape, plan form, slope, bed material, and distribution of channel bars. Emphasizes field analysis of these topics, and application of geomorphology to aquatic ecology and environmental restoration. Prerequisite: Geol/AWER 3600. Also taught as AWER 6150/5150. (4 cr) (F)

**\*Geol 6160 (d5160). Hillslope and Landscape Geomorphology.** Includes basics of hillslope weathering, transport, and hydrologic processes. Surveys classic and recent literature on hillslope-scale and landscape-scale geomorphic research. Three lectures and several Saturday field trips. Prerequisite: Geol/AWER 3600. Also taught as AWER 6160/5160. (3 cr) (Sp)

**\*Geol 6250. Mechanics and Processes in Earth Sciences.** Fundamentals of solid and fluid mechanics with applications to the earth sciences. Applications to rock deformation, fluid flow, glacier movement, and slope stability. Designed for graduate students in earth sciences and engineering. Two lectures, one lab per week. Prerequisites: Geol 3700, Math 1210; or permission of instructor. (3 cr) (F)

**\*Geol 6410 (d5410). Introduction to Clay Mineralogy.** Introduction to and application of techniques, such as x-ray diffraction, differential thermal analysis, and chemical analysis, to study of clay minerals. Examination of the effects of clay mineral structures on physical and chemical properties. Three lectures and one lab per week; half semester. Prerequisite: Geol 3500. (2 cr) (Sp)

**\*Geol 6440 (d5440). Paleoecology.** Interrelationships between various organisms and between organisms and their environment. Provides field, laboratory, and quantitative techniques for the interpretation of ancient environments and the analysis of past biotic interrelationships. Three lectures and one lab per week. Half semester; may be paired with Geol 5430. Prerequisite: Geol 5430. (2 cr) (F)

**\*Geol 6460 (d5460). Interpretation of Sedimentary Rocks I.** Detailed interpretation of sedimentary rocks, based on petrography and sedimentary characteristics. Source terranes, tectonic settings, depositional environments, and diagenetic changes during burial. Three lectures and two labs per week. Half semester; may be paired with Geol 6470. Prerequisites: Geol 3500 and 3550. (3 cr)

**\*Geol 6470 (d5470). Interpretation of Sedimentary Rocks II.** Application of field observations, hand-sample, thin-section, and x-ray diffraction analyses to the interpretation of chemical sedimentary rocks. Emphasizes determination of depositional environment and evaluation of diagenetic changes. Three lectures and one lab per week. Half semester; may be paired with Geol 6460. Prerequisites: Geol 3500 and 3550. (2 cr)

**Geol 6480 (d5480). Sedimentary Basin Analysis.** Detailed coverage of techniques of sedimentary basin analysis, including depositional systems, provenance, basin modeling, and fluid and heat flow history. Survey of types of sedimentary basins worldwide. Prerequisites: Geol 3500 and 3550. (3 cr) (F)

**\*Geol 6500 (d5500). Advanced Igneous Petrology.** Advanced concepts in the origin and evolution of magmatic systems, effects of different tectono thermal regimes on magma genesis, magma dynamics, and phase equilibria in magmatic systems. Concepts illustrated by rock suites from classic locations. Three lectures and three laboratory hours each week. Prerequisite: Geol 4500 or equivalent. (4 cr) (F)

**Geol 6520 (d5520). Hydrogeologic Field Methods.** Methods of collection and analysis of field data for groundwater studies. Three lectures per week. Prerequisite: Geol 5510 or permission of instructor. (3 cr) (Sp)

**\*Geol 6540 (d5540). Quantitative Methods in Geology.** Application of various quantitative methodologies to geologic problems. Two lectures and one lab per week. (3 cr)

**\*Geol 6550 (d5550). Geochemical Application of Electron Microprobe and X-Ray Fluorescence Analysis.** Theory and application of X-ray fluorescence spectrometry and the electron microprobe to problems in geochemistry and materials

analysis. Two hours lecture and six hours laboratory per week. Prerequisite: Chem 1210 or equivalent, or permission of instructor. (4 cr) (Sp)

**\*Geol 6610 (d5610). Tectonic Evolution of North America.** Survey of tectonic styles and processes along plate margins, using the tectonic evolution of western North America as the prime example. Two lectures and one lab per week. Prerequisite: Geol 3700. (3 cr)

**\*Geol 6620 (d5620). Global Geophysics.** Application of physics to understanding geologic processes, the earth's interior, and the theory of plate tectonics. Two lectures and one two-hour lab per week. Prerequisites: Geol 3700 and Phyx 2220. (3 cr)

**\*Geol 6680 (d5680). Paleoclimatology.** Covers climate through the past four billion years of geologic time. Explores driving forces behind climate changes. Examines data and methods used in paleoclimate research. Includes discussion of literature and stresses local paleoclimate records. Three lectures per week, along with field trips.

Prerequisite: Geol/AWER 3600 or permission of instructor. Also taught as AWER 6680/5680. (3 cr) (Sp)

**Geol 6800. Seminar.** (1-4 cr) ®

**Geol 6970. Thesis.** (1-9 cr) (F,Sp,Su) ®

**Geol 6990. Continuing Graduate Advisement.** (1-3 cr) (F,Sp,Su) ®

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\*This course is taught alternating years. Check with department for information about when course will be taught.

<sup>1</sup>Parenthetical numbers preceded by *d* indicate a *dual* listing.

® Repeatable for credit. Check with major department for limitations on number of credits that can be counted for graduation.

© This course is also offered by correspondence through Continuing Education Independent and Distance Education.