

Geological Sciences

College of Science and Mathematics

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Programs

Undergraduate

B.S., Geology

Option I: Geology

Option II: Environmental Geology

Option III: Secondary Teaching

Minor in Geology

Graduate

M.S., Geology

Credential: Geological Sciences Subject Matter Program for the Single Subject Credential

Credential Information

The Geology B.S. provides an option for students planning to teach earth science or physical science in secondary schools. This degree program, with some supplementary courses, has been approved by the California Commission on Teacher Credentialing as an academic subject matter program for the Single Subject Credential in Science: Geological Sciences. For details on the Single Subject Credential program, see the Credentials and Department of Secondary Education sections in this catalog.

The Geological Sciences Subject Matter Program for the Single Subject Credential sunsets on July 1, 2009. Only those students who started the program before July 1, 2005 and who can complete it before the sunset date will be eligible to receive the subject matter program verification. Please contact the department for more information.

The Major:

Geology is a multidisciplinary science that applies the concepts of biology, chemistry, physics, mathematics, and engineering to the natural world around us. The rich variety of its fields of study includes oceanography, paleontology, geophysics, geochemistry, hydrogeology, engineering geology, and more. That is what makes geology an exciting and challenging major for students with broad scientific interests and a love of our planet's natural systems, environment, and history.

Geology majors gain basic scientific observational, reasoning, and communication skills and an understanding of geological concepts and history. This blend of interpretive scientific ability and historical perspective gives geologists an important role in society. They apply their skills and knowledge to solve complex problems related to human interaction with natural systems, hazards, and resources and to communicate solutions and options to the public.

Department Programs

The Department offers the B.S. and M.S. in Geology and a minor in Geology. For the B.S. degree, three options are available: Geology (Option I), Environmental Geology (Option II), and Secondary Teaching (Option III).

The major in Geology is designed for students who:

1. wish to pursue careers in geology, geophysics, environmental geology, or related fields;
2. wish to prepare for graduate work in geology, geophysics, environmental geology, or related fields;
3. wish to teach earth science or physical science in secondary schools; *or*
4. desire a liberal arts education with emphasis on geology. Students planning a professional career in geology or earth science should prepare for graduate study; a Master's degree is normally required for professional advancement.

Entry to the B.S. program in geology assumes a high school background in chemistry and mathematics (algebra through trigonometry). A satisfactory score on the Chemistry Placement Test is required as prerequisite to CHEM 101/L. Satisfactory scores on the Entry Level Mathematics Exam and Mathematics Placement Test are required as prerequisites to MATH 255A or 150A and to PHYS 100A/L. Students not having this preparation will need additional course work in deficient subject areas.

The objectives of the Master of Science program in Geology are:

1. to train individuals with the competence required by the geological profession for employment in industry and government agencies;
2. to enable promising students to attain a level of knowledge and research ability required for admission to a Ph.D. program at other universities;
3. to provide an M.S. program with basic course work and research requirements for students planning to teach geology at the community college level.

A minor in Geology is designed for students interested in the Earth, but with a major in another department. Biologists, engineers, mathematicians, and physicists are finding employment in environmental and energy-related industries. For these majors, the Geology minor broadens the individual's background and competence in the earth sciences.

Careers

A wide variety of job opportunities in both private industry and government service are available to geology graduates. Graduates with Bachelor's degrees will normally begin their work career at entry level positions, whereas graduates with Master's degrees will start at positions with greater responsibility and have greater opportunities for long-term career advancement. Examples of opportunities in private industry include engineering geology (evaluating sites for homes, commercial buildings, highways, etc.), environmental geology (environmental impact studies, evaluation and remediation of contaminated sites), hydrogeology (development and quality control of ground water resources), and the discovery and extraction of earth resources such as oil, gas, coal, and metallic and non-metallic resources.

Agencies in all levels of government—city, county, state, and federal—employ geologists for regulatory and oversight (inspection and monitoring) activities. Additionally, a degree in geology is excellent background for preparing to teach physical science and earth science at the secondary school level and—for those with an M.S. degree—at the community college level. Finally, the B.S. degree serves as excellent preparation for entry to graduate programs, either at Cal State Northridge or at other universities.

Academic Advisement

Geology majors, both undergraduate and graduate, must be advised each semester before being permitted to register for classes. Undergraduate students must see Jon Sloan and graduate students must see Kathleen Marsaglia for advisement.

Student Learning Outcomes of the Undergraduate and Graduate Program

Undergraduate majors will receive instruction of sufficient breadth, depth, and currency to prepare them for successful appointment to entry-level professional work or graduate school. At the time of graduation, they will have learned

1. background knowledge of earth materials, processes, and history;
2. skills in standard data-gathering and data-analysis methods in both lab and field settings;
3. how to identify geologic problems and develop testable hypotheses that would aid in their solution in both independent and collaborative modes; and
4. how to present polished summaries, both written and oral, of their geological discoveries.

Graduates of the Master of Science program will have received training and experience sufficient to prepare them for professional positions in the geological sciences that require a broad background knowledge of the geological sciences, substantial experience in gathering and interpreting geologic data, and skill at communicating their knowledge in a confident and competent manner. Such graduates will be well prepared to enter Ph.D. programs at other universities and to assume responsible positions

1. in industry or in government agencies; and
2. as instructors in secondary school and community college classrooms.

Requirements for the Bachelor of Science Degree

A. Option I: Geology

1. Lower Division Required Courses (34 Units)

GEOL	101	Geology of Planet Earth (3)
GEOL	102	Geology of Planet Earth Lab (1)
GEOL	110	Earth History (3)
GEOL	112	Earth History Lab (1)
GEOL	207	Mineralogy (3)
GEOL	235	Field Geology I (2)
CHEM	101/L	General Chemistry I and Lab (4/1)
CHEM	102/L	General Chemistry II and Lab (4/1)
MATH	255A*	Calculus for the Life Sciences I (3)
PHYS	100A/L**	General Physics I and Lab (3/1)
PHYS	100B/L**	General Physics II and Lab (3/1)

* or MATH 150A

** or PHYS 225, 220A/L; 226, 220BL

2. Upper Division Required Courses (31 Units)

GEOL	307	Petrology (4)
GEOL	310	Structural Geology (4)
GEOL	335	Field Geology II (2)
GEOL	341	Sedimentation and Stratigraphy (4)
GEOL	351	Fundamentals of Paleontology (4)
GEOL	435	Field Geology III (2)
GEOL	464	Applied Geophysics (3)
GEOL	497	Research Methods and Design (1)
GEOL	498	Senior Thesis (1)
GEOL	523	Sedimentation and Tectonics (4)
GEOL	535	Field Geology IV (2)

3. Electives (18 Units)

These should be selected from the following list (to include at least 11 units of upper division Geology courses):

BIOL	313
CHEM	235, 321/L, 322/L
CE	426/L
COMP	101, 105
GEOG	306, 365, 406, 465, 466, 467, 468
GEOL	any Upper Division Geology course exclusive of 300, 301.
EOH	454, 457, 459, 469
MATH	140, 150B, 250, 255B, 262, 280, 351
PHYS	227/L

Other electives that meet department approval also qualify.

General Education: Basic Skills Mathematics and the entire section of Natural Sciences are met by required courses in the major.

Total Units in the Major, Option I	83
General Education Units	36
Additional Units	1
Total Units Required in the Major	120

B. Option II: Environmental Geology

1. Lower Division Required Courses (38 Units)

GEOL	101	Geology of Planet Earth (3)
GEOL	102	Geology of Planet Earth Lab (1)
GEOL	110	Earth History (3)
GEOL	112	Earth History Lab (1)
GEOL	207	Mineralogy (3)
GEOL	235	Field Geology I (2)
CHEM	101/L	General Chemistry I and Lab 4/1
CHEM	102/L	General Chemistry II and Lab 4/1
CHEM	235	Introductory Organic Chemistry (4)
MATH	255A*	Calculus for the Life Sciences I (3)
PHYS	100A/L**	General Physics I and Lab (3/1)
PHYS	100B/L**	General Physics II and Lab (3/1)

* or MATH 150A

** or PHYS 225, 220AL; 226, 220BL

2. Upper Division Required Courses (37 Units)

GEOL	307	Petrology (4)
GEOL	310	Structural Geology (4)
GEOL	335	Field Geology II (2)
GEOL	341	Sedimentation and Stratigraphy (4)
GEOL	351	Fundamentals of Paleontology (4)
GEOL	435	Field Geology III (2)
GEOL	464	Applied Geophysics (3)
GEOL	497	Research Methods and Design (1)
GEOL	498	Senior Thesis (1)
GEOL	500	Environmental Geology Seminar (3)
GEOL	535	Field Geology IV (2)
GEOL	575	Hydrogeology (4)
EOH	454	Environmental Health Law (3)
	or EOH 457	Water Supply and Sewage Disposal (3)
	or EOH 459	Hazardous Materials and Waste Management (3)
	or EOH 469	Environmental Risk Analysis (3)

3. Upper Division Electives (8 Units)

These should be selected from the following list:

GEOG	306, 365, 406, 465, 466, 467, 468
GEOL	any upper division geology course exclusive of 300, 301
EOH	454, 457, 459, 469 (choose one not already used for the upper division requirement)

General Education: Basic Skills Mathematics and the entire section of Natural Sciences are met by required courses in the major.

Total Units in the Major, Option	83
General Education Units	36
Additional Units	1
Total Units Required for a B.S. Degree	120

C. Option III: Secondary Teaching

1. Lower Division Required Courses (46 Units)

ASTR	152	Elementary Astronomy (3)
ASTR	154L	Observational Astronomy (1)
BIOL	106/L	Biological Principles I and Lab (3/1)
BIOL	107/L	Biological Principles II and Lab (3/1)
GEOL	101/102	Geology of Planet Earth and Lab (3/1)
GEOL	110/112	Earth History and Lab (3/1)
GEOL	207	Mineralogy (3)
GEOL	235	Field Geology I (2)
CHEM	101/L	General Chemistry I and Lab (4/1)
CHEM	102/L	General Chemistry II and Lab (4/1)
MATH	255A*	Calculus for the Life Sciences I (3)
PHYS	100A/L**	General Physics I and Lab (3/1)
PHYS	100B/L**	General Physics II and Lab (3/1)

* or MATH 150A

** or PHYS 225, 220AL; 226, 220BL

2. Upper Division Required Courses (35 Units)

GEOL	307	Petrology (4)
GEOL	310	Structural Geology (4)
GEOL	322	Introductory Oceanography (4)
GEOL	335	Field Geology II (2)
GEOL	341	Sedimentation and Stratigraphy (4)
GEOL	351	Fundamentals of Paleontology (4)
GEOL	435	Field Geology III (2)
GEOL	497	Research Methods and Design (1)
GEOL	498	Senior Thesis (1)
GEOL	505	The Evolution of Global Systems (3)
GEOL	595Y	Geological Sciences Teacher Enhancement (3)
GEOL	311	Atmosphere (3)

2. Electives (2 Units)

These should be selected from the following list:

BIOL	313
CHEM	235, 321/L, 322/L
CE	426/L
COMP	100
EOH	454, 457, 459, 469
GEOG	306, 365, 406, 465, 466, 467, 468
GEOL	any upper division course exclusive of 300, 301.
MATH	140, 150B, 250, 255B, 262, 280, 351
PHYS	227/L

Other electives that meet department approval also qualify.

General Education: Basic Skills Mathematics and the entire section of Natural Sciences are met by required courses in the major.

Total Units in the Major, Option III	83
General Education Units	36
Additional Units	1
Total Units Required for a B.S. Degree	120

Geological Sciences Subject Matter Program for the Single Subject Credential

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Minor in Geology

1. Lower Division Required Courses (17 or 18 Units)

CHEM	100	General Chemistry I and Lab 4/1 or CHEM 100/110L Principles of Chemistry and Lab (3/1)
GEOL	101	Geology of Planet Earth (3)
GEOL	102	Geology of Planet Earth Lab (1)
GEOL	110	Earth History (3)
GEOL	112	Earth History Lab (1)
GEOL	207	Mineralogy (3)
GEOL	235	Field Geology I (2)

2. Upper Division Required Courses (8 Units)

GEOL	307	Petrology (4)
GEOL	351	Fundamentals of Paleontology (4)

3. Upper Division Electives (3 Units)

These should be selected from any upper division Geology courses exclusive of 498 and 499.

Total Units Required in the Minor	28-29
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Requirements for the Master of Science Degree

A. For admission to the program:

1. B.S. degree in Geology or its equivalent. B.S. degree must contain at least 4 units of field geology courses, to include a significant field mapping experience and a substantial written report. Students who do not have appropriate course work may be conditionally admitted to the program, but will be required to complete any deficient course work without graduate credit during their first year of residence.
2. University requirements for admission, with the exception that the grade point average in the last 60 units must be 2.75. Those applicants with a grade point average in the last 60 units of between 2.5 and 2.75 may still be admitted if the average of the scores on the General Aptitude portion of the Graduate Record Examination is 50th percentile or greater.
3. Graduate Record Examination: General Aptitude only.

B. For the degree:

A minimum of 30 semester units is required, with at least 21 units at the 500 or 600-level. Each student will be advised by a Graduate Advisory Committee consisting of three or more faculty members. The Graduate Advisory Committee will guide the student in the proper selection of courses related to the student's main field of interest to assure that an integrated body of knowledge is obtained. The student must obtain initial approval from the Graduate Advisory Committee for the thesis topic selected. Completion and successful oral defense of a thesis is required.

1. Required courses (6 Units)

GEOL	696	Directed Graduate Research (3)
followed by		
GEOL	698	Thesis or Graduate Project (3)

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2. Elective courses (24 Units)

These should be selected with an advisor approval from 400-level geological sciences courses not required for the B.S. in Geology and from 500-level and 600-level geological sciences courses. With advisor approval, up to 9 units of appropriate courses from related areas in science, mathematics or engineering may be substituted for geological sciences courses. 300-level courses do not carry graduate credit, and a maximum of 9 units of 400-level courses may be applied toward the 30 units required for the degree.

(Note: In some cases service as a teaching assistant in the Department may be advised as part of the student's educational experience.)

Total Units Required for the M.S. Degree

30

Course List**GEOL 101. Geology of Planet Earth (3)**

Studies of the geologic materials and processes that shape our earth and environment are explored as they relate to our everyday lives. Topics include: global tectonics; earthquakes and other geologic hazards; glacial, river and coastal processes that form our landscapes; water, mineral and energy resources; and waste disposal and pollution. Students using this course to satisfy the Natural Sciences section of General Education may satisfy the corresponding lab requirement by completing GEOL 102. Students may not receive credit for both GEOL 100 and 101. Lecture three hours, field trip.

GEOL 102. Geology of Planet Earth Lab (1)

Recommended Corequisite or Preparatory: GEOL 100 or 101. Identification of rocks and minerals. Introduction to topographic maps and how they are used to interpret geologic processes and geologic history. Interpretation of geologic maps and data relating to earthquakes and plate tectonics. Satisfies the lab requirement in Natural Sciences of General Education provided either GEOL 100 or 101 is completed. Lab three hours, field trips.

GEOL 106LRS. Earth and Space Science for Liberal Studies Majors (3)

Prerequisites: Completion of the lower division writing requirement. Analysis of Earth systems (atmosphere, hydrosphere, lithosphere, and biosphere), the solar system, and the universe. Selected topics include structure and composition of the Earth; minerals and rocks; plate tectonics; landforms and surface processes; natural hazards, such as floods, earthquakes and volcanic eruptions; physical oceanography, the water cycle, weather and climate; formation of the universe and solar system, and evolution of stars and galaxies. Three hours of lecture per week. Available for Earth Science credit for Liberal Studies

GEOL 110. Earth History (3)

Introduction to the dynamic study of the Earth's evolution, including changes in its crust, oceans, atmosphere, and climate, and how these changes, woven into the fabric of geologic time, affected major groups of plants and animals, including dinosaurs and humans. Students using this course to satisfy a General Education requirement in Natural Sciences may satisfy the corresponding lab requirement by completing GEOL 112.

GEOL 112. Earth History Lab (1)

Recommended Corequisite or Preparatory: GEOL 100 or 101. Course content includes introduction to fossil, relative-age relationships, and construction and interpretation of maps and cross-sections that emphasize paleogeography and sedimentary rocks. May be used to satisfy the lab requirement in Natural Sciences of General Education provided GEOL 110 is completed. Lab three hours, a one-day field trip.

GEOL 122. The World Ocean (3)

Introduction to the oceans. Evolution of the ocean basins, their environment and resources. Aspects of biological, chemical, geological and

physical oceanography. Students using this course to satisfy a General Education requirement may satisfy the corresponding lab requirement by completing GEOL 123. Lecture three hours, field trips.

GEOL 123. World Ocean Lab (1)

Recommended Corequisite or Preparatory: GEOL 122. Introduction to oceanographic data, its collection and interpretation. May be used to satisfy the lab requirement in the Natural Sciences of General Education provided GEOL 122 is also completed. Lab three hours, field trips.

GEOL 130. Geologic Hazards (3)

Study of geologic conditions that pose a potential danger to life and property such as earthquakes, volcanoes, landslides, floods, beach erosion and waste disposal. Included are cause and effect relationships and mitigation and control measures. (Available for General Education, Natural Sciences) Credit cannot be received for both GEOL 130 and 300. Lecture three hours, field trips.

GEOL 207/L. Mineralogy and Lab (2/1)

Corequisite: 207L. Preparatory: GEOL 101 and 102 and CHEM 101 or 105. Study of the nonsilicate and silicate minerals with emphasis on crystallography, mineral chemistry, physical properties, occurrence, origin and associations. Lecture two hours, lab three hours, field trips. (Offered fall semester)

GEOL 235. Field Geology I (2)

Preparatory: GEOL 102. Study of and practice in techniques and methods of geologic field studies, including note taking, mapping, analysis of geologic history and structures, and introduction to geologic illustration and report writing. Approximately six days of field work (including overnight weekend trips), associated with a weekly 3 hour instructional and advisement meeting designed to develop skills in field techniques and to use GIS in creating geologic illustrations.

Upper Division**GEOL 300. Environmental Geology (3)**

Preparatory: Completion of the lower division writing requirement. Study of the relationship between humans and the earth and the application of geology to environmental problems. Topics include geological hazards, pollution, mineral and energy resources, land use planning, and environmental impact. Students using this course to satisfy a General Education requirement in the Natural Sciences may satisfy the corresponding lab requirement by completing GEOL 301. Credit cannot be received for both GEOL 130 and 300. Lecture three hours, field trips.

GEOL 301. Environmental Geology Lab (1)

Recommended Corequisite or Preparatory: GEOL 300. Introduction to geologic materials and processes as they are applicable to the human environment. Included are practical exercises on rocks, minerals, geologic maps, and water, mineral and energy resources. Earthquake, volcanic, landslide, and flood hazard evaluations are also performed. Lab three hours, field trips. May be used to satisfy the lab requirement in the Natural Sciences of General Education provided GEOL 300 is also completed.

GEOL 307/L. Petrology and Lab (2/2)

Corequisite: GEOL 307L. Preparatory: GEOL 207/L. Introduction to the classification and origin of igneous and metamorphic rocks, including the optical properties of minerals. Lab study of these rocks utilizes hand-specimen characteristics and the petrographic microscope. Lecture two hours, lab six hours, field trips. (Offered spring semester)

GEOL 310/L. Structural Geology and Lab (2/2)

Corequisite GEOL 310L. Recommended Corequisite or Preparatory: GEOL 307. Study of rock deformational processes and resulting structures in the Earth's crust. Lab work emphasizes the use of graphic methods to assist in the geometric and kinematic interpretation of rock structures. Lecture two hours, lab six hours.

GEOL 322/L. Introductory Oceanography and Lab (3/1)

Corequisite: GEOL 322L. *Preparatory:* GEOL 101 and completion of the lower division writing requirement. Designed for the engineering or science major who requires a general background in oceanography. Study of biological, chemical, geological, and physical oceanography. Lecture three hours, lab three hours, field trips.

GEOL 335. Field Geology II (2)

Preparatory: GEOL 235. *Recommended Corequisite:* GEOL 341. Emphasizes the observation and interpretation of sedimentary rocks and stratigraphic problems in the field and techniques used to measure stratigraphic sections. Six days of study in the field (including overnight weekend trips), associated with a weekly three-hour instructional and advisement meeting designed to develop skills in field techniques and report writing and illustration.

GEOL 341/L. Sedimentation and Stratigraphy and Lab (2/2)

Corequisite: 341L. *Preparatory:* GEOL 307; *instructor consent.* Introduction to the processes of sedimentation; the texture, composition, and classification of sedimentary rocks; depositional environments; and stratigraphic sequences and correlation techniques. Lecture two hours, lab six hours.

GEOL 345. Geology of California (2)

Preparatory: Completion of the lower division writing requirement. Study of the geologic history, structure, minerals, rocks, fossil, and modern geologic processes of California. Lecture two hours, field trips.

GEOL 351/L. Fundamentals of Paleontology and Lab (3/1)

Corequisite: GEOL 351L. *Preparatory:* two courses in either *Geology or Biology.* Survey of past life on the earth, including fossil cyanobacteria, macroscopic algae, protocists, plants (also spores and pollen), invertebrate, and vertebrates, their evolution, distribution, and paleontology, with emphasis on methods used by paleontologists, especially for environmental studies. Lecture three hours, lab three hours, field trips.

GEOL 406LRS. Liberal Studies Science Experience Capstone (1)

Prerequisites: BIOL 100, 101 or 102; PHSC 170; GEOL 106LRS or GEOG 106LRS. This laboratory course serves as a culminating science experience for Liberal Studies majors in the pre-credential and ITEP options. An interdisciplinary blend of biology, physics, chemistry, and earth and space sciences from Lower Division courses will be integrated into the course as various topics are explored through the broad lens of earth science. Hands-on investigations will include topics linked to California K-6 State Science Standards such as the nature of science, astronomy and the solar system, solar energy and meteorology, the water cycle, fossils and the evolution of life, rocks and minerals, natural resources, plate tectonics and Earth's structure, earthquakes and volcanic eruptions, and geomorphology. Three-hour laboratory.

GEOL 431A-R. Advanced Field Studies (1)

Preparatory: GEOL 435. Advanced techniques of field observation, recording, analysis, and report writing in various fields of geology. A-Minerals; B-Igneous Rocks; C-Metamorphic Rocks; D-Sedimentary Rocks; E-Sedimentary Environments; F-Invertebrate Paleontology; G-Micropaleontology; H -Oceanography; I-California Geology; J-Environmental Geology; K-Engineering Geology; L-Hydrogeology; M-Geophysics; N-Remote Sensing; O-Geochemistry; P-Structural Geology; Q-Quaternary Geology; R-General Geology. Individual courses may not be repeated. (Requires six days of field work, usually on weekends.)

GEOL 435. Field Geology III (2)

Preparatory: GEOL 335 and 341. *Recommended Corequisite or Preparatory:* GEOL 310. Geologic field mapping of moderately deformed sedimentary rocks. At least six days of field work (including

overnight weekend trips), associated with a weekly three-hour instructional and advisement meeting designed to provide extensive practice in writing and illustrating geologic reports.

GEOL 460. Theoretical Geophysics (3)

Preparatory: PHYS 225, 226, and 227 and MATH 250, or *instructor consent.* Application of classical physics to the study of the Earth. Topics include origin of earth, its gravitational, geomagnetic, and geothermal characteristics, seismicity and the dynamics of the Earth's crust, plate tectonics, and continental drift. Lecture three hours, field trips.

GEOL 464/L. Applied Geophysics and Lab (2/1)

Corequisite: GEOL 464L. *Preparatory:* GEOL 235, 307, MATH 150A or 255A or *instructor consent.* Introduction to the basic principles and techniques of geophysics. Includes study of seismic reflection and refraction, earthquakes, gravity, magnetic, electrical resistivity, ground penetrating radar, and global positioning system satellites. Lecture two hours, lab three hours, field trips.

GEOL 497. Research Methods and Design (1)

Preparatory: Junior or senior standing and *instructor consent.* Students are advised and guided in research methods and design. Students use critical reasoning and the scientific method to develop and write their own research proposal, to execute the project for their Senior thesis. The written proposal is patterned after those required by the National Science Foundation.

GEOL 498. Senior Thesis (1)

Preparatory: GEOL 497 and *instructor consent.* Following approval by the thesis advisor of a written proposal, the student completes an original research project in consultation with the faculty advisor. Results of the research is presented orally to the Department of Geological Sciences.

GEOL 499. Independent Study (1-3)

See Independent Study under Courses of Study. Cannot be used for General Education credit.

Graduate Courses

GEOL 500. Environmental Geology Seminar (3)

Prerequisite: Upper Division standing in *Geology or consent of instructor.* Seminar on current literature and research dealing with contemporary problems in environmental geology. Suggested topics are: environmental impact analysis; hazard evaluation for earthquakes, volcanoes, floods, landslides; coastal erosion; surface and subsurface water resources and pollution; mineral and energy resources and waste disposal. Seminar three hours.

GEOL 505. The Evolution of Global Systems (3)

Preparatory: GEOL 351. The impact of biological, physical, and astronomical forces on the evolution of Earth systems throughout all of geologic time are studied. Combination of lecture/discussion and student seminars on material from the scientific literature including use of internet resources.

GEOL 508/L. Invertebrate Paleontology and Lab (3/1)

Corequisite: 508L. *Preparatory:* GEOL 351 or BIOL 313 and 392B. Detailed study of mega-invertebrate fossils including their taxonomy, morphology, skeletal chemistry, fossil record, evolutionary trends, ecology, and paleoecology. Lecture three hours, lab three hours, field trips.

GEOL 510. Advanced Topics in Paleontology (3)

Preparatory: GEOL 341, 351 and 508. Seminars in various topics in Invertebrate Paleontology, such as biostratigraphy, paleoecology, functional morphology, etc. May be repeated for credit as topic changes. Seminar three hours.

GEOL 513/L. Micropaleontology and Lab (2/2)

Corequisite: 513L. *Preparatory:* GEOL 351 or BIOL 313. Study of microfossils, especially Foraminifer and Radiolaria; their classification, common genera, morphology, evolutionary trends, ecology, paleoecology, and use as indicators of present and past environments. Students are required to work and report on unknown material. Lecture two hours, lab six hours.

GEOL 520/L. Advanced Stratigraphic Analysis and Lab (1/1)

Corequisite: 520L. *Preparatory:* GEOL 341 or instructor consent. Principles and techniques of stratigraphic analysis with emphasis on interpreting the stratigraphic record to aid in reconstruction of environment of deposition and paleogeography. Revolves around a field problem and includes application of methods from physical stratigraphy, biostratigraphy, and sedimentary petrology to solution of the problem. Lecture 1 hour, lab three hours.

GEOL 521. Sedimentary Environments (3)

Preparatory: GEOL 341 or instructor consent. Study of the characteristics of modern sedimentary environments and how these characteristics are used to recognize ancient sedimentary environments. Seminar three hours.

GEOL 523/L. Sedimentation and Tectonics and Lab (2/2)

Corequisite: GEOL 523L. *Preparatory:* GEOL 310, 335, and 341, or instructor consent. Lecture topics include a review of plate tectonic theory, followed by detailed discussions of the sedimentary and structural histories of basins from assorted tectonic settings. Labs include study of thin sections of sediments and sedimentary rocks, particularly clastic sedimentary rocks from basin types discussed in lecture, and the collection and analysis of field data used in basin studies. Lecture two hours, lab six hours, field trips.

GEOL 525/L. Seismic Stratigraphy Seminar and Lab (1/2)

Corequisite: GEOL 525L. *Preparatory:* GEOL 464. Introduction to the fundamentals of seismic stratigraphy, emphasizing the interpretation of seismic reflection profiles. Seminar 1 hour, lab six hours, field trip.

GEOL 528/L. Sedimentary Petrology and Lab (2/2)

Corequisite: 528L. *Preparatory:* GEOL 341 or instructor consent. Lecture topics include review of the depositional characteristics and classification of sedimentary rocks, followed by discussion of diagenesis and its impact on rock properties. Lab study emphasizes common techniques used in the study of sedimentary rocks, such as standard and cathodoluminescence petrography, scanning-electron microscopy, heavy-mineral separation, and X-ray diffraction. Lecture two hours, lab six hours.

GEOL 530. Seminar in Structural Geology and Tectonics (3)

Prerequisite: GEOL 310. Critical review of selected topics concerning the analysis, interpretation, and origin of geologic structures, and the mechanics of rock deformation and of large scale crustal deformation. Seminar three hours.

GEOL 532/L. Microtectonics and Lab (3/1)

Preparatory: GEOL 307/L and 310/L. This course will emphasize the microstructural and textural analysis of metamorphic rocks in thin section to aid in the interpretation of tectonic evolution. Topics include identification of igneous and metamorphic assemblages, identification of textures and microstructures, identification of deformation mechanisms at the grain and crystal lattice scale, secondary foliation and lineation development, the origin of lattice preferred orientation, porphyroblast growth, microgauges of temperature, pressure, and differential stress; and special techniques used to study deformation fabrics. Lecture three hours, lab three hours.

GEOL 533/L. Geology of Earthquakes (2/1)

Preparatory: GEOL 310. Lecture topics will include a review of plate tectonics, rock mechanics, seismology, tectonic geodesy, paleoseismology, tectonic geomorphology, and seismic hazard assessment. Detailed discussions will include study of recent major earthquakes that have occurred in strike-slip, thrust/reverse, megathrust (subduction zone), and normal-fault tectonic settings. Labs will include study of air photos, geologic maps, trench logs, and core descriptions from studies of recent earthquakes; and the collection and analysis of field data used in earthquake studies. Lecture two hours, lab three hours, field trips.

GEOL 535. Field Geology IV (2)

Preparatory: GEOL 310 and 435. Advanced geologic field mapping of structurally complex sedimentary, igneous, and/or metamorphic rocks. At least six days of field work (including overnight weekend trips), associated with a weekly three-hour instructional and advisement meeting designed to provide extensive practice in writing and illustrating geologic reports and analysis of field data.

GEOL 536/L. Igneous Petrology and Lab (3/1)

Corequisite: 536L. *Preparatory:* GEOL 307. Study of the more important kinds of igneous rocks, emphasizing distribution, origin, causes of compositional variation, and relation to tectonic factors. Representative rock suites and computer techniques are studied in the lab. Lecture three hours, lab three hours, field trips.

GEOL 538/L. Metamorphic Petrology and Lab (1/1)

Corequisite: 538L. *Preparatory:* GEOL 307. Study of the various facies of metamorphic rocks with emphasis on classification, mineralogy, and environments of formation. Mineral assemblages and textural relationships are studied in thin sections. Lecture 1 hour, lab three hours, field trips.

GEOL 545. Plate Tectonics (3)

Preparatory: GEOL 310 and GEOL 464 or consent of instructor. This course will provide a look at the quantitative side of plate tectonics, a subject to which many geology students are introduced at a qualitative level in introductory courses. The course will examine the power and limitations of the theory of plate tectonics and cover topics such as driving mechanisms, absolute plate motion, velocity vectors and finite rotations, Euler poles, plate reconstructions, gravity and heat flow of the earth, and controversies related to mantle convection and hotspots. Lecture /discussion three hours.

GEOL 550. Paleomagnetism (3)

This course will examine (1) the properties of earth's magnetic field and its behavior in the historical and geologic past (geomagnetism), (2) the fossil magnetization preserved in rocks and sediments (paleomagnetism), and (3) the use of physical stratigraphy and magnetic zonation to solve problems in stratigraphic correlation (magnetostratigraphy). One weekend field trip will involve sample collection for paleomagnetic analysis. Topics will include reversals of earth's magnetic field, polar wandering, rock magnetism, oceanic magnetic anomalies, the geomagnetic time scale, paleomagnetic sampling and demagnetization techniques, statistical data interpretation, and the application of paleomagnetism to studies of tectonic rotations and latitudinal translations of microplates. Lecture three hours, one field trip.

GEOL 552. Geochemistry (3)

Preparatory: GEOL 307 or instructor consent. Application of the principles of chemistry to geological problems. Topics include nucleosynthesis, origin of the solar system, elemental distribution, and stable and unstable isotopes. Lecture three hours.

GEOL 553. Analytical Geochemistry (1)

Preparatory: CHEM 102 and GEOL 307, or instructor consent. Instrumental analysis of rocks and minerals. Includes theory and practical application of X-ray spectrography, X-ray diffraction, atomic absorption spectrophotometry, mass-spectrometry, and electron microprobe. Lab three hours.

GEOL 563. Marine Geology (3)

Preparatory: GEOL 307 and 322, or instructor consent. Plate tectonics and evolution of the ocean, geomorphology and structure of the ocean floor, classification, distribution, and environment of marine sediments, paleo-oceanography. Field trips, class participation, and research paper required. Lecture and seminar three hours.

GEOL 567/L. Geological Remote Sensing and Lab (1/2)

Corequisite: 567L. *Preparatory:* Upper Division standing in Geology or instructor consent. By using multiple types of airborne and satellite remote sensing imagery, including analog and digital photography, radar (SAR) and satellite thematic mapper and SPOT images, students will learn to identify and map geologic and environmental features and conditions. Field trips to JPL and a geologic/ environmental site. Lecture 1 hour, lab six hours.

GEOL 570VLA. Volcanology (3)

Preparatory: GEOL 307 and GEOL 341, or consent of instructor. Course topics include styles of volcanic eruptions, volcanic landforms, physicochemical controls on eruptions, characteristics and interpretation of volcanic deposits, emplacement of pyroclastic density currents, volcanic hazards, and impacts of volcanism on Earth's environment. Lecture three hours.

GEOL 575/L. Hydrogeology and Lab (3/1)

Corequisite: 575L. *Preparatory:* Upper Division standing in Geology, Engineering, or other related areas; MATH 255A. Study of groundwater, emphasizing geologic controls, occurrence, movement, development, management, and quality. Lab: Mapping and interpretation of hydrogeologic data. Field and lab methods are used to characterize and quantify aquifer properties, geometry and input and output. Lecture three hours, lab three hours, field trips. (Offered fall semester)

GEOL 578. Groundwater Modeling (3)

Preparatory: GEOL 575 and computer literacy. Approximation of groundwater equations by finite-difference and finite-element methods. Practical exercises on calibration, verification, and prediction of groundwater behavior and solute movement under various initial and boundary conditions.

GEOL 580/L. Engineering Geology and Lab (2/1)

Corequisite: 580L. *Preparatory:* Upper Division standing in Geology or consent of instructor. Application of geologic factors to engineering projects such as residential developments, buildings, dams, bridges, tunnels and waste disposal sites. Topics include an introduction to soil mechanics, groundwater in engineering geology, landslides, earthquakes, subsidence, waste disposal and engineering geologic site investigations, maps and reports. Lecture two hours, lab three hours, field trips.

GEOL 590 Literature Seminar (1)

Preparatory: Senior undergraduate or graduate standing in Geological Sciences Program. Students will make oral presentations of and lead discussions about current research literature in geological sciences.

GEOL 595A-Z. Experimental Topics Courses in Geological Sciences (1-3)

Preparatory: Instructor consent. Experimental topics in the geological sciences with the course content to be determined. (A) Crystallography, (B) Mineralogy, (C) Geochemistry, (D) Igneous Petrology, (E) Sedimentary Petrology, (F) Metamorphic Petrology, (G) Structural Geology, (H) Economic Geology, (I) Stratigraphy, (J) Seismic Stratigraphy, (JL) Seismic Stratigraphy Lab, (K) Engineering Geology, (L) Isotope Geology, (M) Paleontology, (N) Field Problems, (R) Current Research, (S) Groundwater Modeling, (T) Advanced Hydrogeology, (U) Hydrogeochemistry, (V) Geologic Evolution of California, (W) Remote Sensing and the Environment, (X) Marine Paleocology and Sedimentation, (Y) Geological Sciences Teacher Enhancement, (YG) General Geology for the K-12 Teacher and (ZOL) Global Geologic Issues for the K-12 Teacher (on-line). Topics may be repeated with advisor approval.

GEOL 694 Graduate Thesis Research Design (1)

Instruction and practice in the process required to construct a research proposal, culminating in the development of a graduate-level research proposal suitable as a Master's thesis project.

GEOL 696. Directed Graduate Research (1-3)**GEOL 698. Thesis or Graduate Project (1-6)****GEOL 699. Independent Study (1-3)**