

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

Option IV: Geophysics

Minor in Geology

Graduate:

M.S., Geology

M.S., Geology, Option Geophysics

The Major

Geologists play an important role in society. They apply their skills and knowledge to solve complex problems related to how humans interact with natural systems and hazards as well as the exploration for water, petroleum and other natural resources. They share their unique knowledge of Earth systems through teaching and public outreach on topics such as understanding earthquake hazards. Geology majors gain scientific knowledge of past and present planetary processes and laboratory and field skills that prepare them for post-graduate study and professional careers in diverse fields such as oceanography, paleontology, geophysics, geochemistry, hydrogeology, engineering geology, and teaching.

The major in Geology is designed for students who:

1. want to gain a better understanding of the world around them;
 2. wish to pursue careers in geology, geophysics, environmental geology, or related fields;
 3. wish to prepare for graduate work in geology, geophysics, environmental geology, or related fields;
 4. wish to teach earth science or physical science in secondary schools;
- or
5. desire a liberal arts education with emphasis on geology.

Careers

Careers in geosciences are rewarding in every sense. Jobs in geosciences are in high demand and pay well. A wide variety of job opportunities in both private industry and government service are available to geology graduates. Engineering geologists evaluate sites for homes, commercial buildings, highways, and dams; environmental geologists conduct environmental impact studies and evaluate the pollution distribution and remediation of contaminated sites; hydrogeologists evaluate the development and quality control of ground water resources; and economic geologists explore for earth resources such as oil, gas, coal,

precious and semi-precious metals, and uranium. Agencies in all levels of government—city, county, state, and federal—employ geologists for regulatory, 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. Many students go on to earn advanced degrees, and the department's majors have been accepted by some of the nation's best graduate programs in the geosciences.

Academic Advisement

Undergraduate and graduate majors must be advised each semester by the appropriate advisor in their degree program in order to register for classes.

Student Learning Outcomes of the Undergraduate and Graduate Programs

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

Department Programs

The Department offers the B.S., M.S., and minor in Geology. There are four B.S. degree options:

Option 1: Geology

This option provides the most flexibility, preparing students for a full range of technical careers in geoscience and for advanced studies in graduate school.

Option 2: Environmental Geology

For students desiring additional focus on problems related to environmental impacts, this degree includes additional interdisciplinary coursework from fields such as biology, chemistry, and environmental safety. Students with this background may be better positioned to obtain an entry level job in the environmental industry.

Option 3: Secondary Teaching

Students planning on teaching science need a different set of skills, so this option allows them to pursue basic coursework in a broader range of sciences as well as classes in education.

Option 4: Geophysics

Many geoscientists solve problems using a strong understanding of the laws of physics and quantitative reasoning. This option provides the necessary preparation in mathematics and physics to succeed in this pursuit. Students that complete this option will be well prepared for graduate studies in geophysics or an entry level position in geophysics.

The Master of Science program has two options: Geology and Geophysics. These programs prepare are designed to: 1) train individuals with the competence required by the geological profession for employment in industry and government agencies; 2) enable promising students to attain a level of knowledge and research ability required for admission to a Ph.D. program; and 3) provide 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.

Requirements for the Bachelor of Science Degree

To enroll in MATH 225A or MATH 150A and PHYS 100A, students must first obtain a satisfactory score on the Mathematics Placement Test (MPT). To enroll in CHEM 101/L, students must first obtain a satisfactory score on the Chemistry Placement Test (CPT). Without satisfactory scores, students will be required to take additional courses in preparation for the required courses.

A. Option I: Geology

1. Lower-Division Required Courses (34-35 Units)

GEOL 101/102	Geology of Planet Earth and Lab (3/1)
or GEOL 110/112	Earth and Life through Time and Lab (3/1)
GEOL 207/L	Mineralogy and Lab (3/1)
GEOL 235	Introduction to Field Methods (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)
MATH 255B*	Calculus for the Life Sciences II (3)
or MATH 140	Introductory Statistics (4)
PHYS 100A/L**	General Physics I and Lab (3/1)
PHYS 100B/L**	General Physics II and Lab (3/1)

* or MATH 150A and MATH 150B

**or PHYS 225, 226, 220A/L, 220B/L

2. Upper-Division Required Courses (29 Units)

GEOL 307/L	Petrology and Lab (3/1)
GEOL 310/L	Structural Geology and Lab (3/1)
GEOL 341/L	Sedimentary Geology and Lab (3/1)
GEOL 343/L	Principles of Stratigraphy and Lab (3/1)
GEOL 351/L	Fundamentals of Paleontology and Lab (3/1)
GEOL 430A, B	Summer Field Geology (2, 2)
GEOL 464/L	Applied Geophysics and Lab (3/1)
GEOL 497	Research Methods and Design (1)

3. Electives (10 Units)

These should be selected from any upper-division geology courses exclusive of 300, 301. Other electives might qualify, but require approval of the departmental undergraduate advisor. 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	73-74
General Education	36
Additional Units	10-11
Total Units Required for the B.S. Degree, Option I	120

B. Option II: Environmental Geology

1. Lower-Division Required Courses (38-39 Units)

GEOL 101/102	Geology of Planet Earth and Lab (3/1)
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or GEOL 110/112	Earth and Life through Time and Lab (3/1)
GEOL 207/L	Mineralogy and Lab (3/1)
GEOL 235	Introduction to Field Methods (2)
CHEM 101/L	General Chemistry I and Lab 4/1
CHEM 102/L	General Chemistry II and Lab (4/1)
CHEM 235/L	Introductory Organic Chemistry and Lab (3/1)
MATH 255A*	Calculus for the Life Sciences I (3)
MATH 255B*	Calculus for the Life Sciences II (3)
or MATH 140	Introductory Statistics
PHYS 100A/L**	General Physics I and Lab (3/1)
PHYS 100B/L**	General Physics II and Lab (3/1)

* or MATH 150A and MATH 150B

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

2. Upper-Division Required Courses (39 Units)

GEOL 307/L	Petrology and Lab (3/1)
GEOL 310/L	Structural Geology and Lab (3/1)
GEOL 341/L	Sedimentary Geology and Lab (3/1)
GEOL 343/L	Principles of Stratigraphy and Lab (3/1)
GEOL 351/L	Fundamentals of Paleontology and Lab (3/1)
GEOL 430A, B	Summer Field Geology (2, 2)
GEOL 464/L	Applied Geophysics and Lab (3/1)
GEOL 497	Research Methods and Design (1)
GEOL 500	Environmental Geology Seminar (3)
GEOL 575/L	Hydrogeology and Lab (3/1)
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 (5 Units)

These should be selected from any upper-division geology courses exclusive of 300, 301. Other electives might qualify, but require approval of the departmental undergraduate advisor. Basic Skills Mathematics and the entire section of Natural Sciences are met by required courses in the major.

Total Units in the Major, Option II	82-83
General Education	36
Additional Units	1-2
Total Units Required for the B.S. Degree, Option II	120

C. Option III: Secondary Teaching

1. Lower-Division Required Courses (47 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 and Life through Time and Lab (3/1)
GEOL 207/L	Mineralogy and Lab (3/1)
GEOL 235	Introduction to Field Methods (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, 226; 220A/L, 220B/L

2. Upper-Division Required Courses (35 Units)

GEOL 307/L	Petrology and Lab (3/1)
GEOL 310/L	Structural Geology and Lab (3/1)
GEOL 322/L	Introductory Oceanography and Lab (3/1)

GEOL 341/L	Sedimentary Geology and Lab (3/1)
GEOL 343/L	Principles of Stratigraphy and Lab (3/1)
GEOL 351/L	Fundamentals of Paleontology and Lab (3/1)
GEOL 497	Research Methods and Design (1)
GEOL 505	The Evolution of Global Systems (3)
GEOL 595Y	Geological Sciences Teacher Enhancement (3)
GEOG 311/L	Atmosphere and Lab (3/1)

3. Electives (2 Units)

These should be selected from any upper-division geology courses exclusive of 300, 301. Other electives might qualify, but require approval of the departmental undergraduate advisor. 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	84
General Education	36
Total Units Required for the B.S. Degree, Option III	120

D. Option IV: Geophysics

1. Lower-Division Required Courses (55 Units)

GEOL 101/102	Geology of Planet Earth and Lab (3/1)
or GEOL 110/112	Earth and Life through Time and Lab (3/1)
GEOL 207/L	Mineralogy and Lab (3/1)
GEOL 235	Introduction to Field Methods (2)
COMP 110/L	Introduction to Algorithms and Programming and Lab (3/1)
MATH 150A	Calculus I (5)
MATH 150B	Calculus II (5)
MATH 250	Calculus III (3)
MATH 280	Applied Differential Equations (3)
CHEM 101/L	General Chemistry I and Lab (4/1)
CHEM 102/L	General Chemistry II and Lab (4/1)
PHYS 225/220AL	Physics I and Mechanics Lab (4/1)
PHYS 226/220BL	Physics II and Electricity and Magnetism Lab (4/1)
PHYS 227/L	Physics III and Lab (4/1)

2. Upper-Division Required Courses (20 Units)

GEOL 307/L	Petrology and Lab (3/1)
GEOL 310/L	Structural Geology and Lab (3/1)
GEOL 343/L	Principles of Stratigraphy and Lab (3/1)
GEOL 460	Theoretical Geophysics (3)
GEOL 464/L	Applied Geophysics and Lab (3/1)
GEOL 497	Research Methods and Design (1)

3. Electives (9 Units)

These should be selected from any upper-division geology courses exclusive of 300, 301. Other electives might qualify, but require approval of the departmental undergraduate advisor. Basic Skills Mathematics, the entire section of Natural Sciences, and Lifelong Learning are met by required courses in the major.

Total Units in the Major, Option I	84
General Education	33
Additional Units	3
Total Units Required for the B.S. Degree, Option IV	120

B.S. Honors Program

This program provides an opportunity for outstanding geology majors to gain intensive research experience under individual faculty guidance. The designation "Honors" will be added to the academic record of any student who completes the program. Admission to the Honors Program is granted by approval of the department undergraduate advisor. Students in any of the B.S. options are eligible provided they have:

1. completed 90 units of college work;

2. maintained a grade point average of 3.0 overall and in the upper-division geology major;
3. received a minimum grade of A minus in GEOL 497; and
4. obtained the approval of a faculty sponsor who will supervise their research.

Students interested in the honors program should contact their department undergraduate advisor.

Graduation with Honors in Geology requires:

1. Admission to the Honors Program.
2. Completion of all requirements for one of the BS Options, plus the completion of:
 - GEOL 498 Senior Thesis (3 units)
3. Maintenance of a grade point average of 3.0 overall and in the upper-division geology major
4. Approval of the undergraduate thesis by the faculty advisor, including a presentation of the research.

Minor in Geology

1. Lower Division Required Courses (18 or 19 Units)

CHEM 101	General Chemistry I and Lab 4/1 or CHEM 100/100L 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 and Life through Time (3)
GEOL 112	Earth and Life through Time Lab (1)
GEOL 207/L	Mineralogy and Lab (3/1)
GEOL 235	Introduction to Field Methods (2)

2. Upper Division Required Courses (8 Units)

GEOL 307/L	Petrology and Lab (3/1)
GEOL 351/L	Fundamentals of Paleontology and Lab (3/1)

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	29-30
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Requirements for the Master of Science Degree

See departmental web site www.csun.edu/geology for departmental application and other information.

MS in Geology

A. For admission to the M.S. in Geology 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 hours 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. Undergraduate Geology GPA at or above 3.0, or strong written support of a faculty sponsor in the department.
4. Graduate Record Examination: General Aptitude only. Scoring at or above the 50th percentile on at least one section.

B. For the degree:

Completion, with a B average (3.0) or higher, of 30 units of approved graduate study, including a minimum of 21 units of 500 and 600-level courses. Completion and successful oral defense of a thesis is required.

1. Required core courses (8 units)

- GEOL 590 Literature Seminar (1)
- GEOL 694 Graduate Thesis Research Design (1)
- GEOL 696 Directed Graduate Research (3)
- GEOL 698 Thesis or Graduate Project (3)

2. Electives (22 units)

Electives should be selected with approval of the graduate student's Primary Advisor and Graduate Coordinator from 400, 500, and 600 level courses in Geology or other fields relevant to thesis work. One 400 or 500 level course must include a lab or field component. A maximum of 9 units of 400 level courses may be applied toward the 30 units required for the degree. The choice of electives will vary with thesis topic. Service as a teaching assistant in the Department may be advised as part of the student's educational experience.

MS in Geology, Geophysics Option**A. For admission to the M.S. in Geology, Geophysics Option program:**

1. B.S. in geology, geophysics, physics, or its equivalent.
Students who do not have the appropriate course work will be conditionally admitted to the program, but will be required to complete any deficient course work without graduate credit during the 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. Scoring at or above the 50th percentile on at least one section.

B. For the degree:

Completion, with a B average (3.0) or higher, of 30 units of approved graduate study, including a minimum of 21 units of 500 and 600-level courses. Completion and successful oral defense of a thesis is required. 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.

1. Required Courses (9 units)

- GEOL 460 Theoretical Geophysics (3)
- GEOL 696 Directed Graduate Research (3)
- GEOL 698 Graduate Thesis (3)

2. Electives (21 units)

Electives should be selected with approval of the graduate student Primary Advisor and Graduate Coordinator from 400, 500, and 600 level courses in Geology, Physics, Math, Engineering or other fields relevant to thesis work. One 400 or 500 level course must include a lab or field component. A maximum of 9 units of 400 level courses may be applied toward the 30 units required for the degree. The choice of electives will vary with thesis topic. A list of possible choices (although not exhaustive) is presented here. Service as a teaching assistant in the Department may be advised as part of the student's educational experience.

- GEOL 464/L Applied Geophysics
- GEOL 595-R Current Research
- MATH 481A Numerical Analysis
- ME 490 (Fluid Dynamics)
- PHYS 420 Modern Optics

- PHYS 431 Thermodynamics and Statistical Mechanics
- PHYS 465 (Experimental Physics III) with optics

Total Units Required for the M.S. Degree in Geology, Option Geophysics	30
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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 104. Living With Earthquakes in California (3)

Not for credit in Geology major. Examines the revolution in earthquake hazard awareness that has occurred in California since the mid-1980's when the scale of the earthquake hazard began to emerge from scientific discovery. Students will investigate the reciprocal ways in which science has informed the public, political, and economic debate over the implications of earthquake hazard as well as exploring the manner by which public and political priorities have shaped the direction of scientific and engineering response to the hazard. Lecture 3 hours. (Available for General Education, Lifelong Learning)

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. (Cross listed with GEOG 106LRS)

GEOL 107OL/LOL. Geology Goes Hollywood and Lab (3/1)

Corequisite: GEOL 107LOL. This online lecture and laboratory combination explores how earth science issues that impact society are depicted in film and television and how these depictions influence the viewers' perceptions of earth science. Students will learn fundamental concepts of earth science and how to evaluate the appropriateness and accuracy of earth science portrayed in fictional and documentary film and television. (Available for General Education, Natural Sciences, fulfills lecture and lab credit.)

GEOL110. Earth and Life through Time (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 us-

ing this course to satisfy a General Education requirement Natural Sciences may satisfy the corresponding lab requirement by completing GEOL 112.

GEOL 112. Earth and Life through Time Lab (1)

Recommended Corequisite or Preparatory: GEOL 110. 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 satisfy the lab requirement in Natural Sciences of General Education provided GEOL 110 is completed. Lab 3 hours, a 1-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 (3/1)

Study of the nonsilicate and silicate minerals with emphasis on crystallography, mineral chemistry, physical properties, occurrence, origin and associations. Lecture 3 hours, lab 3 hours, field trips.

GEOL 235. Introduction to Field Methods (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 6 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 and other relevant software 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 (3/1)

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 3 hours, lab 3 hours, field trips.

GEOL 310/L. Structural Geology and Lab (3/1)

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 3 hours, lab 3 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 3 hours, lab 3 hours, field trips.

GEOL 341/L. Sedimentary Geology and Lab (3/1)

Corequisite: 341L. *Preparatory:* GEOL 307; instructor consent. Introduction to the processes of sedimentation; the texture, composition, and classification of sedimentary rocks; and depositional systems. Lecture 3 hours, lab 3 hours, field trips.

GEOL 343/L. Principles of Stratigraphy and Lab (3/1)

Corequisite: GEOL 343L. *Recommended preparatory:* GEOL 341/L. Introduction to the basic principles of stratigraphy and application of stratigraphic methods (e.g., lithostratigraphy, biostratigraphy, chronostratigraphy, sequence stratigraphy, and magnetic stratigraphy) essential for basin analysis and interpretation of sedimentary facies. Lecture 3 hours, lab 3 hours, field trips.

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 2 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 3 hours, lab 3 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 430A/B. Summer Field Geology (2-2)

Prerequisites: GEOL 310/L, 341/L, and 343/L. A two-course sequence on advanced observation and collection of geologic field data and the construction of geologic maps, cross-sections and stratigraphic sections

during four weeks of field study. Field work for GEOL 430A is completed during the first two weeks and field work for GEOL 430B is completed during the second two weeks. During the remaining weeks of the summer session, students must complete two comprehensive formal geologic field reports, including geologic maps and cross-sections, one for GEOL 430A and one for 430B. Students must enroll in both courses during the same summer session. Available for graduate credit.

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 452/L. Mathematical Tools in Geology and Lab (2/1)

Corequisite: 452L. Introduction to the mathematical methods used in the field of Geology. Introductory topics are introduced in general problem solving, algebra, vector, and calculus with applications to geological problems. Geological applications such as sediment basins, geotherms, gradients, topography, volume calculations of volcanic flows and planetary bodies, tectonics, and mineral fractionation. Quantitative material is presented in an encouraging, approachable, yet challenging methodology which is intended to be easily grasped by those with a fundamental background in university mathematical requirements. Final exercises consider typical geological data sets, linear and nonlinear data analysis, significant figures, measurement and collection errors, and statistics. Exposure will also be provided to computer programs using Excel, Matlab, and Autocad. Designed for senior-level undergraduate and beginning graduate students in geology and/or geophysics. 2 hours lecture, 3 hours lab. Available for graduate credit.

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 3 hours, field trips.

GEOL 464/L. Applied Geophysics and LAB (3/1)

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 3 hours, lab 3 hours, field trips.

GEOL 471LB. Petroleum Geology (2)

Recommended prerequisite: GEOL 341. This course will introduce students to various aspects of petroleum geology: the geochemistry and generation of petroleum, methods of exploration including seismic and electric logs, migration and trapping mechanisms, and aspects of petroleum production including reservoir characterization. Students will also examine the geology of some major petroleum provinces. Lecture/discussion 2 hours, field trips. Available for graduate credit.

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 (3)

Prerequisite: 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. Upon completion of the research, student will submit the written thesis to the advisor and give an oral presentation 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 3 hours, lab 3 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 Radiolara; 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 2 hours, lab 6 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 3 hours.

GEOL 521. Sedimentary Environments (3)

Preparatory: GEOL 341 or instructor consent. Study of the characteristics of modern sedimentary environments and how these characteris-

tics are used to recognize ancient sedimentary environments. Seminar 3 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 2 hours, lab 6 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 6 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 2 hours, lab 6 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 3 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 3 hours, lab 3 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 2 hours, lab 3 hours, field trips.

GEOL 535. Advanced Geologic Field Methods (2)

Preparatory: GEOL 310/L. Advanced geologic field mapping of structurally complex sedimentary, igneous, and/or metamorphic rocks. At least 6 days of field work (including overnight weekend trips), associated with a weekly 3-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 3 hours, lab 3 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 3 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 3 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 3 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 3 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 3 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 3 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 6 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 3 hours.

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

Corequisite: 575L. *Preparatory:* Upper Division standing in Geology, formal geologic field reports, including geologic maps and cross-sections, one for GEOL 430A and one for 430B. Students must enroll in both courses during the same summer session. Available for graduate credit.

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 452/L. Mathematical Tools in Geology and Lab (2/1)

Corequisite: 452L. Introduction to the mathematical methods used in the field of Geology. Introductory topics are introduced in general problem solving, algebra, vector, and calculus with applications to geological problems. Geological applications such as sediment basins, geotherms, gradients, topography, volume calculations of volcanic flows and planetary bodies, tectonics, and mineral fractionation. Quantitative material is presented in an encouraging, approachable, yet challenging methodology which is intended to be easily grasped by those with a fundamental background in university mathematical requirements. Final exercises consider typical geological data sets, linear and nonlinear data analysis, significant figures, measurement and collection errors, and statistics. Exposure will also be provided to computer programs using Excel, Matlab, and Autocad. Designed for senior-level undergraduate and beginning graduate students in geology and/or geophysics. 2 hours lecture, 3 hours lab. Available for graduate credit.

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 3 hours, field trips.

GEOL 464/L. Applied Geophysics and LAB (3/1)

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 3 hours, lab 3 hours, field trips.

GEOL 471LB. Petroleum Geology (2)

Recommended prerequisite: GEOL 341. This course will introduce students to various aspects of petroleum geology: the geochemistry and generation of petroleum, methods of exploration including seismic and electric logs, migration and trapping mechanisms, and aspects of petroleum production including reservoir characterization. Students will also examine the geology of some major petroleum provinces. Lecture/discussion 2 hours, field trips. Available for graduate credit.

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 (3)

Prerequisite: 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. Upon completion of the research, student will submit the written thesis to the advisor and give an oral presentation 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 3 hours, lab 3 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 2 hours, lab 6 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 3 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 3 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 2 hours, lab 6 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 6 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 2 hours, lab 6 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 3 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 3 hours, lab 3 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 2 hours, lab 3 hours, field trips.

GEOL 535. Advanced Geologic Field Methods (2)

Preparatory: GEOL 310/L. Advanced geologic field mapping of structurally complex sedimentary, igneous, and/or metamorphic rocks. At least 6 days of field work (including overnight weekend trips), associated with a weekly 3-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 3 hours, lab 3 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 3 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 3 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 3 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 3 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 3 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 3 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 6 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 3 hours.

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

Corequisite: 575L. 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 6 hours.

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 2 hours, lab 3 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)