

Department of Geological Sciences

Biological Sciences Building, Room 113A

(909) 537-5336 Department of Geological Sciences website (<http://geology.csusb.edu/>)

The study of geology includes working to understand the chemical, physical and biological processes that affect and are recorded in rocks, minerals, and earth materials, and using that information to decipher the development of our planet. In addition, understanding geology is essential for locating necessary earth resources (oil, minerals, water) and solving those environmental problems that affect the Earth's surface. Much of the information geologists use is obtained by careful, systematic fieldwork and laboratory work, the former being an inherent requirement for geological studies.

The mission of the department is to provide high-quality training in the science of geology so as to equip our students (undergraduate and graduate) to successfully enter the geological workforce, and to contribute to the science of geology through faculty and students conducting and disseminating research in this field. Geology is a broad science that integrates with other classical sciences and disciplines such as astronomy, biology, chemistry, computer science, geography, mathematics, and physics. Course work in those disciplines, integrated within a geological framework, provides students with a broad marketable understanding.

The department offers a B.S. and a B.A. degree in geology each of which offers a choice between two concentrations:

The **B.S. in Geology, General Geology Concentration** is recommended for students planning to continue to graduate school or to other careers in the geosciences. This Concentration has more flexibility to allow the student to tailor electives to pursue a particular interest.

The **B.S. in Geology, Environmental Geology Concentration** is recommended for students planning to become professional geologists in the environmental, geotechnical, government service, petroleum, or mining areas, and to prepare for Professional Licensure.

The **B.A. in Geology, General Geology Concentration** is recommended for students planning a career in public service and education (e.g. government agencies, park rangers, and K-12 science teaching), non-profit or non-governmental environmental organizations, or pre-environmental law. This Concentration has maximum elective flexibility to produce an experience tailored to the needs of the student.

The **B.A. in Geology, Field and Applied Geology Concentration** is recommended for students planning to become professional geologists employed by environmental and geotechnical firms, governmental agencies, oil and mining companies, and for those students planning to pursue a graduate degree in geology. Emphasizing field and applied geology courses, and experiential learning, this program is designed to permit students to meet existing requirements for Professional Licensing.

Geology majors must earn a grade of "C-" (1.7) or better in all required geology courses for those courses to satisfy the degree requirements for a B.A or B.S. degree in Geological Sciences.

Departmental Honors

Students majoring in geological sciences are eligible to earn honors in geological sciences at graduation if the following conditions are met:

1. The student applies to the department for candidacy at the beginning of their senior year;
2. A minimum grade-point average of at least 3.5 in all geology courses has been earned, with a minimum of five geology courses taken at this university.
3. Satisfactory completion of at least 2 units of GEOL 4800 Senior Honors Research.

Granting of departmental honors rests with the department faculty.

Emerita

Joan E. Fryxell, Professor

Current Faculty

Kerry Cato, Associate Professor
B.S. 1982, Texas Tech University
M.S. 1985, Ph.D. 1991, Texas A&M University

George Codi Lazar, Associate Professor
B.A. 1995, University of Florida
M.A. 2001, Columbia University
Ph.D. 2010, University of California, Los Angeles

W. Britt Leatham, Associate Professor
B.A. 1981, Weber State College
M.S. 1984, Ph.D. 1987, Ohio State University

Sally McGill, Associate Dean
A.B. 1985, Harvard and Radcliffe
M.S. 1989, Ph.D. 1992, California Institute of Technology

Erik B. Melchiorre, Professor
B.S. 1990, University of Southern California
M.S. 1993, Arizona State University
Ph.D. 1998, Washington University

Claire Todd, Professor, Chair
B. A. 2000, Claremont McKenna College
M. S. 2002, Columbia University School of Engineering and Applied Science
Ph. D. 2007, University of Washington

Emeriti

Louis A. Fernández, Professor

Alan L. Smith, Professor

Undergraduate Degrees

Bachelor of Arts

Geology (<https://catalog.csusb.edu/colleges-schools-departments/natural-sciences/geological-sciences/geology-ba/>) with concentrations in: (<https://catalog.csusb.edu/colleges-schools-departments/natural-sciences/geological-sciences/geology-ba/>)

- General Geology
- Field and Applied Geology

Bachelor of Science

Geology (<https://catalog.csusb.edu/colleges-schools-departments/natural-sciences/geological-sciences/geology-bs/>)

with concentrations in:

- General Geology
- Environmental Geology

Graduate Degrees

Master of Science

Environmental Sciences (<https://catalog.csusb.edu/colleges-schools-departments/natural-sciences/chemistry-biochemistry/environmental-sciences-ms/>)

Geology (<https://catalog.csusb.edu/colleges-schools-departments/natural-sciences/geological-sciences/geology-ms/>)

Minor

Geology (<https://catalog.csusb.edu/colleges-schools-departments/natural-sciences/geological-sciences/geology-minor/>)

Courses

GEOL 1000. Introductory Geology. Units: 3

An introduction to the study of the earth. Topics include the structure, composition, distribution and modification of earth materials, and processes that shape the surface of the earth. Satisfies GE Category B1. Formerly offered as GEOL 101.

GEOL 1000L. Introductory Geology Laboratory. Unit: 1

Hands-on introduction to the structure, composition, distribution and modification of earth materials, and processes that shape the surface of the earth. Taking GEOL 1000 concurrently is strongly recommended. Materials fee required. Satisfies GE Category B3.

GEOL 1020. Plate Tectonics: Key to Understanding Earthquakes, Volcanoes and Tsunami. Units: 3

Development of the theory of plate tectonics as a scientific revolution in our understanding of the Earth. Exploration of the technologies that led to new evidence that was unexplainable by traditional, static models of the Earth, and the ideas that led to a new, coherent view of a dynamic Earth in which some ocean basins expand as a result of sea-floor spreading while others shrink as a result of subduction, and continents are carried along as part of massive, slowly moving tectonic plates. Investigation of how the theory of plate tectonics has led to greater success in understanding, predicting and mitigating the damaging effects of earthquakes, volcanoes and tsunami. Satisfies GE Category B1; G designation.

GEOL 1060. Environmental Geology and Geological Hazards. Units: 3

An introduction to earth science principles, processes, and materials that affect the environment near the surface of the earth where human and biologic activities occur. Topics includes a study of geological factors in land planning such as climate, water use, erosion, faults, ground water origins, water quality, pollution and other geological processes. This course includes an emphasis on hazard mapping and implications of public policies dealing with geologic hazards. Satisfies GE Category B; G designation.

GEOL 1060L. Environmental Geology and Geological Hazards Laboratory. Unit: 1

Laboratory component for GEOL 1060: Environmental Geology and Geological Hazards. Taking GEOL 1060 concurrently is strongly recommended. Materials fee required. Satisfies GE Category B3; G designation.

GEOL 1090. Earth: The Blue Planet. Units: 4

Tailored for students intending to teach grades K-8 Science Domain 3: Earth and Space Science. This course provides scientific content and understanding of Earth's dynamic and interacting processes, including the planet's structure composition, water, atmosphere, place in the solar system and universe. Three hours lecture and three hours laboratory. Equivalent to GEOL 3090; credit cannot be earned for both. Materials fee required. Satisfies GE category B1 and B3.

GEOL 2000. Interpreting Earth Systems History: Stories from an Ancient Planet. Units: 4

Introduction to analytical processes and tools (i.e. chemical, tectonic, environmental, petrological, and biological) for deciphering Earth Systems History, how those systems operate and are delineated, and have evolved/modified our planet from its origins through its present state. Overnight field trips may be required. Formerly offered as GEOL 250; students may not earn credit for both courses. Three hours seminar and three hours laboratory. Materials fee required.

GEOL 2040. Water in the West. Units: 3

Within the framework of Western North America, water use has been a historically contentious issue that still persists today. The course will provide an overview of the fundamentals of hydrology, and through quantitative reasoning and integrative learning examine the impact that the use of water resources have upon the physical and human environment. The historical, present, and future significance of these impacts will be examined through the lens of the global community, and social/economic justice. The effects of climate change and policy on water availability will be examined. Satisfies GE Category B1; G designation.

GEOL 2101. Special Projects in Geology. Unit: 1

Individual investigation, research, study or survey of selected problems. Consent of instructor required. Materials fee required. Formerly offered as GEOL 295A; students may repeat a total of two times.

GEOL 2102. Special Projects in Geology. Units: 2

Quarter Prerequisite: Consent of instructor
Individual investigation, research, study or survey of selected problems. Formerly offered as GEOL 295B; students may repeat a total of two times. Consent of instructor required. Materials fee required.

GEOL 2500. Geology of California. Units: 3

Semester Prerequisite: Any 1000-level GEOL course with lab, or GEOG 1030, or consent of instructor. Quarter Prerequisite: Geol 101
Interpretation of the geological features and evolution of California. Overnight field trips may be required. Formerly GEOL 312; students may not earn credit for both courses.

GEOL 3020. Natural Disasters. Units: 3

Semester Prerequisite: junior or senior standing. Quarter Prerequisite: junior or senior standing
A consideration of natural processes such as volcanic eruptions, earthquakes, global sea level rise, slope failures, floods, wildland fires, meteoric impacts and severe forms of weather, that have had or may have disastrous consequences on both humans and the environment. Satisfies GE Category B5. Formerly offered as NSCI 315, students may not receive credit for both courses. Satisfies Environmental Sustainability GE Pathway.

GEOL 3030. History of Life on Earth. Units: 3

Semester Prerequisite: Junior or senior standing. Quarter Prerequisite: Junior or senior standing
History of life on earth and the processes that govern its genesis, evolution, extinction, ecology, and preservation. Offered as BIOL 3030 and GEOL 3030. Satisfies GE Category B5. Formerly offered as NSCI 360. Students may only receive credit for one of these courses.

GEOL 3040. Energy and the Environment. Units: 3

Quarter Prerequisite: junior or senior standing
Within the framework of the environment, and especially climate change, this course will examine our past and present energy portfolio (biomass, coal, oil, natural gas, nuclear), our present and future energy portfolio options (solar, wind, tides, hydro, hydrogen, etc.), and the transition technologies (energy conservation, hybrids) that will bridge this gap. The course will provide an overview of the geological energy resources, the technology of renewable energy, and through quantitative reasoning and integrative learning examine the impact that each of these energy choices have upon the environment. The significance of these impacts upon the global commons (air-water-soil-climate) will be examined through the lens of the global community, and social/economic justice. Satisfies GE Category B5; G designation. This course satisfies Environmental Sustainability Pathway requirements.

GEOL 3100. Introduction to Geologic Mapping. Units: 3

Semester Prerequisite: Any 1000-level Geology course with lab, or GEOG 1030 with lab. Quarter Prerequisite: GEOL 101 or GEOG 103
Field identification of igneous, sedimentary, and metamorphic rock units, making geologic field notes, making rock descriptions, use of Brunton compass, topographic map reading skills, making and reading geologic maps, geologic cross section construction and interpretation, and preparing geologic reports. Overnight field trips may be required. Formerly offered as GEOL 301; students cannot earn credit for both. One hour lecture and six hours laboratory. Materials fee required.

GEOL 3111. Service Learning in the Earth Sciences. Unit: 1

Supervised activities in geology or geological education providing service to campus or community constituents. Minimum of 45 hours required. Consent of instructor required. Formerly offered as GEOL 307A. May be repeated for credit. Graded credit/no credit.

GEOL 3112. Service Learning in the Earth Sciences. Units: 2

Supervised activities in geology or geological education providing service to campus or community constituents. Minimum of 90 hours required. Consent of instructor required. Formerly offered as GEOL 307B. May be repeated for credit. Graded credit/no credit.

GEOL 3200. Mineralogy. Units: 5

Semester Prerequisite: GEOL 1000, GEOL 1000L, and CHEM 2050 or CHEM 2100, or permission of instructor. Quarter Corequisite: CHEM 205 or CHEM 215. Quarter Prerequisite: GEOL 101
Semester Corequisite: CHEM 2050 or CHEM 2100
Introduction to crystallography, crystal chemistry, mineral classification, mineral genesis, physical and chemical properties of minerals, and identification of important ore and rock-forming minerals using megascopic observation, optical microscopy, x-ray diffraction, and scanning electron microscopy. Field trips may be required. Formerly offered as GEOL 320 and GEOL 321; students earn credit either for those two or for GEOL 3200. Three hours lecture and six hours laboratory. Materials fee required.

GEOL 3220. Introduction to Geochemistry. Units: 4

Semester Prerequisite: GEOL 3200, or consent of instructor. Quarter Prerequisite: GEOL 320 with a grade of "C" or better
Natural distribution, migration, and reactions of chemical elements within the earth and through time. Students will learn essentials for environmental chemistry, water quality, ore deposits, and chemical weathering. Includes stable and radiogenic isotope tracer and age dating methods, basic thermodynamics, and application of chemical analysis techniques. Recommended as an elective for students of chemistry, environmental studies, archaeology/anthropology, and life sciences. Three hours lecture and three hours laboratory. Weekend field trip(s) may be required. Formerly offered as GEOL 322, students may not earn credit for both courses. Materials fee required.

GEOL 3240. Igneous and Metamorphic Petrology. Units: 4

Quarter Prerequisite: GEOL 3200 with grade C or better
Description and genesis of igneous and metamorphic rocks, their mineralogic and chemical composition, internal structure, and mode of occurrence. Formerly offered as GEOL 325; students cannot earn credit for both. Overnight field trips may be required. Three hours lecture and three hours laboratory. Materials fee required.

GEOL 3300. Sedimentary Geology: Principles and Applications. Units: 4

Semester Prerequisite: Any 1000-level GEOL course, or GEOG 1030, BIOL 1000, or consent of instructor
General processes of sedimentary geology including provenance, sediment production, modification, and transportation; principles of fluid dynamics of water, air, and ice; fundamentals of deposition and diagenesis; description and interpretation of stratiform sediments and rocks, including facies relationships; principles of stratigraphic change; correlation methodologies; sequence stratigraphy; the development of stratigraphic thought; biostratigraphic principles and applications; and geophysical/geochemical stratigraphic methodologies and analysis. Overnight field trips may be required. Includes portions of GEOL 330 and GEOL 340; students may not earn credit for both sequences. Three hours discussion and three hours laboratory. Materials fee required.

GEOL 3400. Sedimentary Geology: Environmental Systems Analysis. Units: 4

Semester Prerequisite: Any 1000-level or higher GEOL course, or GEOG 1030 or BIOL 1000, or consent of instructor. Quarter Prerequisite: GEOL 101, or GEOG 103, or BIOL100, or consent of instructor
Description, analysis, and interpretation of modern and ancient sedimentary environmental systems, including terrestrial/continental systems (e.g. fluvial, lacustrine, deltaic, marsh/wetlands, alluvial, pedogenic, glacial, aeolian systems); subaqueous sedimentary systems (e.g. beaches, tidal, estuarine, deltaic, lagoonal, shallow shelf, biogenic (i.e. carbonate), slope, and deep marine). Laboratory work includes analysis of typical suites/specimens, maps, aerial and satellite photos, that characterize those systems. Overnight field trips may be required. Includes portions of GEOL 330 and GEOL 340; students may not earn credit for both sequences. Three hours lecture and three hours laboratory. Materials fee required.

GEOL 3500. Introductory Paleontology. Units: 4

Semester Prerequisite: Any 1000-level or higher GEOL course, or GEOG 1030, or BIOL 1000, or CHEM 2050, or consent of instructor. Quarter Prerequisite: an introductory course in either geology, physical geography, chemistry, or biology
Introduction to basic paleobiological concepts and the systematic study of important fossil groups. Course concepts include organization and nature of the biosphere, fossilization, taxonomy and systematics, paleoecology, and evolution as exemplified by commonly represented fossil groups in the rock record. Laboratory work includes collection, preparation, analysis, description, and interpretation of both modern specimens as well as typical and unusual fossil materials. Formerly offered as GEOL 350, may not receive credit for both courses. Overnight field trips may be required. Three hours seminar and three hours laboratory. Materials fee required.

GEOL 3600. Structural Geology. Units: 4

Semester Prerequisite: Any 1000-level GEOL course with lab, and PHYS 1000, PHYS 2000 or PHYS 2500. Quarter Prerequisite: GEOL 101 and PHYS 121 or PHYS 221
Mechanics and characteristics of rock deformation and analytical techniques for the solution of structural relationships. Three hours lecture and three hours laboratory. Overnight field trips may be required. Formerly offered as GEOL 360; students cannot earn credit for both. Materials fee required.

GEOL 3700. Groundwater Hydrology. Units: 3

Semester Prerequisite: Geol 1000 and 1000L, or Geol 1060 and 1060L or Geol 1020 plus 1000L or 1060L. Quarter Prerequisite: GEOL 101
Occurrence, distribution, and movement of groundwater; properties of aquifers; principles of groundwater flow; effects of well extraction; regional groundwater flow; water quality and contamination. Formerly offered as GEOL 375, students may not earn credit for both courses.

GEOL 3750. Field Methods in Hydrology. Units: 3

Semester Prerequisite: GEOL 3700, or consent of instructor. Quarter Prerequisite: GEOL 375 with a grade of "C" or better
Hydrology data collection in the field, with emphasis on instrumentation and mapping techniques. Water well siting and drilling techniques. Interpretation of data for evaluation of water movement. One hour lecture and six hours laboratory. Weekend field trips are required. Formerly offered as GEOL 376, students may not earn credit for both courses. Materials fee required.

GEOL 3800. Directed Readings in Geology. Units: 2

Quarter Prerequisite: consent of instructor
Directed readings of primary geologic literature on selected topics. Department consent required. Formerly offered as GEOL 520; students may not earn credit for both courses.

GEOL 3901. Advanced Field Geology. Unit: 1

Techniques of field geology as applied to selected disciplines within the broad field of geosciences. Some courses may involve moderate to strenuous physical activity. Depending on course content, additional fitness certification may be needed prior to obtaining the consent of instructor required to register. GEOL 3901-3906 may be repeated for credit up to a total of 6 units. Department consent required. Materials fee required.

GEOL 3902. Advanced Field Geology. Units: 2

Quarter Prerequisite: GEOL 301 with a grade of "C" or better and consent of instructor
Techniques of field geology as applied to selected disciplines within the broad field of geosciences. Some courses may involve moderate to strenuous physical activity. Depending on course content, additional fitness certification may be needed prior to obtaining the consent of the instructor required to register. May be taken three times for six units; Students may only earn six units across GEOL 3901-3906. Department consent required. Formerly offered as GEOL 391B. Materials fee required.

GEOL 3902D. Advanced Field Geology - Dinosaur Excavation. Units: 2

Semester Prerequisite: GEOL 3100
Techniques of field geology and vertebrate paleontology as applied to the study of dinosaur fossils in eastern Wyoming. Introduction to dinosaur fossil excavation, preservation, and prospecting; techniques in field data collection; and interpretation of paleoecology. This course involves moderate to strenuous physical activity. Qualifies for credit in the GEOL 3901-3906 series. Department consent required. May be taken three times for six units. Materials fee required, which includes food, camping and ranch fees, and transportation on-site during the course.

GEOL 3903. Advanced Field Geology. Units: 3

Quarter Prerequisite: GEOL 301 with a grade of "C" or better and consent of instructor
Techniques of field geology as applied to selected disciplines within the broad field of geosciences. Some courses may involve moderate to strenuous physical activity. Depending on course content, additional fitness certification may be needed prior to obtaining the consent of the instructor required to register. May be taken two times for six units; Students may only earn six units across GEOL 3901-3906. Department consent required. Formerly offered as GEOL 391C. Materials fee required.

GEOL 3904. Advanced Field Geology. Units: 4

Quarter Prerequisite: GEOL 301 with a grade of "C" or better and consent of instructor
Techniques of field geology as applied to selected disciplines within the broad field of geosciences. Some courses may involve moderate to strenuous physical activity. Depending on course content, additional fitness certification may be needed prior to obtaining the consent of the instructor required to register. May be taken two times for eight units; Students may only earn six units across GEOL 3901-3906. Department consent required. Formerly offered as GEOL 391D. Materials fee required.

GEOL 3906. Advanced Field Geology. Units: 6

Quarter Prerequisite: GEOL 301 with a grade of "C" or better and consent of instructor

Techniques of field geology as applied to selected disciplines within the broad field of geosciences. Some courses may involve moderate to strenuous physical activity. Depending on course content, additional fitness certification may be needed prior to obtaining the consent of instructor required to register. Students may only earn six units across GEOL 3901-3906. Department consent required. Formerly offered as GEOL 391E. Materials fee required.

GEOL 3951. Directed Studies. Unit: 1

Quarter Prerequisite: consent of the instructor

Individual laboratory, field or library study conducted under the direction of a faculty member. May be repeated for credit. Instructor consent required. Formerly offered as GEOL 395A. Materials fee required.

GEOL 3952. Directed Studies. Units: 2

Quarter Prerequisite: consent of the instructor

Individual laboratory, field or library study conducted under the direction of a faculty member. May be repeated for credit. Instructor consent required. Formerly offered as GEOL 395B. Materials fee required.

GEOL 3953. Directed Studies. Units: 3

Quarter Prerequisite: consent of the instructor

Individual laboratory, field or library study conducted under the direction of a faculty member. May be repeated for credit. Instructor consent required. Formerly known as GEOL 395C. Materials fee required.

GEOL 3990. Geological Research Design. Units: 3

Quarter Prerequisite: NSCI 306 and consent of instructor

Exploration of scientific ways of thinking and how scientific knowledge is created and communicated within the field of geology. Appreciation of the geologic literature as a professional conversation that expands our understanding of geologic processes and features. Development of the reading, thinking, listening, speaking, writing and graphical communication skills that are necessary to join that conversation as a student-scholar, culminating in a written and oral proposal for a research project for GEOL 4000. Revision and collaboration are key components of the course. May require attendance at one or more professional geologic talks or seminars. Two hours seminar and one hour supervision per week. For geology majors and minors only. Consent of Instructor and Department Chair required. Graded A through C-/No Credit. Satisfies requirement for upper-division writing-intensive course. Formerly offered as GEOL 398. Students may not earn credit for both courses.

GEOL 4000. Undergraduate Geological Research. Units: 2

Semester Prerequisite: GEOL 3990 with a grade of "C-" or better. Quarter Prerequisite: GEOL 398 with a grade of "C" or better

Laboratory and/or field research in geological sciences under the direction of a faculty advisor. Results will be presented as a research paper. Grade is consensus grade of geology faculty. Department consent required. Formerly offered as GEOL 399; students may not earn credit for both courses.

GEOL 4100. Engineering Geology. Units: 4

Semester Prerequisite: GEOL 3100 with a grade of "C" or better or consent of the Instructor

A survey of issues and techniques pertinent to geology as it applies to engineering of structures and mitigation of natural hazards. Soil and rock mechanics; mass wasting processes; water-related issues; land subsidence; seismic hazards. Field trips are required. Two hours lecture and six hours laboratory, some of which will be conducted in the field. Formerly offered as GEOL 430; students may not earn credit for both. Materials fee required.

GEOL 4200. Topics in Applied Geology. Units: 3

Semester Prerequisite: GEOL 3600 or consent of instructor. Quarter Prerequisite: GEOL 360 or consent of instructor

A selected topic of applied geology such as engineering geology, groundwater, environmental geology, resource management, well-log analysis, applied geophysics, and geological hazards. Recommended as an elective for students of environmental studies, archaeology/anthropology, and life sciences. Formerly offered as GEOL 460. May be repeated for credit as topics change.

GEOL 4200L. Laboratory for Topics in Applied Geology. Unit: 1

Semester Corequisite: Geol 4200

Laboratory work to accompany some topics offered in GEOL 4200. Overnight field trips may be required. May be repeated for credit as topics change. Department consent required. Materials fee required.

GEOL 4800. Senior Honors Research. Units: 2

Semester Prerequisite: GEOL 4000 with a grade of "C" or better. Quarter Prerequisite: GEOL 399 with a grade of "C" or better

Original research in the geological sciences. Work will be conducted in consultation with a faculty advisor, and will culminate in a written paper. Students are encouraged to present results in a conference setting as well. Consent of Instructor required. Formerly offered as GEOL 597; students may not earn credit for both courses.

GEOL 4900. Senior Seminar. Units: 2

Semester Prerequisite: GEOL 4000 with a grade of "C-" or better. Quarter Prerequisite: GEOL 399 with a grade of "C" or better

Assessment of student learning through a written and practical exam, in-class writing assignments, and oral and poster presentations of a research project completed as part of GEOL 4000. Also includes resume writing and preparation for the Geologist in Training examination (a step toward licensure). This course should be taken in the last spring semester prior to graduation. One hour seminar and three hours supervision per week. Formerly offered as GEOL 590. Students may not earn credit for both courses.

GEOL 5000. Advanced Topics in Geology. Units: 3

An advanced geologic topic, such as geophysics, carbonate petrology, seismic stratigraphy, biostratigraphy, advanced igneous and metamorphic petrology, volcanic processes, geochemistry, paleoecology, Quaternary geology, geostatistics, micropaleontology, vertebrate paleontology, paleobotany, marine geology, orogenic systems, stratigraphic techniques, and rock mechanics. Overnight field trips may be required. May be repeated for credit as topics change. Formerly offered as GEOL 540.

GEOL 5000L. Laboratory for Advanced Topics in Geology. Unit: 1

Semester Prerequisite: Consent of instructor. Quarter Prerequisite: Consent of instructor

Semester Corequisite: GEOL 5000

Laboratory work to accompany some topics offered in GEOL 5000. Overnight field trips may be required. May be repeated for credit as topics change. Formerly offered as GEOL 545A. Materials fee required.

GEOL 5200. Tectonics. Units: 3

Quarter Prerequisite: GEOL 325, 330 and 360

Interpretation of the geological evidence for plate tectonics; the mechanisms that control it; the structures it produces; its control on igneous, metamorphic, sedimentologic, and biological processes; and plate interactions. Formerly offered as GEOL 370, students cannot earn credit for both courses.

GEOL 5220. Neotectonics and Seismic Hazard Analysis. Units: 4

Semester Prerequisite: GEOL 1000 and GEOL 1000L, or GEOG 1030 and GEOG 1030L required, GEOL 3100 and GEOL 3600 strongly recommended. Quarter Prerequisite: GEOL 101 or GEOG 103

State-of-the-art methods for studying active faults. Topics include basic seismology, significant historic earthquakes, identifying active faults, estimating fault slip rates by geologic and geodetic methods, types of evidence for prehistoric earthquakes, models for earthquake recurrence, and evaluating the potential for and likely effects of future earthquakes. Three hours lecture and three hours laboratory. Formerly offered as GEOL 551. Both courses may not be taken for credit. Materials fee required.

GEOL 5240. Volcanology and Volcanic Hazard Assessment. Units: 4

Semester Prerequisite: GEOL 3240 with a grade of C or better. Quarter Prerequisite: GEOL 325 with a grade of C or better

Concepts in modern volcanology and assessment of volcanic hazards. Topics include magma properties, eruptive styles, lava flows, pyroclastic and volcanoclastic deposits, volcanoes and climate, volcanic hazards and their assessment and mitigation, case studies of classic volcanic eruptions. Three hours lecture and three hours laboratory. Weekend field trip(s) will be required. Formerly offered as GEOL 552, students may not receive credit for both courses. Materials fee required.

GEOL 5260. Advanced Structural Geology. Units: 4

Semester Prerequisite: GEOL 3240, 3300, and 3600 with a grade of C or better. Quarter Prerequisite: GEOL 325, 330 and 360 with a grade of C or better

Advanced topics in theory and analysis of stress and strain; examination of deformation mechanisms; geometry, kinematics, and mechanisms of orogenic belts. Recommended: GEOL 5200. Three hours lecture and three hours laboratory. Overnight field trips may be required. Formerly offered as GEOL 553, students may not receive credit for both courses. Materials fee required.

GEOL 5280. Digital Mapping and GIS for Scientists. Units: 3

Semester Prerequisite: GEOL 3100 or consent of instructor. Quarter Prerequisite: GEOG 202

Emphasis on real-time field-data collection in direct digital form, and manipulation of these data using GIS. Scientific application to geologic and/or environmental problems will be stressed. Recommended: GEOG 2050. One hour lecture and six hours laboratory. Previously offered as GEOL 591; students may not earn credit for both courses. Materials fee required.

GEOL 5300. Microscopy. Units: 3

Semester Prerequisite: senior standing or consent of instructor. Quarter Prerequisite: senior standing and consent of instructor

Theory and techniques of modern microscopy. Lectures on theory of optics and imaging for several types of microscopes (Light microscope, fluorescence microscope, confocal microscope, scanning probe microscope, and electron microscope). Laboratory includes hands-on training in the technical aspects of specimen preparation and microscope use. Two hours lecture and three hours laboratory. Formerly offered as BIOL/GEOL 530, students may not receive credit for both courses. Offered as GEOL 5300 and BIOL 5300. Students may not receive credit for both. Materials fee required.

GEOL 5400. Environmental Hydrology. Units: 3

Overview of groundwater and surface water, including Federal and State environmental regulation, groundwater origins and behavior, wells, water quality, waste treatment. Emphasis is given to applications and case studies. Weekend field trip(s) may be required. Formerly offered as GEOL 510, students may not receive credit for both courses.

GEOL 5420. Geochemical Thermodynamics. Units: 3

Semester Prerequisite: CHEM 2200 and MATH 2220. Quarter Prerequisite: CHEM #216 and MATH #212

Application of equilibrium thermodynamics to understand geological, geochemical, and other natural systems. Mathematics of thermodynamics and equations of state, use of thermodynamic datasets and extraction of data from experiments, interpretation of geochemical phase equilibria, introduction to geochemical modeling. Formerly offered as GEOL 554, students may not receive credit for both courses. Geology majors are recommended to take GEOL #320 and GEOL #322 before taking this course.

GEOL 5430. Isotope Geochemistry. Units: 3

Semester Prerequisite: GEOL 3220 and GEOL 3240 or permission of instructor

Introduction to stable and radiogenic isotopes with applications to a variety of geochemical, geological, and environmental research problems. Fundamental topics include nucleosynthesis and nuclear chemistry, radioactive decay, isotopic equilibria, and mass spectrometry. Isotopes will be applied to understanding natural processes in hydrology, water-rock interaction, environmental studies, paleoclimate, petrology, anthropology, biogeochemistry, and radiometric dating.

GEOL 5440. Environmental Geochemistry. Units: 4

Semester Prerequisite: CHEM 2050, or CHEM 2100, or GEOL 3220, or consent of instructor, CHEM 2200 suggested. Quarter Prerequisite: GEOL 610

Contemporary problems in environmental geochemistry, such as fate and transport of inorganic and organic pollutants in the terrestrial environment covering both equilibrium and kinetic descriptions of the processes. Three hours lecture and three hours laboratory. Formerly offered as GEOL 630, students may not receive credit for both courses. Materials fee required.

GEOL 5460. Low-temperature Geochemistry. Units: 3

Low-temperature geochemistry including sedimentary systems, weathering, and aqueous geochemistry. Includes discussion of thermodynamics of aqueous reactions, elemental speciation, activity diagrams, the carbonate system, water-rock reactions and stable isotopes. Formerly offered as GEOL 635, students may not receive credit for both courses.

GEOL 5600. Earth Resources. Units: 4

Semester Prerequisite: GEOL 3200 with a grade of "C" or better, or consent of instructor. Quarter Prerequisite: GEOL 322 with a grade of "C" or better

An overview of the geology, distribution, and occurrence of many types of ore deposits, and the methods and laws governing their extraction. Topics include metallic resources, industrial minerals, building materials, and energy resources. Three hours lecture and three hours laboratory. Weekend field trip(s) may be required. Formerly offered as GEOL 550, students may not receive credit for both courses. Materials fee required.

GEOL 5620. Site Investigation, Siting, and Case Histories in Engineering Geology. Units: 4

Quarter Prerequisite: GEOL 301, GEOL 360, GEOL 370

Discussion and practice of methods and strategies to investigate sites for the purpose of engineered or other human designed improvement. Use of aerial photography, mapping, reconnaissance site visits, geophysics, and exploration borings to obtain data at sites; discussion of guidelines and methods to describe rock and soil borings. Discussion of use of geologic site conditions to develop the scope and strategy of site investigation. Discussion of siting of critical facilities. Well-known successes and failures will be explored by focusing on the geologic details at those sites, and how workers of the day dealt with situations versus how these might be investigated and mitigated with modern techniques. Three hours seminar and three hours lab. Field trips required. Formerly offered as GEOL 555 and GEOL 556, students may not earn credit for both the quarter versions and this version. Materials fee required.

GEOL 5751. Internship in Geology. Unit: 1

Quarter Prerequisite: consent of instructor and department chair
Work experience off and on campus in geologically related work. Supervised by a member of Geological Sciences faculty. A maximum of 3 units may be applied towards the degree. Department consent required. Formerly offered as GEOL 575A or 575B. Students may not receive credit for both courses. Graded credit/no credit.

GEOL 5752. Internship in Geology. Units: 2

Quarter Prerequisite: consent of instructor and department chair
Work experience off and on campus in geologically related work. Supervised by a member of Geological Sciences faculty. A maximum of 3 units may be applied towards the degree. Department consent required. Formerly offered as GEOL 575B or 575C. Students may not receive credit for both courses. Graded credit/no credit.

GEOL 5753. Internship in Geology. Units: 3

Quarter Prerequisite: consent of instructor and department chair
Work experience off and on campus in geologically related work. Supervised by a member of Geological Sciences faculty. A maximum of 3 units may be applied towards the degree. Department consent required. Formerly offered as GEOL 575C or 575D. Students may not receive credit for both courses. Graded credit/no credit.

GEOL 5951. Independent Study. Unit: 1

Semester Prerequisite: consent of instructor. Quarter Prerequisite: consent of instructor
Laboratory, field or library research conducted under the direction of a faculty member. A total of three units may be applied towards obtaining a bachelors degree and a total of three units may be applied towards obtaining a masters degree. Formerly offered as GEOL 595A or 595B.

GEOL 5952. Independent Study. Units: 2

Quarter Prerequisite: consent of instructor
Laboratory, field or library research conducted under the direction of a faculty member. A total of three units may be applied towards obtaining a bachelors degree and a total of three units may be applied towards obtaining a masters degree. Formerly offered as GEOL 595B or 595C. Departmental consent required.

GEOL 5953. Independent Study. Units: 3

Quarter Prerequisite: consent of instructor
Laboratory, field or library research conducted under the direction of a faculty member. A total of three units may be applied towards obtaining a bachelors degree and a total of three units may be applied towards obtaining a masters degree. Formerly offered as GEOL 595C. Departmental consent required.

GEOL 6000. Advanced Environmental Chemistry and Geosciences. Units: 4

Semester Prerequisite: classified standing in either the Master of Science in Geology or Master of Science in Environmental Sciences program, or consent of instructor
Application of earth science principles to the properties of the natural environment and the effects of human and biological activities thereon. Topics include geohazards, erosion, geochemistry, sources and treatment of water, climate change, and the chemistry of environmental pollutants in air, water, and soil. Labs will feature hands-on studies of common methods used in environmental and geological analyses. Materials fee required. Formerly CHEM 610 and GEOL 610; students may not receive credit for both the quarter versions and this version.

GEOL 6100. Graduate Geological Mapping. Units: 3

Quarter Prerequisite: GEOL 301, GEOL 325, GEOL 330, GEOL 340, and GEOL 360 or equivalents, classified standing, and consent of instructor
Application of geologic techniques and principles to selected field problems. Includes geologic mapping, data collection, analysis, and presentation, and report writing. Nine hours laboratory. Overnight field work may be required. Formerly offered as GEOL 621, students may not earn credit for both courses. Materials fee required.

GEOL 6752. Advanced Internship. Units: 2

Semester Prerequisite: CHEM 5753, or GEOL 5753. Quarter Prerequisite: CHEM 575 or GEOL 575 and consent of advisor
Supervised work or study in private or public organizations. Department consent required. Graded Credit/No Credit. Formerly offered as GEOL 697.

GEOL 6900. Graduate Seminar. Units: 2

Current and past student project investigations in the M.S. Environmental Science and Geology programs, including presentation of project implications for the general public and professional non-scientific constituents such as business, law, policy, and public health. Formerly offered as CHEM/GEOL 690, students may not receive credit for both courses. Two hours seminar.

GEOL 6940. Graduate Research Methods and Design. Units: 3

Quarter Prerequisite: Classified standing in the master of science program in geology or environmental sciences, and consent of instructor
Critical literature review and preparation of a master's thesis or project research proposal following program guidelines. Supervised by the student's thesis/project adviser. Graded credit/no credit upon approval of the student's thesis/project committee.

GEOL 6950. Directed Graduate Research in Geology. Units: 3

Semester Prerequisite: classified standing in masters program. Quarter Prerequisite: classified standing in masters program and consent of advisor
Original individual research in geology to be conducted under the supervision of the student's thesis adviser. Formerly offered as GEOL 695. Students may take the course up to a total of three times, but only three units apply to the degree. Department consent required. Materials fee required.

GEOL 6960. Graduate Project. Units: 3

Semester Prerequisite: classified standing and consent of instructor.
Quarter Prerequisite: classified standing and consent of instructor
Original individual research in geology, to be conducted under the guidance of the student's graduate advisor, and if desired, in collaboration with other members of the student's master's committee. Formerly offered as GEOL 696, students may not receive credit for both courses. Graded credit/no credit. Materials fee required.

GEOL 6970. Graduate Thesis. Units: 3

Semester Prerequisite: GEOL 6950. Quarter Prerequisite: CHEM 695 or GEOL 695
Independent graduate research conducted under guidance of the thesis advisor culminating in a written thesis and oral defense. Formerly offered as GEOL 699, students may not receive credit for both courses.

GEOL 6990. Continuous Enrollment for Graduate Candidacy Standing. Units: 0

Quarter Prerequisite: advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.

GEOL 6991. Continuous Enrollment for Graduate Candidacy Standing. Unit: 1

Quarter Prerequisite: Advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.

GEOL 6992. Continuous Enrollment for Graduate Candidacy Standing. Units: 2

Quarter Prerequisite: advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.

GEOL 6993. Continuous Enrollment for Graduate Candidacy Standing. Units: 3

Quarter Prerequisite: advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.

GEOL 6994. Continuous Enrollment for Graduate Candidacy Standing. Units: 4

Quarter Prerequisite: advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.

GEOL 6995. Continuous Enrollment for Graduate Candidacy Standing. Units: 5

Quarter Prerequisite: advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.

GEOL 6996. Continuous Enrollment for Graduate Candidacy Standing. Units: 6

Quarter Prerequisite: advancement to candidacy and approval of program graduate coordinator or, if an interdisciplinary studies major, consent of the Dean of Graduate Studies

Independent study leading to completion of requirements (other than course work) for the master's degree. To retain classified standing in the master's program, a student must enroll in a Continuous Enrollment for Graduate Candidacy Standing course each quarter until the project or thesis is accepted or the comprehensive examination passed. Students who enroll through the university have full use of all university facilities. See Culminating Experience: Exam, Thesis, or Project in Graduate Degree and Program Requirements section of the Bulletin of Courses. Continuous Enrollment for Graduate Candidacy Standing is a variable unit course, see fee schedule in the Financial Information section of the Bulletin of Courses. Earned units are not degree-applicable nor will they qualify for financial aid.