GEOLOGICAL AND ENVIRONMENTAL SCIENCES

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Courses given in Geological and Environmental Sciences have the subject code GES. For a complete list of subject codes, see Appendix.

The geological and environmental sciences are naturally interdisciplinary, and include: the study of processes that shape the Earth's surface; records of Earth's history, including climate, as documented in rocks, sediments, and ice; changes in the oceans and atmosphere; chemical and physical properties of minerals, rocks, soils, sediments, water, and ice, and interactions among them; interactions between earth materials and microbes; sources of energy resources and economic minerals; contamination of natural waters and soils; biogeochemical cycles over multiple timescales; planetary geology and astrobiology; remote sensing and classification of land use and land cover; and natural hazards like volcanoes, earthquakes, and landslides.

Most students and faculty within the department spend time in the field; recent field sites include areas in California, Chile, Antarctica, Easter Island, Hawaii, the Kamchatka peninsula, Utah, Nevada, and S.E. Asia. Departmental facilities that model, simulate, or digitize field data and samples include laboratories that provide access to state-of-the-art techniques including stable isotope analysis, geochronology, thermochronology, electron and ion microprobe analysis, nuclear magnetic resonance, scanning electron microscopy, and geographic information systems (GIS) analysis. Facilities at the Stanford Linear Accelerator Center (SLAC), the Stanford Synchrotron Radiation Laboratory (SSRL), and the U.S. Geological Survey in Menlo Park are available to researchers in the earth sciences.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

The undergraduate program leading to the Bachelor of Science (B.S.) degree in Geological and Environmental Sciences (GES) is designed to leverage the diversity of the field and provide background for a wide variety of careers. Students who complete the undergraduate GES major or minor have gone on to graduate school in the earth sciences and/or employment in geological consulting, environmental engineering, land use planning, law, public service, teaching and other professions in which an understanding of the earth and a background in science are important. Students interested in the GES major should consult with the undergraduate program coordinator for information about options within the curriculum and potential career paths.

The major requires at least 81 units; letter grades are required in all courses if available. Students complete a core sequence of GES courses that introduce earth processes and the properties of earth materials. With this foundation, they focus on a more specialized area within the geological and environmental sciences. The curriculum thus includes courses in chemistry, physics, biology, and mathematics. In addition, nearly all GES students conduct independent research projects, either over the summer or as part of a year-long honors thesis.

The study of earth processes in the natural laboratory of the field is a fundamental component of the major, and most GES courses include field trips. Students must complete at least six weeks of directed field research.

Near the end of the undergraduate program and to fulfill the Writing in the Major requirement, students take a writing-intensive senior seminar (GES 150), in which students share their knowledge with each other while addressing issues at the forefront of the earth sciences.

COURSE SEQUENCE (81-92 UNITS TOTAL)

CORE GEOLOGICAL AND ENVIRONMENTAL SCIENCES COURSES

Subject and Catalog Number	*Units*
GES 1. Dynamic Earth	5
or GES 49N. Field Trip to Death Valley and Owens Valley	*3*
GES 2. The History of Life on Earth	2
GES 102. Earth Materials	5
GES 103. Rocks in Thin Section	3
GES 150. Senior Seminar: Issues in the Earth Sciences (WIM)	3
GES 190, other field course, or field research (6 weeks)	

Four of the following five groups of courses (others may count as electives):

GES 90. Introduction to Geochemistry	3-4
GES 110. Structural Geology and Tectonics	5
or GES 111A. Fundamentals of Structural Geology	*3*
GES 151. Sedimentary Geology and Petrography	4
GES 175. Science of Soils	4
or GES 130. Environmental Earth Sciences I	*5*
or GES 170. Environmental Geochemistry	*4*
GES 180. Igneous Processes	3-5
or GES 181. Metamorphic Processes	*3-5*

REQUIRED SUPPORTING MATHEMATICS

Choose one of the following equivalent series:

MATH 19. Calculus	3
MATH 20. Calculus	3
MATH 21. Calculus	4
or	
MATH 41. Calculus	5
MATH 42. Calculus	5

Choose at least one of the following (the entire series is recommended for students who plan to pursue graduate studies in the sciences or engineering):

MATH 51. Multivariate Mathematics	5
MATH 52. Multivariate Mathematics	5
MATH 53. Multivariate Mathematics	5

REQUIRED SUPPORTING COGNATE SCIENCES

Students must complete course sequences from two of the three fields of cognate sciences: chemistry, physics, and biological sciences. Advanced placement credit may be accepted for these courses as determined by the relevant departments.

Chemistry:	
CHEM 31A,B. Chemical Principles I/II	8
or CHEM 31X. Chemical Principles	*4*
CHEM 135. Physical Chemical Principles	3
or CHEM 171. Physical Chemistry	*3*
or GES 171. Geochemical Thermodynamics	*3*
Physics (choose one of the following series):	
PHYSICS 21. Mechanics and Heat	3
PHYSICS 22. Mechanics and Heat Lab	1
PHYSICS 23. Electricity and Optics	3
PHYSICS 24. Electricity and Optics Lab	1
or	
PHYSICS 41 (formerly 53). Mechanics	4
PHYSICS 45 (formerly 51). Light and Heat	4
PHYSICS 46 (formerly 52). Light and Heat Lab	1
or	
PHYSICS 41 (formerly 53). Mechanics	4
PHYSICS 43 (formerly 55). Electricity and Magnetism	3
PHYSICS 44 (formerly 56). Electricity and Magnetism Lab	1
Biology:	
BIOSCI 41. Genetics, Biochemistry, and Molecular Biology	5
BIOSCI 42. Cell Biology and Animal Physiology	5
or BIOSCI 43. Plant Biology, Evolution, and Ecology	*5*
or BIOSCI 101. Ecology	*3*

ELECTIVES (19 UNITS)

Majors must complete at least 19 units of upper-division electives. A majority (at least 10) of these units must be from courses within GES (excluding GES 7, introductory seminars (GES 30-60), and GES 201). Many courses from departments other than GES are also approved electives; this list is available from the undergraduate program coordinator and at http://pangea.stanford.edu/GES/undergraduates. Additional courses may satisfy this requirement but require prior approval from the undergraduate program director. A maximum of 3 elective units may be fulfilled by GES 192, 198, or an upper-level seminar. Honors research (GES 199) may fulfill up to 6 elective units. Students should discuss their electives with an adviser.

FIELD RESEARCH (6 WEEKS)

Majors must complete six weeks of field research, preferably through departmental offerings (GES 190). Approved field schools offered by another university or other faculty-directed field research projects that involve learning and application of field techniques and the preparation of a written report may be used to fulfill the field research requirement.

ENGINEERING GEOLOGY AND HYDROGEOLOGY SPECIALIZED CURRICULUM

The Engineering Geology and Hydrogeology curriculum is intended for undergraduates interested in the application of geological and engineering data and principles to the study of rock, soil, and water to recognize and interpret geological and environmental factors affecting engineering structures and groundwater resources. Students learn to characterize and assess the risks associated with natural geological hazards, such as landslides and earthquakes, and with groundwater flow and contamination. The curriculum prepares students for graduate programs and professional careers in engineering, and environmental geology, geology, geotechnical engineering, and hydrogeology. Students interested in this curriculum should contact a faculty adviser: Professor Loague, Pollard, or Gorelick.

GES majors who elect the Engineering Geology and Hydrogeology curriculum are expected to complete a core course sequence and a set of courses in supporting sciences and mathematics. The core courses come from Earth Sciences and Engineering. Any substitutions for core courses must be approved by the faculty adviser and through a formal petition to the undergraduate program director. In addition, four elective courses, consistent with the core curriculum and required of all majors, are to be selected with the advice and consent of the adviser. Typically, electives are selected from the list below. Letter grades are required if available.

COURSE SEQUENCE (88-99 UNITS TOTAL)

REQUIRED GEOLOGICAL AND ENVIRONMENTAL SCIENCES (38-39 UNITS)

Subject and Catalog Number	*Units*
GES 1. Dynamic Earth	5
GES 102. Earth Materials	5
GES 111A. Fundamentals of Structural Geology	3
GES 115. Engineering Geology Practice	3
GES 144. Fundamentals of GIS	4
GES 150. Senior Seminar: Issues in the Earth Sciences (WIM)	3
GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction	4
or GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics	3-4
GES 230. Physical Hydrogeology	4
GEOPHYS 190. Applied Geophysical Methods	3

REQUIRED ENGINEERING (20 UNITS)

CEE 101A. Mechanics of Materials	4
CEE 101B. Mechanics of Fluids	4
CEE 101C. Geotechnical Engineering	4
CS 106A. Programming Methodology	5
ENGR 14. Applied Mechanics: Statics	3

REQUIRED SUPPORTING SCIENCES AND MATHEMATICS (23-27 UNITS)

CHEM 31A,B. Chemical Principles I/II	8
or CHEM 31X. Chemical Principles	*4*
MATH 51. Multivariate Mathematics	5
MATH 52. Multivariate Mathematics	5
MATH 53. Multivariate Mathematics	5
PHYSICS 41. Mechanics	4

SUGGESTED ELECTIVES (11-20 UNITS)

Choose *four* courses from the following list or, with faculty approval, four related courses:

CEE 180. Structural Analysis	4
CEE 270. Movement, Fate, and Effects of Contaminants in Surface Waters and Groundwater	3
CEE 293. Foundation Engineering	3
CEE 296. Experimental Soil Mechanics	2
ENGR 30. Engineering Thermodynamics	3
ENGR 50. Introductory Science of Materials	4
GEOPHYS 150. General Geophysics	4
GES 130. Environmental Earth Sciences I	3
GES 131. Environmental Earth Sciences II	3
GES 215A,B. Advanced Structural Geology and Rock Mechanics	3-5
GES 217. Characterization and Hydraulics of Rock Fracture	3
GES 231. Contaminant Hydrogeology	4
GES 235. Role of Fluids in Geologic Processes	3
GES 237. Surface and Near-Surface Hydrologic Response	3
MATH 103. Matrix Theory and its Applications	3
ME 80. Strength of Materials	3

MINORS

The minor in GES consists of a small set of required courses plus 12 elective units. A wide variety of courses may be used to satisfy these elective requirements.

REQUIRED COURSES:

Subject and Catalog Number	*Units*
GES 1. Dynamic Earth	5
or GES 49N. Field Trip to Death Valley and Owens Valley	*3*
GES 2. The History of Life on Earth	4
GES 102. Earth Materials	5

ELECTIVES (12 UNITS)

Electives must include at least three courses from the list below:

GES 8. The Oceans	3
GES 90. Introduction to Geochemistry	3-4
GES 103. Rocks in Thin Section	3
GES 110. Structural Geology	5
GES 111A. Fundamentals of Structural Geology	3
GES 130. Environmental Earth Sciences I	3

GES 131. Environmental Earth Sciences II	3
GES 144. Fundamentals of GIS	4
GES 151. Sedimentary Geology and Petrography	4
GES 170. Environmental Geochemistry	4
GES 175. Science of Soils	4
GES 180. Igneous Processes	3-5
GES 181. Metamorphic Processes	3-5
GES 185. Volcanology	4

Students pursuing a minor in GES are encouraged to take one of the freshman or sophomore seminars (courses with numbers 38-59) and to participate in the senior seminar (GES 150) and in field research (GES 190). Up to 3 units of Stanford Introductory Seminars may be used in fulfilling the 12-unit requirement above.

HONORS PROGRAM

The honors program provides an opportunity for year-long independent study and research on a topic of special interest, culminating in a written thesis. Students select research topics in consultation with the faculty adviser of their choosing. Research undertaken for the honors program may be of a theoretical, field, or experimental nature, or a combination of these approaches. The honors program is open to students with a GPA of at least 3.5 in GES courses and 3.0 in all University course work. Modest financial support is available from several sources to help defray laboratory and field expenses incurred in conjunction with honors research. Interested students must submit an application, including a research proposal, to the department by the end of their junior year.

Upon approval of the research proposal and entrance to the program, course credit for the honors research project and thesis preparation is assigned by the student's faculty adviser within the framework of GES 199; the student must complete a total of 9 units over the course of the senior year. Up to 6 units of GES 199 may be counted towards the elective requirement, but cannot be used as a substitute for regularly required courses.

Both a written and oral presentation of research results are required. The thesis must be read, approved, and signed by the student's faculty adviser and a second member of the faculty. In addition, honors students must participate in the GES Honors Symposium in which they present their research to the broader community. Honors students in GES are also eligible for the Firestone medal, awarded by Undergraduate Advising and Research for exceptional theses.

COTERMINAL B.S. AND M.S. DEGREES

The coterminal B.S./M.S. program offers students the opportunity to pursue graduate research and an M.S. degree concurrently with or subsequent to their B.S. studies. The M.S. degree can serve as an entrance to a professional degree in subdisciplines within the earth sciences such as engineering geology and environmental geology, or to graduate course work and research as an intermediate step to pursuit of the Ph.D. Regardless of professional goals, coterminal B.S./M.S. students are treated as members of the graduate community and are expected to meet all of the standards set for regular M.S. students. Applicants must have earned no fewer than 120 units toward graduation, and must submit their application no later than the quarter prior to the expected completion of their undergraduate degree, normally the Winter Quarter prior to Spring Quarter graduation. The application includes a statement of purpose, a current Stanford transcript, official Graduate Record Examination (GRE) scores, letters of recommendation from two members of the Stanford faculty (at least one of whom must be in the GES department), and a list of courses in which they intend to enroll to fulfill the M.S. degree requirements. Specific research interests should be noted in the statement of purpose and discussed with a member of the GES faculty prior to submission of the application. Coterminal students must complete a thesis describing research results. For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

Students must meet all requirements for both the B.S. and M.S. degrees. Students may either (1) complete 180 units required for the B.S. degree and then complete three full-time quarters (45 units at the 100-level or above) for the M.S. degree, or (2) complete a total of fifteen quarters during which the requirements of the two degrees are fulfilled concurrently. At least half of the courses used to satisfy the 45-unit requirement must be designated as being primarily for graduate students, normally at the 200-level or above. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement. Further information about this program may be obtained from the GES office.

GRADUATE PROGRAMS

Graduate studies in the Department of Geological and Environmental Sciences (GES) involve academic course work and independent research. Students are prepared for careers as professional scientists in research, education, or the application of the earth sciences to mineral, energy, and water resources. Programs lead to the M.S., Engineer, and Ph.D. degrees. Course programs in the areas of faculty interest are tailored to the student's needs and interests with the aid of his or her research adviser. Students are encouraged to include in their program courses offered in other departments in the School of Earth Sciences as well as in other departments in the University. Diplomas designate degrees in Geological and Environmental Sciences and may also indicate the following specialized fields of study: Geostatistics and Hydrogeology.

Admission—For admission to graduate work in the department, the applicant must have taken the Aptitude Test (verbal, quantitative, and analytical writing assessment) of the Graduate Record Examination. In keeping with University policy, applicants whose first language is not English must submit TOEFL (Test of English as a Foreign Language) scores from a test taken within the last 18 months. Individuals who have completed a B.S. or two-year M.S. program in the U.S. or other English-speaking country are not required to submit TOEFL scores. Previously admitted students who wish to change their degree objective from M.S. to Ph.D. must petition the GES Admissions Committee.

FIELDS WITH DIPLOMA DESIGNATION

Hydrogeology—The Hydrogeology program, which leads to an M.S., Engineer, or Ph.D. degree in GES, balances research in the purely scientific and applied aspects of groundwater resources and near-surface processes.

The program requires students to obtain a broad background in earth sciences and engineering. Students in the program must have a strong general scientific background in basic physics, chemistry, computer science, and mathematics, and a demonstrated aptitude for solving quantitative problems. They must complete a core curriculum involving courses in fluid mechanics, hydrogeology, hydrology, and water quality. A list of required and recommended courses is supplied upon request.

Geostatistics—The Geostatistics program leads to an M.S. or Ph.D. degree in GES. Strong interactions have been developed with faculty and students in the departments of Geophysics and Energy Resources Engineering.

The program requires a geological background and a fair level of calculus and programming (Fortran and/or C++). Recent graduates have found jobs in the extractive (mining, oil) and environmental (EPA) fields.

MASTER OF SCIENCE

Objectives—The purpose of the master's program in Geological and Environmental Sciences is to continue a student's training in one of a broad range of earth science disciplines and to prepare students for either a professional career or doctoral studies.

Procedures—The graduate coordinator of the department appoints an academic adviser during registration with appropriate consideration of the student's background, interests, and professional goals. In consultation with the adviser, the student plans a program of course work for the first year. The student should select a thesis adviser within the first year of residence and submit to the thesis adviser a proposal for thesis research as soon as possible. The academic adviser supervises completion of the department requirements for the M.S. program (as outlined below) until the research proposal has been accepted; responsibility then passes to the thesis adviser. The student may change either thesis or academic advisers by mutual agreement and after approval of the graduate coordinator.

Requirements—The University's requirements for M.S. degrees are outlined in the "Graduate Degrees" section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. Additional department requirements include the following:

1. A minimum of 45 units of course work at the 100 level or above.
   a. Half of the courses used to satisfy the 45-unit requirement must be intended as being primarily for graduate students, usually at the 200 level or above.
   b. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement.
   c. Some students may be required to make up background deficiencies in addition to these basic requirements.
2. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
3. Each student must have a research adviser who is a faculty member in the department and is within the student's thesis topic area or specialized area of study.
4. Each student must complete a thesis describing his or her research. Thesis research should begin during the first year of study at Stanford and should be completed before the end of the second year of residence.
5. Early during the thesis research period, and after consultation with the student, the thesis adviser appoints a second reader for the thesis, who must be approved by the graduate coordinator; the thesis adviser is the first reader. The two readers jointly determine whether the thesis is acceptable for the M.S. degree in the department.

ENGINEER DEGREE

The Engineer degree is offered as an option for students in applied disciplines who wish to obtain a graduate education extending beyond that of an M.S., yet do not have the desire to conduct the research needed to obtain a Ph.D. A minimum of two years (six quarters) of graduate study is required. The candidate must complete 90 units of course work, no more than 10 of which may be applied to overcoming deficiencies in undergraduate training. The student must prepare a substantial thesis that meets the approval of the thesis adviser and the graduate coordinator.

DOCTOR OF PHILOSOPHY

Objectives—The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship, high attainment in a particular field of knowledge, and the ability to conduct independent research. To this end, the objectives of the doctoral program are to enable students to develop the skills needed to conduct original investigations in a particular discipline or set of disciplines in the earth sciences, to interpret the results, and to present the data and conclusions in a publishable manner.

Requirements—The University's requirements for the Ph.D. degree are outlined in the "Graduate Degrees" section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. A summary of additional department requirements is presented below:

1. Ph.D. students must complete the required courses in their individual program or in their specialized area of study with a grade point average (GPA) of 3.0 (B) or higher, or demonstrate that they have completed the equivalents elsewhere. Ph.D. students must complete a minimum of four letter-grade courses of at least 3 units each from four different faculty members on the Academic Council in the University. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
2. Each student must qualify for candidacy for the Ph.D. by the end of the sixth quarter in residence, excluding summers. Department procedures require selection of a faculty thesis adviser, preparation of a written research proposal, approval of this proposal by the thesis adviser, selection of a committee for the Ph.D. qualifying examination, and approval of the membership by the graduate coordinator and chair of the department. The research examination consists of three parts: oral presentation of a research proposal, examination on the research proposal, and examination on subject matter relevant to the proposed research. The exam should be scheduled for prior to May 1, so that the outcome of the exam is known at the time of the annual spring evaluation of graduate students.
3. Upon qualifying for Ph.D. candidacy, the student and thesis adviser, who must be a department faculty member, choose a research committee that includes a minimum of two faculty members in the University in addition to the adviser. Annually, in the month of March or April, the candidate must organize a meeting of the research committee to present a brief progress report covering the past year.
4. Under the supervision of the research advisory committee, the candidate must prepare a doctoral dissertation that is a contribution to knowledge and is the result of independent research. The format of the dissertation must meet University guidelines. The student is strongly urged to prepare dissertation chapters that, in scientific content and format, are readily publishable.
5. The doctoral dissertation is defended in the University oral examination. The research adviser and two other members of the research committee are determined to be readers of the draft dissertation. The readers are charged to read the draft and to certify in writing to the department that it is adequate to serve as a basis for the University oral examination. Upon obtaining this written certification, the student is permitted to schedule the University oral examination.

PH.D. MINOR

Candidates for the Ph.D. degree in other departments who wish to obtain a minor in Geological and Environmental Sciences must complete, with a GPA of 3.0 (B) or better, 20 units in the geosciences in lecture courses intended for graduate students. The selection of courses must be approved by the student's GES adviser and the department chair.

COURSES

WIM indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

UNDERGRADUATE

GES 1. Dynamic Earth: Fundamentals of Earth Science—For nonmajors or prospective majors in Geological and Environmental Sciences or Earth Systems. Activity-based; field trips. Processes that shape the earth's landforms, produce minerals and rocks, create soils, deform its crust, and move continents; surficial processes involving water, wind, and ice, and their role in erosion and sediment production; processes within the earth's interior with emphasis on global tectonics; determining the ages of rocks and geologic events; hazards including earthquakes, volcanoes, flooding, landslides, and their mitigation; and nonrenewable resources, energy, and environmental problems. Recommended: high school chemistry and physics. GER:DB-NatSci

5 units, Aut (Egger, A), Spr (Hilley, G)

GES 1X. Digging Deeper: Exploring the Literature of Geology—Additional meetings with instructors and guest scientists concerning primary literature and research studies that underpin concepts and readings in GES 1. Corequisite: GES 1.

1 unit, Aut (Egger, A), Spr (Hilley, G)

GES 2. The History of Life on Earth—How life evolved on Earth from the formation of the planet to the origin of humans. Includes the origin of life, the origin and impact of oxygenic photosynthesis, the evolution of multicellular life, and trends in biodiversity. Focus is on interactions between environmental change and biological evolution and how geological processes affect the fossil record. Required lab. GER:DB-NatSci

4 units, Win (Payne, J)

GES 7A. An Introduction to Wilderness Skills—Living, traveling, and working in the wilderness for those planning fieldwork in the backcountry. Local geology, environmental ethics, trip planning, first aid, and leadership techniques. Four weekend outings focus on backcountry travel, minimum impact camping, equipment use and maintenance, rock climbing, navigation, and telemark skiing. 7A emphasizes wilderness travel and climbing. 7B emphasizes winter camping skills and backcountry skiing. Food, group and major personal gear provided. Guest speakers. Fee. See http://www.stanford.edu/class/ges7, or email oep-teachers@lists.stanford.edu.

1 unit, Aut (Bird, D)

GES 7B. An Introduction to Wilderness Skills—Living, traveling, and working in the wilderness for those planning fieldwork in the backcountry. Local geology, environmental ethics, trip planning, first aid, and leadership techniques. Four weekend outings focus on backcountry travel, minimum impact camping, equipment use and maintenance, rock climbing, navigation, and telemark skiing. 7A emphasizes wilderness travel and climbing. 7B emphasizes winter camping skills and backcountry skiing. Food, group and major personal gear provided. Guest speakers. Fee. See http://www.stanford.edu/class/ges7, or email oep-teachers@lists.stanford.edu.

1 unit, Win (Bird, D)

GES 7C. Advanced Wilderness Skills—For students with prior backcountry experience. Backcountry skiing, mountaineering, climbing, first aid, and trip planning. Focus is on outdoor leadership experience and trip management techniques. Food, group, and major personal gear provided. Four mandatory weekend trips. Fee. See http://www.stanford.edu/class/ges7/ for information or contact oep-teachers@lists.stanford.edu. Prerequisite: application.

1 unit, Spr (Bird, D)

GES 8. The Oceans: An Introduction to the Marine Environment—For non-majors and earth science and environmental majors. Topics: topography and geology of the sea floor; evolution of ocean basins; circulation of ocean and atmosphere; nature of sea water, waves, and tides; and the history of the major ocean basins. The interface between continents and ocean basins, emphasizing estuaries, beaches, and continental shelves with California margin examples. Relationships among the distribution of inorganic constituents, ocean circulation, biologic productivity, and marine environments from deep sea to the coast. One-day field trip to measure and analyze waves and currents. GER:DB-NatSci

3 units, Spr, Sum (Ingle, J)

GES 42N. Earthquakes, Faults, and Mountains of the Bay Area—Stanford Introductory Seminar. Active faulting and erosion in the Bay Area, and its effects upon landscapes. Earth science concepts and skills through investigation of the valley, mountain, and coastal areas around Stanford. Faulting associated with the San Andreas Fault, coastal processes along the San Mateo coast, uplift of the mountains by plate tectonic processes, and landsliding in urban and mountainous areas. Field excursions; student projects.

5 units, Aut (Hilley, G)

GES 43N. Environmental Problems—Stanford Introductory Seminar. Preference to freshmen. Components of multidisciplinary environmental problems and ethical questions associated with decision making in the regulatory arena. Students lead discussions on environmental issues such as groundwater contamination from point and nonpoint sources, cumulative watershed effects related to timber and mining practices, acid rain, subsurface disposal of nuclear waste, pipelines, slope stability, and oil tanker spills. GER:DB-NatSci

3 units, Win (Loague, K)

GES 44N. A Transition to Sustainability: Development and Environment in the 21st Century—Preference to freshmen. What will it take to meet the needs of the human population while preserving Earth's life support systems? Trends and transitions in population growth, resource consumption, and environmental conditions at regional and global scales. Approaches to move the world towards sustainability in energy, industry, urbanization, living resources, air, and water. Students prepare a case study of sustainable development in the area of their choice. GER:DB-NatSci

3 units, not given this year

GES 45N. Powering the Rim: Energy Issues for the Pacific—(Same as EARTHSYS 45N.) Stanford Introductory Seminar. Preference to freshman. Geologic, economic, and policy issues shaping energy use and development throughout the Pacific Rim. Topics include the resource potential of fossil fuels, the curse of oil, energy security, global climate change, how efficiency and conservation can reduce demand, alternative energy resources, trade vulnerabilities, the geopolitics of energy use, and energy flow among the countries of the Pacific. Game simulation. Students develop an energy profile for a specific country.

3 units, Win (Howell, D; Graham, S)

GES 49N. Field Trip to Death Valley and Owens Valley—Stanford Introductory Seminar. Preference to freshmen. California's Death Valley and Owens Valley as natural laboratories for exploring a billion years of earth history: ancient ocean sediments, mountain building, earthquake faulting, glacial landscapes, volcanic eruptions, prehistoric climate changes, and historic human impacts. Six-day field trip to these areas during Spring Break. Term paper is written as a chapter for a field trip guidebook. Oral presentation on the outcrop at the field trip stop described in the guidebook chapter. The basics of plate tectonics and geology. Rock identification, reading topographic and geologic maps, and interpreting remote sensing imagery. Camping and moderate hiking required. GER:DB-NatSci

3 units, Win (Mahood, G)

GES 50Q. The Coastal Zone Environment—Stanford Introductory Seminar. Preference to sophomores. The oceanographic, geological, and biological character of coastal zone environments, including continental shelves, estuaries, and coastal wetlands, with emphasis on San Francisco Bay. Five required field trips examine estuarine and coastal environments, and agencies and facilities that manage these resources. Students present original research. Prerequisite: beginning course in Biology such as BIOSCI 51, Chemistry such as CHEM 30 or 31, Earth Sciences such as GES 1 or 2, or Earth Systems such as EARTHSYS 10. GER:DB-NatSci

3 units, Win (Ingle, J)

GES 54Q. California Landforms and Plate Tectonics—Stanford Introductory Seminar. Preference to sophomores. The forces of plate tectonics at work on the landscape of California. Faulting, folding and volcanism analyzed with satellite imagery and air photos. Principles of rock deformation introduced with laboratory experiments that produce structures similar to those forming in California. Field trips provide human perspective of large scale tectonic features. Final paper involves analyzing active deformation and earthquakes in a region of student's choice. GER:DB-NatSci

3 units, Aut (Miller, E)

GES 55Q. The California Gold Rush: Geologic Background and Environmental Impact—Stanford Introductory Seminar. Preference to sophomores. Topics include: geologic processes that led to the concentration of gold in the river gravels and rocks of the Mother Lode region of California; and environmental impact of the Gold Rush due to population increase, mining operations, and high concentrations of arsenic and mercury in sediments from hard rock mining and milling operations. Recommended: introductory geology. GER:DB-NatSci, WRITE-2

3 units, Spr (Bird, D)

GES 57Q. How to Critically Read and Discuss Scientific Literature—Stanford Introductory Seminar. Preference to sophomores. Topics: how to approach the reading of scientific articles, and how to understand and evaluate the information contained in them through guided reading, and a review of such papers. GER:DB-NatSci, WRITE-2

3 units, Win (Paytan, A)

GES 90. Introduction to Geochemistry—The chemistry of the solid earth and its atmosphere and oceans, emphasizing the processes that control the distribution of the elements in the earth over geological time and at present, and on the conceptual and analytical tools needed to explore these questions. The basics of geochemical thermodynamics and isotope geochemistry. The formation of the elements, crust, atmosphere and oceans, global geochemical cycles, and the interaction of geochemistry, biological evolution, and climate. Recommended: introductory chemistry. GER:DB-NatSci

3-4 units, Win (Stebbins, J)

GES 102. Earth Materials—The minerals, rocks, soils, and liquids that comprise the earth. How to identify, classify, and interpret rock-forming minerals and igneous, metamorphic, and sedimentary rock types. Emphasis is on information provided by common minerals and rocks about the earth's major processes including magmatism, metamorphism, weathering, erosion, and deposition; the relationship of these processes to plate tectonics and earth cycles. Prerequisite: introductory geology course. Recommended: introductory chemistry. GER:DB-NatSci
5 units, Aut (Brown, G)

GES 103. Rocks in Thin Section—How to identify minerals and common mineral associations in igneous, metamorphic, and sedimentary rocks. How to describe typical crystallization relations and textures of igneous rocks, mineral growth and reaction relations in metamorphic rocks, and deformational textures and their relation to mineral growth. The petrographic microscope. Prerequisite: 102.
3 units, Win (Miller, E)

GES 110. Structural Geology and Tectonics—Techniques, principles, and theory to describe, measure, analyze, and interpret deformation-related structures in rocks and minerals. Techniques of structural data collection in the field; lab and computer analysis of structural data; theory and principles of brittle deformation, faulting, and folding; interpretation of geologic maps and principles of cross-section contruction; strain measurement and the structural analysis of metaphorphic rocks; evolution of fold and thrust belts, rift-related sedimentary basins, and strike-slip fault systems. Prerequisites: 1, calculus. Recommended: 102. GER:DB-NatSci
5 units, Spr (Miller, E)

GES 111A. Fundamentals of Structural Geology—(Same as CEE 195A.) Techniques for structural mapping; using differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; measurement and analysis of stress. Sources include field and laboratory data integrated with conceptual and mechanical models. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisites: GES 1, MATH 51, 52. GER:DB-NatSci
3 units, Aut (Pollard, D)

GES 111B. Fundamentals of Structural Geology—(Same as CEE 195B.) Continuation of GES 111A/CEE 195A. Conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding and magma dynamics; model development and methodology. Sources include field and laboratory data integrated with conceptual and mechanical models. Models of tectonic processes are constructed and solutions visualized using MATLAB. Prerequisite: GES 111A/CEE 195B.
3 units, Win (Pollard, D)

GES 112. Mapping the Geological Environment—Geological mapping tools and techniques. Field training with GPS and laser ranging tools. Data sets from modern surveying and mapping campaigns employing lab and field-based laser scanning, field-based total stations, airborne photography and laser swath mapping (ALSM), the satellite Global Positioning System (GPS), and 3D seismic reflection surveys. These data analyzed using elementary differential geometry. MATLAB introduced as the computational and graphics engine. Prerequisites: GES 1, MATH 51, 52. GER: DB-NatSci
3 units, Win (Pollard, D)

GES 115. Engineering Geology Practice—(Same as CEE 196.) The application of geologic fundamentals to the planning and design of civil engineering projects. Field exercises and case studies emphasize the impact of site geology on the planning, design, and construction of civil works such as buildings, foundations, transportation facilities, excavations, tunnels and underground storage space, and water supply facilities. Topics: Quaternary history and tectonics, formation and physical properties of surficial deposits, site investigation techniques, geologic hazards, and professional ethics. Prerequisite: GES 1 or consent of instructor. GER:DB-NatSci
3 units, alternate years, not given this year

GES 120. Planetary and Early Biological Evolution Seminar—(Graduate students register for 220.) Interdisciplinary. For upper division science undergraduates and graduate students. Synthesis of biology, geology, physics, and chemistry. Recent approaches for identifying traces of past life on Earth. How to look for life on other planets such as Mars, Europa, and Titan. May be repeated for credit.
2-3 units, Spr (Lowe, D)

GES 121. What Makes a Habitable Planet?—Physical processes affecting habitability such as large impacts and the atmospheric greenhouse effect, comets, geochemistry, the rise of oxygen, climate controls, and impact cratering. Detecting and interpreting the spectra of extrasolar terrestrial planets. Student-led discussions of readings from the scientific literature. Team taught by planetary scientists from NASA Ames Research Center.
3 units, Aut (Lowe, D)

GES 130. Soil Physics and Hydrology—First of a two-part sequence on surface and near-surface processes. The waters of the Earth, and their occurrence, distribution, circulation, and reaction with the environment. Topics: precipitation, evapotranspiration, infiltration and vadose zone, groundwater, surface water and streamflow generation, lakes, water supply and use, and water balance and flood frequency estimates. Current and classic theory in soil physics and hydrology. Urban, rangeland, and forested environments. GER:DB-NatSci
3 units, Aut (Loague, K)

GES 131. Fluvial Systems and Landscape Evolution—Second part of sequence on surface and near-surface processes. Materials of the Earth and hydrologically driven landscape processes. Topics: hillslope hydrology, weathering of rocks and soils, erosion, flow failures, mass wasting, and conceptual models of landscape evolution. Current and classic theory in geomorphology. GER:DB-NatSci
3 units, Win (Staff)

GES 138. Urbanization, Global Change, and Sustainability—The relationship between urbanization and global change at local, regional, and global scales. Global environmental change as driver and outcome of human (economic, political, cultural, and social) and physical (urban structure, expansion, and land use) processes in urban areas. Urbanization as a demographic and biophysical phenomenon. Topics include the human and biophysical dimensions of global environmental change as relevant to the process of urbanization, environmental implications of urban processes and form, urban ecological services, and urban climate.
3 units, not given this year

GES 142. Remote Sensing of Land Use and Land Cover—(Same as EARTHSYS 142/242.) The use of satellite remote sensing to monitor land use and land cover, with emphasis on terrestrial changes. Topics include pre-processing data, biophysical properties of vegetation observable by satellite, accuracy assessment of maps derived from remote sensing, and methodologies to detect changes such as urbanization, deforestation, vegetation health, and wildfires.
4 units, Win (Seto, K)

GES 144. Fundamentals of Geographic Information Science (GIS)—Survey of geographic information including maps, satellite imagery, and census data, approaches to spatial data, and tools for integrating and examining spatially-explicit data. Emphasis is on fundamental concepts of geographic information science and associated technologies. Topics include geographic data structure, cartography, remotely sensed data, statistical analysis of geographic data, spatial analysis, map design, and geographic information system software. Computer lab assignments. GER:DB-NatSci
4 units, Win (Seto, K)

GES 145. Energy Flow and Policy: The Pacific Rim—(Graduate students register for 245; same as EARTHSYS 145/245.) Factors shaping energy use and development throughout the Pacific Rim. Topics include fossil and alternative energy resources, supply and trade vulnerabilities, the geopolitics of energy use, and the environmental and social impacts of waste streams. Class develops a game simulation based on critical energy issues, student-initiated energy projections, and assessment of the principal stakeholders.

3 units, alternate years, not given this year

GES 150. Senior Seminar: Issues in Earth Sciences—Focus is on written and oral communication in a topical context. Topics from current frontiers in earth science research and issues of concern to the public. Readings, oral presentations, written work, and peer review. May be repeated for credit. WIM.

3 units, Win (Egger, A; Bird, D)

GES 151. Sedimentary Geology and Petrography: Depositional Systems—Topics: weathering, erosion and transportation, deposition, origins of sedimentary structures and textures, sediment composition, diagenesis, sedimentary facies, tectonics and sedimentation, and the characteristics of the major siliciclastic and carbonate depositional environments. Lab: methods of analysis of sediments in hand specimen and thin section. Field trips. Prerequisites: 1, 102, 103. GER:DB-NatSci

4 units, Win (Graham, S; Lowe, D)

GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction—Extracting information from data using statistical summaries and graphical visualization, statistical measures of association and correlation, distribution models, sampling, error estimation and confidence intervals, linear models and regression analysis, introduction to time-series and spatial data with geostatistics, applications including environmental monitoring, natural hazards, and experimental design. Either or both of 160 and 161 may be taken. GER:DB-NatSci

3 units, Spr (Switzer, P)

GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics—(Same as ENERGY 161.) Statistical analysis and graphical display of data, common distribution models, sampling, and regression. The variogram as a tool for modeling spatial correlation; variogram estimation and modeling; introduction to spatial mapping and prediction with kriging; integration of remote sensing and other ancillary information using co-kriging models; spatial uncertainty; introduction to geostatistical software applied to large environmental, climatological, and reservoir engineering databases; emphasis is on practical use of geostatistical tools. GER:DB-NatSci

3-4 units, Win (Caers, J)

GES 164. Stable Isotopes—(Graduate students register for 264.) Light stable isotopes and their application to geological, ecological, and environmental problems. Isotopic systematics of hydrogen, carbon, nitrogen, oxygen, and sulfur; chemical and biogenic fractionation of light isotopes in the atmosphere, hydrosphere, and rocks and minerals. GER:DB-NatSci

3 units, alternate years, not given this year

GES 164L. Stable Isotopes Laboratory—Practical laboratory for 164.

2-3 units, Win (Chamberlain, P)

GES 165. Radiogenic Isotopes and Geochronology—Applications to geological and geophysical problems. Topics: nuclear structure, isotope systematics, decay schemes for the principal nuclides used in earth sciences, equilibrium and disequilibrium, diffusion and transport phenomena, blocking (closure) of isotopic and magnetic systems, creation and annealing of fission tracks, neutron activation, a review of geologic timescales, chronostratigraphy, magnetostratigraphy, and cosmogenic exposure ages. Alpha counting, mass spectrometry by gas source, solid source, ion probe and accelerator methods. Fundamentals of K-Ar, Ar-Ar, Rb-Sr, U-Pb fission track (U+Th)/He, and cosmogenic isotope methods. Recommended: undergraduate calculus, chemistry, geology, and physics. GER:DB-NatSci

3 units, not given this year

GES 166. Soil Chemistry—(Graduate students register for 266.) Practical and quantitative treatment of soil processes affecting chemical reactivity, transformation, retention, and bioavailability. Principles of primary areas of soil chemistry: inorganic and organic soil components, complex equilibria in soil solutions, and adsorption phenomena at the solid-water interface. Processes and remediation of acid, saline, and wetland soils. Recommended: soil science and introductory chemistry and microbiology. GER:DB-NatSci

4 units, alternate years, not given this year

GES 170. Environmental Geochemistry—Solid, aqueous, and gaseous phases comprising the environment, their natural compositional variations, and chemical interactions. Contrast between natural sources of hazardous elements and compounds and types and sources of anthropogenic contaminants and pollutants. Chemical and physical processes of weathering and soil formation. Chemical factors that affect the stability of solids and aqueous species under earth surface conditions. The release, mobility, and fate of contaminants in natural waters and the roles that water and dissolved substances play in the physical behavior of rocks and soils. The impact of contaminants and design of remediation strategies. Case studies. Prerequisite: 90 or consent of instructor. GER:DB-NatSci

4 units, Win (Brown, G)

GES 171. Geochemical Thermodynamics—Introduction to the application of chemical principles and concepts to geologic systems. The chemical behavior of fluids, minerals, and gases using simple equilibrium approaches to modeling the geochemical consequences of diagenetic, hydrothermal, metamorphic, and igneous processes. Topics: reversible thermodynamics, solution chemistry, mineral-solution equilibria, reaction kinetics, and the distribution and transport of elements by geologic processes. Prerequisite: 80. GER:DB-NatSci

3 units, Aut (Bird, D)

GES 175. Science of Soils—Physical, chemical, and biological processes within soil systems. Emphasis is on factors governing nutrient availability, plant growth and production, land-resource management, and pollution within soils. How to classify soils and assess nutrient cycling and contaminant fate. Recommended: introductory chemistry and biology. GER:DB-NatSci

4 units, Spr (Fendorf, S)

GES 180. Igneous Processes—For juniors, seniors and beginning graduate students in Earth Sciences. Structure and physical properties of magmas; use of phase equilibria and mineral barometers and thermometers to determine conditions of magmatic processes; melting and magmatic lineages as a function of tectonic setting; processes that control magma composition including fractional crystallization, partial melting, and assimilation; petrogenetic use of trace elements and isotopes. Labs emphasize identification of volcanic and plutonic rocks in thin section and interpretation of rock textures. May be taken for 3 units without lab. Prerequisite 102, 103, or consent of instructor.

3-5 units, Spr (Stebbins, J), alternate years, not given next year

GES 181. Metamorphic Processes—For juniors, seniors, and beginning graduate students in Earth Sciences. Thermodynamics and phase equilibria of multiple component systems; use of phase equilibria to determine pressure and temperature of metamorphic assemblages; use of the Gibbs method to reconstruct pressure-temperature paths of metamorphic rocks; metamorphic thermochronology; heat flow in the continental crust; links between tectonics and metamorphism; and the role of heat and mass transfer in the Earth's crust. Labs emphasize identification of metamorphic rocks and minerals for common pelitic and basic rocks and interpretation of rock textures. May be taken for 3 units without lab. Prerequisites: 102, 103. GER:DB-NatSci

3-5 units, not given this year

SCHOOL OF EARTH SCIENCES

GES 182. Field Seminar on Continental-Margin Volcanism—For juniors, seniors, and graduate students in the earth sciences and archeology. One weekend-long, and two one-day field trips to study Cenozoic volcanism associated with subduction and with passage of the Mendocino Triple Junction off the west coast of California: Mt. Lassen/Mt. Shasta/Modoc plateau; Clear Lake/Sonoma volcanics; Pinnacles National Monument. Andesite and basalt lavas, cinder cones, mixed magmas, blast deposit, debris avalanches, volcanic mudflows, hydrologic controls of springs in volcanic terrains, hydrothermal alteration and modern geothermal systems, Hg mineralization, obsidian source. Prerequisite: 1, 80 or equivalent.
2 units, not given this year

GES 183. California Desert Geology—Field seminar. For upper division undergraduates and graduate students in the earth sciences and archaeology. Six-day field trip over Spring Break to Mojave Desert, Death Valley, and Owens Valley. Basin-and-range faulting, alluvial fans, playas, sand dunes, metamorphic rocks, granites of the Sierra Nevada, obsidian lava flows and the deposits of major explosive eruptions, hot springs and ore deposits, and desert landscapes. Camping and moderate hiking.
1 unit, not given this year

GES 185. Volcanology—For juniors, seniors, and beginning graduate students in Earth Sciences and Archaeology. How volcanic landforms and deposits relate to the composition and physical properties of magmas and the modes of emplacement. Labs emphasize recognizing types of lavas and products of explosive eruptions. Volcanic hazards and the effects of eruptions on climate and the atmosphere; volcanic-hosted geothermal systems and mineral resources. Required four-day field trip over Memorial Day weekend to study silicic and mafic volcanism associated with the western margin of the Basin and Range province. Prerequisite: 1, 102 or equivalent. GER:DB-NatSci
4 units, Spr (Mahood, G), alternate years, not given next year

GES 186. Geoarchaeology—(Graduate students register for 286; same as ARCHLGY 118/218.) For juniors, seniors, and beginning graduate students with interests in archaeology or geosciences. Geological concepts, techniques, and data in the study of artifacts and the interpretation of the archaeological record. Topics include: sediments and soils; sedimentary settings of site formation; postdepositional processes that disturb sites; paleoenvironmental reconstruction of past climates and landscapes using plant and animal remains and isotopic studies; raw materials (minerals, metals, stone, shells, clay, building materials) and methods used in sourcing; estimating age based on stratigraphic and radiometric techniques. Weekly lab; weekend field trip to local archaeological/geological site. GER:DB-NatSci
5 units, alternate years, not given this year

GES 188. Analytical Perspectives on Archaeological Pottery—(Graduate students register for 288.) Geoarchaeological analysis to understand pottery as an artifact that reflects the interactions of people with the geological components of their landscapes. Additional topics include: ceramic technology; organization of ceramic production and distribution; consumption and reuse; typological analysis; stylistic analysis; and the interpretation of pottery as markers of social identities and boundaries. Examination of objects in the Cantor Arts Center and the use of analytical laboratories in GES.
3-5 units, Aut (Carter, S)

GES 190. Field Research—(Graduate students register for 299.) Two-three week field research projects. Written report required. May be repeated three times.
2-4 units, Aut, Win, Spr, Sum (Staff)

GES 191. GES Field Trips—Field trips for teaching and research purposes. Trips average 5-10 days. Prerequisite: consent of instructor.
1 unit, Aut, Win, Spr, Sum (Staff)

GES 192. Undergraduate Research in Geological and Environmental Sciences—Field-, lab-, or literature-based. Faculty supervision. Written reports.
1-10 units, Aut, Win, Spr, Sum (Staff)

GES 197. Senior Thesis—For seniors who wish to write a thesis based on research in 192 or as a summer research fellow. May not be repeated for credit; may not be taken if enrolled in 199.
3-5 units, Aut, Win, Spr, Sum (Staff)

GES 198. Special Problems in Geological and Environmental Sciences—Reading and instruction under faculty supervision. Written reports.
1-10 units, Aut, Win, Spr, Sum (Staff)

GES 199. Honors Program—Research on a topic of special interest. See Undergraduate Honors Program above.
1-10 units, Aut, Win, Spr, Sum (Staff)

GRADUATE

GES 200. Professional Development in Geoscience Education—May be repeated for credit.
1 unit, Aut, Win, Spr (Staff)

GES 201. Science Course Design—(Same as CTL 201.) For students interested in an academic career and who anticipate designing science courses at the undergraduate or graduate level. Goal is to apply research on science learning to the design of effective course materials. Topics include syllabus design, course content and format decisions, assessment planning and grading, and strategies for teaching improvement.
2-3 units, Aut (Wright-Dunbar, R)

GES 205. Advanced Oceanography—For upper-division undergraduates and graduate students in the earth, biologic, and environmental sciences. Topical issues in marine science/oceanography. Topics vary each year following or anticipating research trends in oceanographic research. Focus is on links between the circulation and physics of the ocean with climate in the N. Pacific region, and marine ecologic responses. Participation by marine scientists from research groups and organizations including the Monterey Bay Aquarium Research Institute.
3 units, not given this year

GES 206. Antarctic Marine Geology—For upper-division undergraduates and graduate students. Intermediate and advanced topics in marine geology and geophysics, focusing on examples from the Antarctic continental margin and adjacent Southern Ocean. Topics: glaciers, icebergs, and sea ice as geologic agents (glacial and glacial marine sedimentology, Southern Ocean current systems and deep ocean sedimentation), Antarctic biostratigraphy and chronostratigraphy (continental margin evolution). Students interpret seismic lines and sediment core/well log data. Examples from a recent scientific drilling expedition to Prydz Bay, Antarctica. Up to two students may have an opportunity to study at sea in Antarctica during Winter Quarter.
3 units, Win (Dunbar, R)

GES 209. Microstructures—For upper-division undergraduates and graduate students. Structural and metamorphic fabrics, whose interpretation are essential to understand the thermo-mechanical behavior of the crust, produced by variations in temperature, pressure, and deformation. Topics include rheology of the crust, strain partitioning, the brittle ductile transition, development of foliations, lineations, relation to metamorphic mineral growth, preferred crystallographic orientations, shear zone deformation, and geochronologic methods of dating deformation. Lab involves study of deformed and metamorphosed rocks in thin section. By arrangement.
3-5 units, Win (Miller, E)

GES 210. Geologic Evolution of the Western U.S. Cordillera—For upper level undergraduates and graduates. From the Precambrian to contemporary strike-slip faulting and extension based on the rock record through time. Characteristic structures formed by crustal shortening, extension and strike slip, the origins of magmatism and batholiths, metamorphism and mountain building, and how this land-based geologic record is related to crustal-scale processes and plate tectonic motions.
2-3 units, Win (Miller, E)

GES 211. Topics in Regional Geology and Tectonics—May be repeated for credit.
2-3 units, Spr (Miller, E)

GES 212. Topics in Tectonic Geomorphology—For upper-division undergraduates and graduate students. Topics vary and may include coupling among erosional, tectonic, and chemical weathering processes at the scale of orogens; historical review of tectonic geomorphology; hillslope and fluvial process response to active uplift; measures of landscape form and their relationship to tectonic uplift and bedrock lithology. May be repeated for credit.

2 units, Aut (Hilley, G)

GES 214. Topics in Paleobiology—For upper division undergraduates and graduate students. Topics vary each year; focus is on paleontological, sedimentological, and geochemical approaches to the history of life. Topics may include: mass extinction events; evolutionary radiations; the history of global biodiversity; links between evolutionary histories of primary producers and consumers; and the quality of the fossil record. May be repeated for credit.

1 unit, alternate years, not given this year

GES 215A. Structural Geology and Rock Mechanics—(Same as CEE 297G.) Quantitative field and laboratory data integrated with solutions to initial and boundary-value problems of continuum mechanics introduce tectonic processes in Earth's crust that lead to the development of geological structures including folds, faults, fractures and fabrics. Topics include: techniques and tools for structural mapping; using differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis. Data sets analyzed using MATLAB. Prerequisites: GES 1, MATH 53, MATLAB or equivalent.

3-5 units, Aut (Pollard, D)

GES 215B. Structural Geology and Rock Mechanics—(Same as CEE 297H.) Field equations for elastic solids and viscous fluids derived from conservation laws to develop mechanical models for tectonic processes and their structural products. Topics include: conservation of mass and momentum in a deformable continuum; linear elastic deformation and elastic properties of rock; brittle deformation including fracture and faulting; linear viscous flow including folding, model development, and methodology. Models constructed and solutions visualized using MATLAB. Prerequisite: GES 215A.

3-5 units, Win (Pollard, D)

GES 216. Rock Fracture Mechanics—Principles and tools of elasticity theory and fracture mechanics are applied to the origins and physical behaviors of faults, dikes, joints, veins, solution surfaces, and other natural structures in rock. Field observations, engineering rock fracture mechanics, and the elastic theory of cracks. The role of natural fractures in brittle rock deformation, and fluid flow in the earth's crust with applications to crustal deformation, structural geology, petroleum geology, engineering, and hydrogeology. Prerequisite: 215 or equivalent.

3-5 units, alternate years, not given this year

GES 217. Faults, Fractures, and Fluid Flow—Process-based approach to rock failure; the microstructures and overall architectures of the failure products including faults, joints, solution seams, and types of deformation bands. Fluid flow properties of these structures are characterized with emphasis on sealing and transmitting of faults and their role in hydrocarbon flow, migration, and entrapment. Case studies of fracture characterization experiments in aquifers, oil and gas reservoirs, and waste repository sites. Guest speakers; weekend field trip. Prerequisite: first-year graduate student in Earth Sciences.

3 units, alternate years, not given this year

GES 218. Communicating Science—For undergraduates and graduate students interested in teaching science in local schools. Inquiry-based science teaching methods. How to communicate scientific knowledge and improve presentations. Six weeks of supervised teaching in a local school classroom. Prerequisite: course in introductory biology, geology, chemistry, or marine sciences.

3 units, Aut (Saltzman, J)

GES 219. Paleoceanography—For upper-division undergraduates and graduate students. How can we learn about the chemistry, circulation, biology, and geology of past oceans and why is this of interest? Evidence for substantial changes in Earth's climate and surficial environment in the sedimentary record. Fundamentals of gathering and interpreting this information in the context of how earth processes functioned in the past and their relevance for the future habitability of Earth.

1-3 units, alternate years, not given this year

GES 220. Planetary and Early Biological Evolution Seminar—(For graduate students; see 120.)

2-3 units, Spr (Lowe, D)

GES 222. Planetary Systems: Dynamics and Origins—For students with a background in astronomy, earth sciences, geophysics, or physics. Motions of planets, moons, and small bodies; energy transport in planetary systems; meteorites and the constraints they provide on the formation of the solar system; asteroids and Kuiper belt objects; comets; planetary rings; planet formation; and extrasolar planets. In-class presentation of student papers.

3-4 units, Aut (Staff)

GES 223. Planetary Systems: Atmospheres, Surfaces, and Interiors—Focus is on physical processes, such as radiation transport, atmospheric dynamics, thermal convection, and volcanism, shaping the interiors, surfaces, and atmospheres of the major planets in the solar system. How these processes manifest themselves under various conditions in the solar system. Case study of the surface and atmosphere of Mars. Application of comparative planetary science to extrasolar planets and brown dwarfs. In-class presentation of student papers.

3 units, Win (Staff)

GES 225. Isotopes in Geological and Environmental Research—For upper-division undergraduates and graduate students. The applications of isotopic systems in geological, oceanographic, and environmental studies at low temperature. The use of isotopes as tracers for weathering rate, biogeochemical cycling, food-web structures, ecology, paleochemistry, provenance, circulation, and anthropogenic and extraterrestrial inputs. Emphasis is on developing skills in reading and evaluation of scientific papers, manuscript reviews, and proposal preparation. Prerequisite: 163, 164, or consent of instructor.

1-3 units, not given this year

GES 230. Physical Hydrogeology—(Same as CEE 260A.) Theory of underground water occurrence and flow, analysis of field data and aquifer tests, geologic groundwater environments, solution of field problems, groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.

4 units, Aut (Gorelick, S)

GES 231. Contaminant Hydrogeology—(Same as CEE 260C.) For earth scientists and engineers. Environmental and water resource problems involving contaminated groundwater. The processes affecting contaminant migration through porous media including interactions between dissolved substances and solid media. Conceptual and quantitative treatment of advective-dispersive transport with reacting solutes. Predictive models of contaminant behavior controlled by local equilibrium and kinetics. Modern methods of contaminant transport simulation and optimal aquifer remediation. Prerequisite: GES 230 or CEE 260A or equivalent.

4 units, Spr (Staff)

GES 237. Surface and Near-Surface Hydrologic Response—(Same as CEE 260B.) Quantitative review of process-based hydrology and geomorphology. Introduction to finite-difference and finite-element methods of numerical analysis. Topics: biometeorology, unsaturated and saturated subsurface fluid flow, overland and open channel flow, and physically-based simulation of coupled surface and near-surface hydrologic response. Links hydrogeology, soil physics, and surface water hydrology.

3 units, alternate years, not given this year

GES 238. Soil Physics—Physical properties of the soil solid phase emphasizing the transport, retention, and transformation of water, heat, gases, and solutes in the unsaturated subsurface. Field experiments.
3 units, Aut (Loague, K)

GES 240. Geostatistics for Spatial Phenomena—(Same as ENERGY 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and cokriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Multiple-point geostatistics and training image-based stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB and SGEMS software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, STATS 116, GES 161 or equivalent.
3-4 units, Win (Journel, A)

GES 242. Topics in Advanced Geostatistics—(Same as ENERGY 242.) Conditional expectation theory and projections in Hilbert spaces; parametric versus non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, and annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, C++/Fortran.
3-4 units, alternate years, not given this year

GES 245. Energy Flow and Policy: The Pacific Rim—(For graduate students; see 145; same as EARTHSYS 145/245.)
3 units, alternate years, not given this year

GES 246. Reservoir Characterization and Flow Modeling with Outcrop Data—(Same as ENERGY 246.) Project addresses a reservoir management problem by studying an outcrop analog, constructing geostatistical reservoir models, and performing flow simulation. How to use outcrop observations in quantitative geological modeling and flow simulation. Relationships between disciplines. Weekend field trip.
3 units, Aut (Graham, S; Journel, A; Tchelepi, H)

GES 249. Petroleum Geochemistry in Environmental and Earth Science—How molecular fossils in crude oils, oil spills, refinery products, and human artifacts identify their age, origin, and environment of formation. The origin and habitat of petroleum, technology for its analysis, and parameters for interpretation, including: origins of molecular fossils; function, biosynthesis, and precursors; tectonic history related to the evolution of life, mass extinctions, and molecular fossils; petroleum refinery processes and the kinds of molecular fossils that survive; environmental pollution from natural and anthropogenic sources including how to identify genetic relationships among crude oil or oil spill samples; applications of molecular fossils to archaeology; worldwide petroleum systems through geologic time.
3 units, Win (Staff)

GES 250. Sedimentation Mechanics—The mechanics of sediment transport and deposition and the origins of sedimentary structures and textures as applied to interpreting ancient rock sequences. Dimensional analysis, fluid flow, drag, boundary layers, open channel flow, particle settling, erosion, sediment transport, sediment gravity flows, soft sediment deformation, and fluid escape. Field trip required.
4 units, not given this year

GES 251. Sedimentary Basins—Analysis of the depositional framework and tectonic evolution of sedimentary basins. Topics: tectonic and environmental controls on facies relations, synthesis of basin development through time in terms of depositional systems and tectonic settings. Weekend field trip required. Prerequisites: 110, 151.
3 units, alternate years, not given this year

GES 252. Sedimentary Petrography—Siliciclastic sediments and sedimentary rocks. Research in modern sedimentary mineralogy and petrography and the relationship between the composition and texture of sediments and their provenance, tectonic settings, and diagenetic histories. Topics vary yearly. Prerequisite: 151 or equivalent.
4 units, Aut (Lowe, D)

GES 253. Petroleum Geology and Exploration—The origin and occurrence of hydrocarbons. Topics: thermal maturation history in hydrocarbon generation, significance of sedimentary and tectonic structural setting, principles of accumulation, and exploration techniques. Prerequisites: 110, 151. Recommended: GEOPHYS 184.
3 units, Aut (Graham, S)

GES 254. Carbonate Sedimentology—The formation and post-depositional alteration of carbonate sediments and sedimentary structures primarily formed by organisms. Emphasis is on interacting influences of carbonate producing environments and other ecological, physical, and chemical considerations. Carbonate deposit stratigraphy and the development of carbonate terrains in contrasting tectonic settings. The post-depositional history and petrographic development of carbonate structures and carbonate rocks. Paleoecological aspects of carbonate sediments as proxies in broader geological context.
3 units, alternate years, not given this year

GES 255. Basin Modeling and 3-D Visualization—For advanced undergraduates or graduate students. Students use stratigraphy, subsurface maps, and basic well log, lithologic, paleontologic, and geochemical data to construct 1-D, 2-D, and 3-D models of petroleum systems that predict the extent of source-rock thermal maturity, petroleum migration paths, and the volumes and compositions of accumulations through time (4-D). Recent software such as PetroMod designed to reconstruct basin geohistory. Recommended: 251 or 253.
3 units, Win, Spr (Magoon, L; Peters, K)

GES 257. Clastic Sequence Stratigraphy—Sequence stratigraphy facilitates integration of all sources of geologic data, including seismic, log, core, and paleontological, into a time-stratigraphic model of sediment architecture. Tools applicable to regional and field scales. Emphasis is on practical applications and integration of seismic and well data to exploration and field reservoir problems. Examples from industry data; hands-on exercises.
3 units, Spr (Graham, S; McHargue, T)

GES 258. Introduction to Depositional Systems—The characteristics of the major sedimentary environments and their deposits in the geologic record, including alluvial fans, braided and meandering rivers, aeolian systems, deltas, open coasts, barred coasts, marine shelves, and deep-water systems. Emphasis is on subdivisions; morphology; the dynamics of modern systems; and the architectural organization and sedimentary structures, textures, and biological components of ancient deposits.
3 units, alternate years, not given this year

GES 260. Laboratory Methods in Organic Geochemistry—Knowledge of components in geochemical mixtures to understand geological and environmental samples. The presence and relative abundance of these compounds provides information on the biological source, depositional environment, burial history, biodegradation, and toxicity of organic materials. Laboratory methods to detect and quantify components of these mixtures. Methods for separation and analysis of organic compounds in geologic samples: extraction, liquid chromatography, absorption by zeolites, gas chromatography and gas chromatography-mass spectrometry. Student samples considered as material for analysis. Recommended: 249.
2-3 units, Spr (Moldowan, J)

GES 261. Physics and Chemistry of Minerals and Mineral Surfaces—The concepts of symmetry and periodicity in crystals; the physical properties of crystals and their relationship to atomic-level structure; basic structure types; crystal chemistry and bonding in solids and their relative stability; the interaction of x-rays with solids and liquids (scattering and spectroscopy); structural variations in silicate glasses and liquids; UV-visible spectroscopy and the color of minerals; review of the mineralogy, crystal chemistry, and structures of selected rock-forming silicates and oxides; mineral surface and interface geochemistry.
4 units, Spr (Brown, G)

GES 264. Stable Isotopes—(For graduate students; see 164.)
3 units, alternate years, not given this year

GES 265. Microbially Mediated Redox Processes—Chemical and biologically mediated oxidation and reduction processes within soils, sediments, and surface/subsurface waters. Emphasis is on reactions and processes at the solid-water interface. Topics include electron transfer processes, dissimilatory metal reduction, redox reaction rates, alterations in mineralogy, and modifications in chemical behavior with changes in redox state.
3 units, Win (Fendorf, S; Francis, C)

GES 266. Soil Chemistry—(For graduate students; see 166.)
4 units, alternate years, not given this year

GES 267. Solution-Mineral Equilibria: Theory—Procedures for calculating and evaluating the thermodynamic properties of reversible and irreversible reactions among rock-forming minerals and aqueous solutions in geologic systems. Emphasis is on the generation and utility of phase diagrams depicting solution-mineral interaction relevant to phase relations associated with weathering diagenetic, hydrothermal, and metamorphic processes, and the prediction of temperature, pressure, and the chemical potential of thermodynamic components compatible with observed mineralogic phase relations in geologic outcrops. Individual research topics. Prerequisite: 171.
3 units, Win (Bird, D)

GES 268. Geomicrobiology—How microorganisms shape the geochemistry of the Earth's crust including oceans, lakes, estuaries, subsurface environments, sediments, soils, mineral deposits, and rocks. Topics include mineral formation and dissolution; biogeochemical cycling of elements (carbon, nitrogen, sulfur, and metals); geochemical and mineralogical controls on microbial activity, diversity, and evolution; life in extreme environments; and the application of new techniques to geomicrobial systems. Recommended: introductory chemistry and microbiology such as CEE 274A.
3 units, not given this year

GES 269. Environmental Microbial Genomics—The application of molecular and environmental genomic approaches to the study of biogeochemically-important microorganisms in the environment without the need for cultivation. Emphasis is on genomic analysis of microorganisms by direct extraction and cloning of DNA from natural microbial assemblages. Topics include microbial energy generation and nutrient cycling, genome structure, gene function, physiology, phylogenetic and functional diversity, evolution, and population dynamics of uncultured communities.
1-3 units, not given this year

GES 270. Elkhorn Slough Microbiology—The microbial ecology and biogeochemistry of Elkhorn Slough, an agriculturally-impacted coastal estuary draining into Monterey Bay. The diversity of microbial lifestyles associated with estuarine physical/chemical gradients, and the influence of microbial activity on the geochemistry of the Slough, including the cycling of carbon, nitrogen, sulfur, and metals. Labs and field work. Location: Hopkins Marine Station.
3 units, Sum (Francis, C)

GES 275. Electron Probe Microanalytical Techniques—The practical and theoretical aspects of x-ray generation and detection, and the behavior of electron beams and x-rays in solids. The basic principles needed to quantitatively analyze chemically complex geological materials. Operation of the JEOL 733 electron microprobe and associated computer software for quantitatively analyzing materials. X-ray chemical mapping. Enrollment limited to 8.
2-3 units, Win (Jones, R)

GES 284. Field Seminar on Eastern Sierran Volcanism—For graduate students in the earth sciences and archaeology. Four-day trip over Memorial Day weekend to study silicic and mafic volcanism associated with the western margin of the Basin and Range province: basaltic lavas and cinder cones erupted along normal faults bounding Owens Valley, Long Valley caldera, postcaldera rhyolite lavas, hydrothermal alteration and hot springs, Holocene rhyolite lavas of the Inyo and Mono craters, volcanism of the Mono Basin with subaqueous basaltic eruptions, floating pumice blocks, and cryptodomes punching up lake sediments. If snow-level permits, silicic volcanism associated with the Bodie gold district. Prerequisite: 1, 102 or equivalent.
1 unit, (Mahood, G), alternate years, not given this year

GES 285. Petrogenesis of Crustal Magmatism—Radiogenic isotopes, stable isotopes, and trace elements applied to igneous processes; interaction of magmas with mantle and crust; convergent-margin magmatism; magmatism in extensional terrains; origins of rhyolites; residence times of magmas and magma chamber processes; granites as imperfect mirrors of their source regions; trace element modeling of igneous processes; trace element discriminant diagrams in tectonic analysis; sources of ore forming metals. Topics emphasize student interest. Prerequisite: 180 or equivalent.
3 units, Spr (Mahood, G), alternate years, not given next year

GES 286. Geoarchaeology—(For graduate students; see 186; same as ARCHLGY 118/218.)
5 units, alternate years, not given this year

GES 287. Tectonics, Topography, and Climate Change—For upper-division undergraduates and graduate students. The links between tectonics and climate change with emphasis on the Cenozoic era. Focus is on terrestrial climate records and how they relate to large-scale tectonics of mountain belts. Topics include stable isotope geochemistry, geochronology, chemical weathering, stratigraphy of terrestrial rocks, paleofauna and flora, climate proxies and records, and Cenozoic tectonics. Guest speakers, student presentations.
3 units, Spr (Chamberlain, P)

GES 288. Analytical Perspectives on Archaeological Pottery—(For graduate students; see 188.)
3-5 units, Aut (Carter, S)

GES 291. GES Field Trips—Field trips for teaching and research purposes. Trips average 5-10 days. Prerequisite: consent of instructor. (Staff)
1 unit, Aut, Win, Spr, Sum (Staff)

GES 299. Field Research—(For graduate students; see 190.)
2-4 units, Aut, Win, Spr, Sum (Staff)

GES 300. Earth Sciences Seminar—(Same as EARTHSYS 300, GEOPHYS 300, IPER 300, ENERGY 300.) Required for incoming graduate students except coterms. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and introduce them to each other across departments and research groups. Two faculty members present work at each meeting. May be repeated for credit.
1 unit, Aut (Matson, P; Graham, S)

GES 310. Climate Change, Climate Variability, and Landscape Development—The impact of long-term climate change on erosional processes and the evolution of Cenozoic landscapes. Climate data that highlight recurring climate variability on inter-annual to decadal timescales. The behavior of climate on multi-decadal to tectonic timescales over which significant changes in topography take place. The effects of climate change and variability on landscape development, sedimentary environments, and the deposits of these events.
1 unit, Aut (Hilley, G)

GES 314. Structural Geology and Geomechanics—Research seminar. May be repeated for credit.
1 unit, Aut, Win, Spr (Staff)

GES 322A,B,C. Seminar in Biogeochemistry—Current topics. May be repeated for credit.
1-2 units, not given this year

GES 323. Stanford at Sea—(Same as BIOHOPK 182H/323H, EARTHSYS 323.) Five weeks of marine science including oceanography, marine physiology, policy, maritime studies, conservation, and nautical science at Hopkins Marine Station, followed by five weeks at sea aboard a sailing research vessel in the Pacific Ocean. Shore component comprised of three multidisciplinary courses meeting daily and continuing aboard ship. Students develop an independent research project plan while ashore, and carry out the research at sea. In collaboration with the Sea Education Association of Woods Hole, MA.
16 units, Spr (Block, B; Dunbar, R; Micheli, F), alternate years, not given next year

GES 324. Seminar in Oceanography—Current topics. May be repeated for credit.
1-2 units, Aut, Win, Spr (Paytan, A; Arrigo, K)

GES 325. The Evolution of Body Size—(Same as BIOSCI 325.) For upper division undergraduates and graduate students. The influence of organism size on evolutionary and ecological patterns and processes. Focus is on integration of theoretical principles, observations of living organisms, and data from the fossil record. What are the physiological and ecological correlates of body size? Is there an optimum size? Do organisms tend to evolve to larger size? Does productivity control the size distribution of consumers? Does size affect the likelihood of extinction or speciation? How does size scale from the genome to the phenotype? How is metabolic rate involved in evolution of body size? What is the influence of geographic area on maximum body size?
2 units, Aut (Hadly, E; Payne, J)

GES 326. Isotopes and Biogeochemical Tracers in the Hydrological Cycle—Practical applications of environmental isotopes. The systematics of isotope fractionations and the distributions of isotopes in natural systems. Focus is on applications of isotopes for tracing waters, solutes, and biogeochemical reactions in hydrologic systems. Hydrological topics include tracing sources of ground and surface water, isotope hydrograph separations, groundwater influence on coastal systems, rock-water interactions, recharge rate, and groundwater dating. Biogeochemical topics include sources of contaminants, biogeochemical reaction mechanisms, nutrient sources and pathways, and food web studies.
3 units, not given this year

GES 327. The Glacial World—(Same as GEOPHYS 327.) The environmental changes that took place on Earth between the last glacial maximum (LGM) and the present. Focus is on the cause of the low atmospheric CO2 concentrations characteristic of the LGM and what conditions explain these reduced CO^2 levels. How changes in sea level, marine primary production, ocean circulation, and elemental cycling may have contributed to past global changes.
2-3 units, not given this year

GES 329. Topics in Near-Surface Hydrologic Processes—Classic studies and current research in hydrology, geomorphology, and soil physics. Topics: nonpoint source groundwater contamination (agriculture), evapotranspiration, unsaturated fluid flow and solute transport, rainfall-runoff mechanisms, slope stability, restoration geomorphology. May be repeated for credit. By arrangement.
1-3 units, Aut, Win (Loague, K)

GES 330. Advanced Topics in Hydrogeology—Topics: questioning classic explanations of physical processes; coupled physical, chemical, and biological processes affecting heat and solute transport. May be repeated for credit.
1-2 units, Aut, Win (Gorelick, S)

GES 332A. Seminar in Hydrogeology—Current topics. May be repeated for credit. Autumn Quarter has open enrollment. For Winter Quarter, consent of instructor is required.
1 unit, Aut (Gorelick, S)

GES 332B. Seminar in Hydrogeology—Current topics. May be repeated for credit. Prerequisite: consent of instructor.
1 unit, Win (Gorelick, S)

GES 333. Water Policy Colloquium—(Same as CEE 333, IPER 333.) Student-organized interdisciplinary colloquium. Creation, implementation, and analysis of policy affecting the use and management of water resources. Weekly speakers from academia and local, state, national, and international agencies and organizations. Previous topics include water policy in California and developing countries.
1 unit, Spr (Freyberg, D)

GES 342A,B,C. Geostatistics—Classic results and current research. Topics based on interest and timeliness. May be repeated for credit.
1-2 units, **A:** *Aut,* **B:** *Win,* **C:** *Spr (Journel, A)*

GES 343. Geographic Science Seminar: Why Space Matters—Current environmental research that incorporates geographic and spatial analysis using technological and analytical methods such as spatial econometrics, geostatistics, remote sensing, and GIS. May be repeated for credit.
1 unit, not given this year

GES 355. Advanced Stratigraphy Seminar and Field Course—Student-led presentations; poster-sized display on assigned topic; field trip.
1-3 units, not given this year

GES 385. Practical Experience in the Geosciences—On-the-job training in the geosciences. May include summer internship; emphasizes training in applied aspects of the geosciences, and technical, organizational, and communication dimensions. Meets USCIS requirements for F-1 curricular practical training.
1 unit, Aut, Win, Spr, Sum (Staff)

GES 398. Current Topics in Ecosystem Modeling
1-2 units, not given this year

GES 399. Advanced Projects—Graduate research projects that lead to reports, papers, or other products during the quarter taken. On registration, students designate faculty member and agreed-upon units.
1-10 units, Aut, Win, Spr, Sum (Staff)

GES 400. Graduate Research—Faculty supervision. On registration, students designate faculty member and agreed-upon units.
1-15 units, Aut, Win, Spr, Sum (Staff)

OVERSEAS STUDIES

Courses approved for the Geological and Environmental Sciences major and taught overseas can be found in the "Overseas Studies" section of this bulletin, or in the Overseas Studies office, 126 Sweet Hall.

BEIJING

GES 135. China's Environment and Prospects for Sustainability—(Same as EARTHSYS 137X, URBANST 159V.)
4 units, Spr (Seto, K)

GES 136. Urbanization and Land-Use Change in China—(Same as EARTHSYS 139X, URBANST 158V.)
4 units, Spr (Seto, K)