GEOLOGICAL SCIENCES

Courses offered by the Department of Geological Sciences (formerly the Department of Geological and Environmental Sciences) are listed under the subject code GEOLSCI on the Stanford Bulletin's ExploreCourses web site (https://explorecourses.stanford.edu/search?q=GEOLSCI&view=catalog&page=0&academicYear=&filter-term-Autumn=on&filter-term-Winter=on&filter-term-Spring=on&filter-term-Summer=on&collapse=&filter-departmentcode-GEOLSCI=on&filter-catalognumber-GEOLSCI=on&filter-coursestatus-Active=on&filter-catalognumber-GEOLSCI=on).

The geological sciences are naturally interdisciplinary, and include: the study of earth materials, earth processes, and how they have changed over Earth's 4.56 billion year history. More specifically, courses and research within the department address: the chemical and physical makeup and properties of minerals, rocks, soils, sediments, and water; the formation and evolution of Earth and other planets; the processes that deform Earth's crust and shape Earth's surface; the stratigraphic, paleobiological, and geochemical records of Earth history including changes in climate, oceans, and atmosphere; present-day, historical, and long-term feedbacks between the geosphere and biosphere, and the origin and occurrence of our natural resources.

The department's research is critical to the study of natural hazards (earthquakes, volcanic eruptions, landslides, and floods), environmental and geological engineering, surface and groundwater management, the assessment, exploration, and extraction of energy, mineral and water resources, ecology and conservation biology, remediation of contaminated water and soil, geological mapping and land use planning, and human health and the environment.

A broad range of instrumentation for elemental and radiogenic/stable isotope analysis is available, including ion microprobe, electron microprobe, thermal and gas source mass spectrometry, inductively coupled plasma mass spectrometry and nuclear magnetic resonance. The Center for Materials Research and facilities at the SLAC National Accelerator Laboratory, Stanford Synchrotron Radiation Laboratory (SSRL), and the U.S. Geological Survey in nearby Menlo Park are also available for the department's research. Branner Library, devoted exclusively to the Earth Sciences, represents one of the department's most important resources. The department also maintains rock preparation (crushing, cutting, polishing), mineral separation, and microscopy facilities.

Mission of the Undergraduate Program in Geological Sciences

The purpose of the undergraduate program in Geological Sciences is to provide students with a broad background in the fundamentals of the Earth sciences and the quantitative, analytical, and communications skills necessary to conduct research and think critically about questions involving the Earth. The major provides excellent preparation for graduate school and careers in geological and environmental consulting, land use planning, law, teaching, and other professions in which an understanding of the Earth and a background in science are important.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to develop and demonstrate:

1. an understanding of fundamental concepts in Earth science.
2. the ability to collect, analyze, and interpret geological and environmental data using a variety of techniques to test hypotheses.
3. the ability to address real geological and/or environmental problems in the field.
4. the ability to communicate scientific knowledge orally, visually, and in writing.

Graduate Programs in Geological Sciences

Graduate Studies in the Department of Geological Sciences 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, Energy and Environmental Sciences as well as in other departments in the University. Diplomas designate degrees in Geological and Environmental Sciences or Geological Sciences and may also indicate the following specialized fields of study: Geostatistics and Hydrogeology.

Learning Outcomes (Graduate)

The purpose of the master's program in Geological 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.

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.

On April 16, 2015, the Senate of the Academic Council approved the Bachelor of Science in Geological Sciences. Students who declared the Bachelor of Science in Geological and Environmental Sciences have the option of changing the name of their degree to Geological Sciences. Degree requirements remain the same.

Bachelor of Science in Geological Sciences

The major consists of five interrelated components:

1. *Earth Sciences Fundamentals*—Students must complete a set of core courses that introduce the properties of Earth materials, the processes that change the Earth, and the timescales over which those processes act. These courses provide a broad foundational knowledge that can lead to specialization in many different disciplines of the geological and environmental sciences.
2. *Quantitative and Analytical Skills*—Students must complete adequate course work in mathematics, chemistry, and physics or biology. In addition, they learn analytical techniques specific to the Earth sciences through the laboratory component of courses.
3. *Advanced Course Work and Research*—Students gain breadth and depth in upper-level electives and are encouraged to apply these skills and knowledge to problems in the Earth sciences through directed research.
4. *Field Research Skills*—Most GS courses include field trips and/or field-based projects. In addition, students must complete at least six

weeks of field research through departmental offerings (Introduction to Field Methods (GEOLSCI 105) and GEOLSCI 190 Research in the Field), in which they learn and apply field techniques, field mapping, and the prepare a written report.

5. *Communication Skills*—To fulfill the Writing in the Major requirement, students take a writing-intensive senior seminar (GEOLSCI 150 Senior Seminar: Issues in Earth Sciences), in which they give both oral and written presentations that address current research in the earth sciences.

The major requires at least 93 units; letter grades are required in all courses if available. Students interested in the GS major should consult with the undergraduate program coordinator for information about options within the curriculum.

Course Sequence (103-121 units total)

Core Requirement

Students are required to take all of the following:

		Units
GEOLSCI 1	Introduction to Geology	5
GEOLSCI 4	Coevolution of Earth and Life	4
GEOLSCI 90	Introduction to Geochemistry	3-4
GEOLSCI 102	Earth Materials: Introduction to Mineralogy	4
GEOLSCI 103	Earth Materials: Rocks in Thin Section	3
GEOLSCI 104	Introduction to Petrology	3-4
GEOLSCI 105	Introduction to Field Methods	3
GEOLSCI 106	Sedimentary Geology and Depositional Systems	4
GEOLSCI 110	Rock Deformation and Tectonics	5
GEOLSCI 150	Senior Seminar: Issues in Earth Sciences	3
GEOLSCI 190	Research in the Field	3-6
Total Units		40-45

Breadth in the Discipline Requirement

To gain understanding of the breadth of subject areas within the geological sciences, students are required to take one course from each of the following five groups (15-23 units).

Surface and Hydrologic Processes

		Units
GEOLSCI 118X	Sustainable Urban Systems Fundamentals	3-5
or GEOLSCI 121	What Makes a Habitable Planet?	
or ESS 117	Earth Sciences of the Hawaiian Islands	
or ESS 155	Science of Soils	
or ESS 220	Physical Hydrogeology	
or ESS 256	Soil and Water Chemistry	
or GEOPHYS 120	Ice, Water, Fire	
or GEOPHYS 190	Near-Surface Geophysics	

Biogeosciences

		Units
GEOLSCI 123	Evolution of Marine Ecosystems	3-4
or GEOLSCI 128	Evolution of Terrestrial Ecosystems	
or GEOLSCI 233A	Microbial Physiology	
or ESS 158	Geomicrobiology	

Earth Materials and Geochemistry

		Units
GEOLSCI 135	Sedimentary Geochemistry and Analysis	3-4
or GEOLSCI 163	Introduction to Isotope Geochemistry	
or GEOLSCI 180	Igneous Processes	
or CEE 177	Aquatic Chemistry and Biology	
or ESS 152	Marine Chemistry	

Tectonics and Geophysics

		Units
GEOPHYS 120	Ice, Water, Fire	3-5
or GEOPHYS 110	Introduction to the Foundations of Contemporary Geophysics	
or GEOPHYS 130	Introductory Seismology	
or GEOLSCI 122	Planetary Systems: Dynamics and Origins	
or GEOPHYS 150	Geodynamics: Our Dynamic Earth	
or GEOPHYS 182	Reflection Seismology	

Geospatial Statistics and Computer Science

		Units
CS 106A	Programming Methodology	3-5
or ENERGY 160	Uncertainty Quantification in Data-Centric Simulations	
or ESS 164	Fundamentals of Geographic Information Science (GIS)	
or GEOPHYS 112	Exploring Geosciences with MATLAB	

Additional Field Opportunities (optional)

GEOLSCI 5	Living on the Edge	1
GEOLSCI 135A	Sedimentary Geochemistry Field Trip	1
OSPAUSTL 10	Coral Reef Ecosystems	3
OSPAUSTL 25	Freshwater Systems	3
OSPAUSTL 30	Coastal Forest Ecosystems	3

Depth in the Discipline Requirement (10 Units)

To allow students to go into greater depth in the major, students must complete at least 10 units of electives drawn primarily from the list above and other upper-level courses in GS (including graduate-level courses). Additional courses in Geophysics, ESS, and ERE may be counted towards the elective units if they allow a student to pursue a topic in depth; these options should be discussed with an adviser. A maximum of 3 elective units may be fulfilled by:

		Units
GEOLSCI 192	Undergraduate Research in Geological Sciences	1-10
GEOLSCI 197	Senior Thesis	3-5
GEOLSCI 198	Special Problems in Geological Sciences	1-10
Advanced Seminars		

Honors research (GEOLSCI 199 Honors Program) may fulfill up to 4 elective units.

Required Supporting Mathematics (20 Units)

Choose one of the following equivalent series:

		Units
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	10
or a score of 4-5 on the Calculus BC exam		
And at least TWO of the following:		
CME 100	Vector Calculus for Engineers	5
or MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CME 102	Ordinary Differential Equations for Engineers	5
or MATH 52	Integral Calculus of Several Variables	

CME 104	Linear Algebra and Partial Differential Equations for Engineers	5
or MATH 53	Ordinary Differential Equations with Linear Algebra	

Required Supporting Sciences (16-23 Units)
Advanced placement credit may be accepted for these courses as determined by the relevant departments.

		Units
Chemistry		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31X	Chemical Principles Accelerated	
or a score of 4-5 on the Chemistry AP exam		
And one of the following:		
MATSCI 194	Thermodynamics and Phase Equilibria	3-4
or CHEM 171	Physical Chemistry I	
In addition to chemistry, students may choose between introductory sequences in biology and physics. This choice should be made after discussion with an adviser and based on a student's interests.		
Biology		
BIO 82	Genetics	4
or BIO 83	Biochemistry & Molecular Biology	
or BIO 84	Physiology	
or BIO 86	Cell Biology	
And one of the following:		
BIO 81	Introduction to Ecology	4
or BIO 85	Evolution	
or ESS 151	Biological Oceanography	
or BIO 116	Ecology of the Hawaiian Islands	
Or		
Physics		
Select one of the following Series:		9-10
Series A		
PHYSICS 21 & PHYSICS 22 & PHYSICS 23 & PHYSICS 24	Mechanics, Fluids, and Heat and Mechanics, Fluids, and Heat Laboratory and Electricity, Magnetism, and Optics and Electricity, Magnetism, and Optics Laboratory	10
Series B		
PHYSICS 41 & PHYSICS 43 & PHYSICS 44	Mechanics and Electricity and Magnetism and Electricity and Magnetism Lab	9
Series C		
PHYSICS 41 & PHYSICS 45 & PHYSICS 46	Mechanics and Light and Heat and Light and Heat Laboratory	9

Field Research

Field research skills are a critical component of the undergraduate curriculum in GS. The conventional and most straightforward way for undergraduates to meet the field requirement is to take the GS courses (GEOLSCI 105 Introduction to Field Methods and GEOLSCI 190 Research in the Field):

- GEOLSCI 105 Introduction to Field Methods, is a two-week introduction to field techniques and geologic mapping that is taught every year in the White Mountains of eastern California prior to the start of Autumn Quarter in September. This course gives students the tools to undertake geologic research in the field. GEOLSCI 105 is required of all GS majors and is the framework upon which all subsequent undergraduate field-related instruction is based.
- GEOLSCI 190 Research in the Field, gives GS undergraduates additional training in field research. This course provides undergraduates with a team-based experience of collecting data to answer research questions and is directed by faculty and graduate students. Offered in June and/or September.

By taking GEOLSCI 105 and two iterations of GEOLSCI 190, GS undergraduates develop the broad experience and confidence necessary to go out and evaluate a geological or environmental geology question by collecting field-based data. The main goal is that, upon graduation, GS undergraduates will be able to plan and execute independent field research.

GEOLSCI 190 can also be satisfied by enrolling in a single four-to-six week geology field camp offered by another institution. This externally administered experience can substitute for two three-week GS 190 courses, subject to approval by the Undergraduate Curriculum Committee.

Engineering Geology and Hydrogeology Undergraduate 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, environmental geology, geology, geotechnical engineering, and hydrogeology.

GS 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 chosen with the advice and consent of the adviser. Typically, electives are chosen from the list below. Letter grades are required if available.

Course Sequence (100-113 Units Total)

Required Geological Sciences (26-27 Units)

		Units
GEOLSCI 1	Introduction to Geology	5
GEOLSCI 90	Introduction to Geochemistry	3-4
GEOLSCI 102	Earth Materials: Introduction to Mineralogy	4
GEOLSCI 104	Introduction to Petrology	3-4
or ESS 155	Science of Soils	
GEOLSCI 150	Senior Seminar: Issues in Earth Sciences	3
ENERGY 160	Uncertainty Quantification in Data-Centric Simulations	3
or STATS 110	Statistical Methods in Engineering and the Physical Sciences	
or CEE 203	Probabilistic Models in Civil Engineering	
or CME 106	Introduction to Probability and Statistics for Engineers	
ESS 220	Physical Hydrogeology	4

or GEOPHYS 120	Ice, Water, Fire	
Total Units		25-27

Required Engineering (14-16 Units)

		Units
CEE 101A	Mechanics of Materials	4
or CEE 177	Aquatic Chemistry and Biology	
CEE 101B	Mechanics of Fluids	4
CS 106A	Programming Methodology	3-5
ENGR 90	Environmental Science and Technology	3
Total Units		14-16

Required Supporting Sciences and Mathematics (37-42 Units)

		Units
MATH 19	Calculus	3
MATH 20	Calculus	3
MATH 21	Calculus	4
CME 100	Vector Calculus for Engineers	5
CME 102	Ordinary Differential Equations for Engineers	5
PHYSICS 41	Mechanics	4
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31X	Chemical Principles Accelerated	
BIO 82	Genetics	4
or BIO 83	Biochemistry & Molecular Biology	
or BIO 84	Physiology	
or BIO 86	Cell Biology	
BIO 81	Introduction to Ecology	4
or BIO 85	Evolution	
or ESS 151	Biological Oceanography	
or BIO 116	Ecology of the Hawaiian Islands	
Total Units		37-42

Breadth (15-20 Units)

Select one course from each of the five topics listed below. Courses listed as options in multiple categories (either required foundations or breadth requirements) can only be used to fulfill one requirement. Students are encouraged to work with their academic advisor to develop cross-cutting themes among their breadth requirements. Examples of cross-cutting themes could include: Earth and Energy Resources, Natural Hazards, Coastal Processes, Freshwater, etc.

Atmosphere and Ocean Dynamics

		Units
CEE 172	Air Quality Management	3-4
or ESS 141	Remote Sensing of the Oceans	
or EARTHSYS 146A	Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation	
or EARTHSYS 146B	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	
or ESS 148	Introduction to Physical Oceanography	
or ESS 151	Biological Oceanography	
or ESS 152	Marine Chemistry	

Biogeosciences

		Units
CEE 177	Aquatic Chemistry and Biology	3-4
or CHEMENG 174	Environmental Microbiology I	
or EARTHSYS 111	Biology and Global Change	
or EARTHSYS 151	Biological Oceanography	
or EARTHSYS 158	Geomicrobiology	
or GEOLSCI 123	Evolution of Marine Ecosystems	
or GEOLSCI 128	Evolution of Terrestrial Ecosystems	
or GEOLSCI 233A	Microbial Physiology	

Hydrological Processes

		Units
CEE 166A	Watersheds and Wetlands	3-4
or CEE 166B	Floods and Droughts, Dams and Aqueducts	
or ENERGY 121	Fundamentals of Multiphase Flow	
or ENERGY 153	Carbon Capture and Sequestration	
or GEOPHYS 181	Fluids and Flow in the Earth: Computational Methods	
or GEOPHYS 190	Near-Surface Geophysics	

Geological and Geophysical Sciences

		Units
GEOLSCI 104	Introduction to Petrology	3-4
or GEOLSCI 105	Introduction to Field Methods	
or GEOLSCI 106	Sedimentary Geology and Depositional Systems	
or GEOLSCI 110	Rock Deformation and Tectonics	
or GEOLSCI 118X	Sustainable Urban Systems Fundamentals	
or GEOLSCI 180	Igneous Processes	
or GEOPHYS 110	Introduction to the Foundations of Contemporary Geophysics	
or GEOPHYS 120	Ice, Water, Fire	
or GEOPHYS 130	Introductory Seismology	
or GEOPHYS 150	Geodynamics: Our Dynamic Earth	
or ENERGY 120	Fundamentals of Petroleum Engineering	

Surface and Environmental Processes

		Units
CEE 101C	Geotechnical Engineering	3-4
or CEE 171	Environmental Planning Methods	
or EARTHSYS 142	Remote Sensing of Land	
or ESS 117	Earth Sciences of the Hawaiian Islands	
or ESS 256	Soil and Water Chemistry	
or ESS 164	Fundamentals of Geographic Information Science (GIS)	
or GEOLSCI 170	Environmental Geochemistry	
or GEOPHYS 190	Near-Surface Geophysics	

Suggested Electives (up to 8 Units)

Breadth electives may be relevant courses from breadth areas listed above and not used toward the breadth or core requirements, IntroSems (List 1 below), or Overseas/Off-Campus classes (List 2 below).

		Units
List 1. Relevant Introductory Seminars or courses		
CEE 64	Air Pollution and Global Warming: History, Science, and Solutions	3
or CEE 29N	Managing Natural Disaster Risk	
or EARTHSYS 41N	The Global Warming Paradox	
or EARTHSYS 44N	The Invisible Majority: The Microbial World That Sustains Our Planet	
or EARTHSYS 46N	Exploring the Critical Interface between the Land and Monterey Bay: Elkhorn Slough	

or EARTHSYS 46Q	Environmental Impact of Energy Systems: What are the Risks?	
or EARTHSYS 56Q	Changes in the Coastal Ocean: The View From Monterey and San Francisco Bays	
or GEOPHYS 20N	Predicting Volcanic Eruptions	
or BIO 35N	Climate change ecology: Is it too late?	
List 2. Off-campus courses		
EARTHSYS 117	Earth Sciences of the Hawaiian Islands	3-5
or ESS 101	Environmental and Geological Field Studies in the Rocky Mountains	
or GEOLSCI 190	Research in the Field	
or OSPMADRD 79	Earth and Water Resources' Sustainability in Spain	
or OSPAUSTL 10	Coral Reef Ecosystems	
or OSPAUSTL 25	Freshwater Systems	
or OSPAUSTL 30	Coastal Forest Ecosystems	
or BIOHOPK 163H	Oceanic Biology	
or BIOHOPK 172H	Marine Ecology: From Organisms to Ecosystems	
or BIOHOPK 182H	Stanford at Sea	
or OSPSANTG 58	Living Chile: A Land of Extremes	

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 GS 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 GEOLSCI 199 Honors Program; the student must complete a total of 9 units over the course of the senior year. Up to 4 units of GEOLSCI 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 GS Honors Symposium in which they present their research to the broader community. Honors students in GS are also eligible for the Firestone medal, awarded by Undergraduate Advising and Research (http://ual.stanford.edu) for exceptional theses.

Minor in Geological Sciences

The minor in GS 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. All courses must be taken for a letter grade.

Required Courses

		Units
GEOLSCI 1	Introduction to Geology	5
GEOLSCI 4	Coevolution of Earth and Life	4
GEOLSCI 102	Earth Materials: Introduction to Mineralogy	4
GEOLSCI 104	Introduction to Petrology	3-4
Total Units		16-17

Electives (12 Units)

Students must take a minimum of 12 additional units drawn primarily from the Breadth in the Discipline list in the GS major; a majority of units must be from classes within the GS department. Up to 3 units of Stanford Introductory Seminars in GS may be counted.

Students pursuing a minor in GS are encouraged to participate in the senior seminar (GEOLSCI 150 Senior Seminar: Issues in Earth Sciences) and in field research (GEOLSCI 105 Introduction to Field Methods)

On April 16, 2015, the Senate of the Academic Council approved the Master of Science in Geological Sciences. Students who matriculated into the Master of Science in Geological and Environmental Sciences have the option of changing the name of their degree to Geological Sciences. Degree requirements remain the same.

Coterminal Master of Science Degree in Geological Sciences

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 in 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 GS 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 GS faculty prior to submission of the application. Coterminal students must complete a thesis describing research results.

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
2. or. 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 GS office.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

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.

Master of Science in Geological Sciences

Objectives

The purpose of the master's program in Geological 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

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 Director of Graduate Studies.

Requirements

The University's requirements for M.S. degrees are outlined in the "Graduate Degrees (http://www.stanford.edu/dept/registrar/bulletin/4901.htm)" section of this bulletin. Practical training (GEOLSCI 385 Practical Experience in the Geosciences) 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 Spring Quarter of their first year in residence, students must complete at least three graduate level courses taught by a minimum of two different GS 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. M.S. students must complete at least one TA appointment (25%). Additional TA quarters may be considered and/or required in consultations with the research advisor, depending on academic goals, funding availability, or the requirements of individual graduate programs.
5. 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.
6. 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 Director of Graduate Studies; 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 in Geological Sciences

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.

On April 16, 2015, the Senate of the Academic Council approved the Doctor of Philosophy in Geological Sciences. Students who matriculated into the Doctor of Philosophy in Geological and Environmental Sciences have the option of changing the name of their degree to Geological Sciences. Degree requirements remain the same.

Doctor of Philosophy in Geological Sciences

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.

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 GS Admissions Committee.

Requirements

The University's requirements for the Ph.D. degree are outlined in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)" section of this bulletin. Practical training (GEOLSCI 385 Practical Experience in the Geosciences) 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 graduate level, 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 Spring Quarter of their first year in residence, students must complete at least three graduate level courses taught by a minimum of two different GS faculty members.
2. Ph.D. students must complete at least one TA appointment (25%). Additional TA quarters may be considered and/or required in consultations with the research advisor, depending on academic goals, funding availability, or the requirements of individual doctoral programs.
3. 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 prior to May 1, so that the outcome of the exam is known at the time of the annual spring evaluation of graduate students.
4. 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, during the Spring Quarter, the candidate must organize a meeting of the research committee to present a brief progress report covering the past year.
5. 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.
6. 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 in Geological Sciences

Candidates for the Ph.D. degree in other departments who wish to obtain a minor in Geological 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 GS adviser and the department chair.

Graduate Advising Expectations

The Department of Geological Sciences is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

Emeriti: (Professors) Atilla Aydin, Dennis K. Bird, Gordon E. Brown, W. Gary Ernst, James C. Ingle, Jr., Juhn G. Liou, Keith Loague, Gail A. Mahood, David D. Pollard

Chair: Jonathan Payne

Associate Chair: C. Kevin Boyce

Professors: C. Kevin Boyce, Jef Caers, Page Chamberlain, Rodney C. Ewing, Stephan A. Graham, Donald R. Lowe, Elizabeth L. Miller, Jonathan Payne, Jonathan F. Stebbins

Associate Professors: George Hilley, Wendy Mao

Assistant Professors: Erik Sperling

Professors (Research): Martin J. Grove

Courtesy Professors: Elizabeth Hadly, Simon L. Klemperer, Anders R. Nilsson, Alfred M. Spormann

Cognate Courses

Many courses offered within the School of Earth, Energy and Environmental Sciences, as well as courses in other schools with a significant Earth sciences component, may be used in satisfaction of optional requirements for the Geological Sciences degree. Undergraduates should discuss the options available to them with the undergraduate program coordinator; graduate students should discuss options with their advisers.

The following courses outside the School of Earth, Energy and Environmental Sciences are particularly applicable:

		Units
BIOHOPK 182H	Stanford at Sea	16
CEE 63	Weather and Storms	3
CEE 64	Air Pollution and Global Warming: History, Science, and Solutions	3
CEE 101A	Mechanics of Materials	4
CEE 101B	Mechanics of Fluids	4
CEE 101C	Geotechnical Engineering	3-4
CEE 166A	Watersheds and Wetlands	4

Overseas Studies Courses in Geological Sciences

The Bing Overseas Studies Program (http://bosp.stanford.edu) manages Stanford study abroad programs for Stanford undergraduates. Students should consult their department or program's student services office for applicability of Overseas Studies courses to a major or minor program.

The Bing Overseas Studies course search site (https://undergrad.stanford.edu/programs/bosp/explore/search-courses) displays courses, locations, and quarters relevant to specific majors.

For course descriptions and additional offerings, see the listings in the Stanford Bulletin's ExploreCourses (http://explorecourses.stanford.edu) or Bing Overseas Studies (http://bosp.stanford.edu).

		Units
explorecourses:OSP	gs	