# GEOLOGY — M.S.

**Program director**
Kevin E. Nick

The Department of Earth and Biological Sciences offers the Master of Science in geology degree. Coursework and research culminating in a thesis emphasize field and laboratory studies in sedimentology, paleontology, igneous petrology, and environmental geology. Research in paleontology may also be pursued through the M.S. and Ph.D. degree curricula in biology and through the Ph.D. degree curriculum in earth science.

## Program objectives

The Master of Science in geology program prepares a student to enter the fields of applied geosciences or further graduate studies. The integrated core course sequence provides the background to take the National Association of State Boards of Geology (ASBOG) Fundamentals of Geology (FG) examination leading to Geologist-In-Training (GIT) certification. Fieldwork is emphasized and provides a first-hand experience with geological phenomena that cannot be satisfactorily grasped or understood solely from classroom or laboratory study. Students will develop skills to critically evaluate and conduct research in the subdisciplines of sedimentology, paleontology, igneous petrology, or environmental geology. Throughout the geology curriculum, students are encouraged to develop an open-minded and investigative approach to the application of the scientific method to the resolution of geologic problems.

The geology program aims to instill in students the values of honesty, scientific integrity, careful research, and independent critical thinking; provide the tools and intellectual environment in which geologists can attain their highest potential in scholarship and research; and challenge graduate students to consider the relationships among science, faith, and societal responsibility.

## Program learning outcomes

By the end of this program, the graduate should be able to:

1. **Foundational Knowledge and Skills**. Characterize earth materials and their stratigraphic relations, demonstrating understanding of current geologic processes and geoscience theory at a level required for their chosen degree program.
2. **Research.** Conduct research in their chosen field of specialization, acquiring professional-level knowledge and expertise appropriate to their degree.
3. **Professionalism.** Demonstrate professional attributes necessary for interacting with colleagues and contributing to the discipline.
4. **Societal Interaction and Impact.** Interact with others on issues in philosophy of science and public interest.

## Financial aid

Research and teaching assistantships are available at the Department of Earth and Biological Sciences on a competitive basis. Further information can be obtained by contacting the department at ebs@llu.edu. Qualified students are also encouraged to seek fellowships and grants from federal and private agencies with the help of their advisors.

## Overview of program requirements

### Two-year track—for students with an undergraduate degree in geology

A minimum of 52 quarter units, including 44 at or above the 500 level, constitutes the curriculum for the Master of Science degree in geology.

### Three-year track—for students without an undergraduate degree in geology

Students with a variety of majors (including science and some nonscience majors) are encouraged to enter the M.S. degree in geology program. Students will take 16 units of undergraduate geology courses as corequisites that are not part of the M.S. curriculum, as well as M.S. degree curriculum courses in geology with a minimum of 52 quarter units, including 44 at or above the 500 level. Total for the three-year track is 68 quarter units. Advanced standing may be granted toward corequisite requirements.

## Admissions

Applicants must meet Loma Linda University (http://llucatalog.llu.edu/about-university/admission-policies-information/#admissionrequirementstext), Faculty of Graduate Studies, and Program admission requirements summarized below.

- Hold an undergraduate or graduate degree from an accredited institution.
- Achieve acceptable scores in English proficiency and general GRE examinations.
- Demonstrate the minimum required G.P.A. of at least 3.0.
- Participate in an interview with a program faculty member prior to acceptance.
- Expected undergraduate preparation includes:
  - College mathematics to include the content of one term of calculus
  - General physics with laboratory (two quarters or one semester)
  - General chemistry with laboratory (one year)
  - Statistics (one course)
  - Undergraduate geology courses (see corequisites listed under program requirements)

Some of these courses, including undergraduate geology courses, may be taken during residence at Loma Linda University, with approval of the admissions committee.

Students may contact the department at ebs@llu.edu for advice on admission requirements. Advanced standing toward M.S. course requirements may be granted based on coursework taken prior to admission and beyond undergraduate degree requirements.

Applications should be completed by January 31 of the calendar year being considered for admission and for priority consideration. Review of applications begins in February for Autumn Quarter admission. Research assistantships are competitively awarded.

Applicants without undergraduate geology courses are accepted in alternate years. It is recommended that applicants contact the department early in the application process at ebs@llu.edu.

# Program requirements

### Three-year Track additional requirements

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|---|---|---|
| **Corequisites** | | |
| The following courses are required of all students who have not completed a bachelor's degree in geology. Courses do not apply toward graduate credit. | | |
| GEOL 316 | Mineralogy | 4 |
| GEOL 317 | Igneous and Metamorphic Petrology | 4 |
| GEOL 318 | Sedimentary Petrology | 3 |
| GEOL 424 | Structural Geology | 5 |
| **Total Units** | | **16** |

### M.S. degree requirements for all students—both two-year and three-year tracks

Students with an undergraduate geology degree may be granted advanced standing toward some requirements.

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|---|---|---|
| **Core** | | |
| GEOL 443 | Historical Geology | 4 |
| GEOL 510 | Orientation to Graduate Geology | 1 |
| GEOL 515 | Sedimentology and Stratigraphy | 3 |
| GEOL 537 | Field Geology Sedimentology and Stratigraphy | 2 |
| GEOL 538 | Field Mapping and Geologic Report Writing | 4 |
| GEOL 539 | Field Geology Structures and Igneous Rocks | 2 |
| GEOL 558 | Philosophy of Science [3] | 4 |
| or GEOL 559 | Philosophy of Science and Origins | |
| GEOL 607 | Seminar in Geology (0.5) [1] | 4 |
| GEOL 617 | Proposal Writing and Grantsmanship | 2 |
| GEOL 664 | Science Communication Outreach | 1 |
| Select one earth materials course from the following: | | 3-4 |
| GEOL 527 | Earth Materials – Advanced Mineralogy (4) | |
| GEOL 528 | Earth Materials – Advanced Igneous Petrology (4) | |
| GEOL 529 | Earth Materials – Advanced Sedimentary Petrology (3) | |
| Select one paleontology course from the following: | | 4 |
| GEOL 512 | Invertebrate Paleontology (4) | |
| GEOL 513 | Vertebrate Paleontology (4) | |
| GEOL 514 | Paleobotany (4) | |
| GEOL 545 | Taphonomy (4) | |
| Select two courses to total at least five hours from the following: | | 5-8 |
| GEOL 526 | Introduction to GIS for the Natural Sciences (2) | |
| GEOL 535 | GIS Spatial Analysis for the Natural Sciences (3) | |
| GEOL 565 | Analysis of Sedimentary Rocks (4) | |
| GEOL 575 | Hydrogeology (4) | |
| HGIS 522 | Principles of Geographic Information Systems and Science (2) | |
| HGIS 524 | GIS Software Applications and Methods (3) | |
| **Religion** | | |
| REL_5__ | Graduate-level Religion | 3 |
| **Thesis research and writing** | | |
| GEOL 698 | Thesis Research (1-3) | 6 |
| **Electives** | | |
| Additional courses recommended by the student's guidance committee to complete total requirements of 52 or 68 units. All GEOL graduate-level courses not counted towards core requirements may be counted towards elective requirement. | | |
| **Total Units** | | **52** |

1. Registration is required for each quarter in the program, maximum units counted toward the degree total is 4.
2. Fulfills service learning requirement
3. GEOL 559 Philosophy of Science and Origins required, in lieu of GEOL 558 Philosophy of Science, for students who have completed GEOL 475 Philosophy of Science and Origins.
4. 6 units minimum; registration permitted for 1 to 3 units per quarter; typically research units will be graded each quarter; can be repeated for additional credit; GEOL 697 may apply towards elective credit but should not be used for thesis research topics

### Seminar attendance

All graduate students must register for and attend in person GEOL 607 Seminar in Geology each quarter while in the program. Students who are doing fieldwork away from campus, will attend via Zoom.

### Varied course offerings

In addition to the primary offerings of the department, the student, with committee approval, may take courses in other departments as part of the graduate work, according to special interests and needs.

## Noncourse requirements

### Advancement to candidacy

Students are urged to select a research project early in their program, in consultation with a faculty member approved by the department. By the third quarter of study, students should apply for advancement to candidacy and develop an approved, comprehensive, plan for completion of the degree. Advancement to candidacy is petitioned by completing Form A, which requires:

1. Departmental approval of a research advisor, academic advisor, and research committee.
2. Showing progress in the program while maintaining a satisfactory G.P.A.
3. Research committee approval of the written research proposal.
4. Passing the oral defense of the research proposal.
5. Being recommended by the program faculty.

### Research Presentation

Presentation of research findings at a scientific meeting is required.

### Thesis

The written thesis must demonstrate significant conclusions based on analysis of original data generated by the student. Chapters must be written in the style of an appropriate scientific journal.

### Defense of thesis

A public, oral presentation of the thesis is required. The written thesis is presented to each member of the research committee for evaluation. The committee also evaluates the oral presentation and student's responses in a final oral defense of the research. When all steps are approved, the committee completes Form D.

### Grade requirement for graduation

An overall G.P.A. of 3.0 is required for graduation.

## Normal time to complete the program

27-month track — 2.33 years (seven [7] academic quarters) — based on full-time enrollment; part time permitted

36-month track — three (3) years (nine [9] academic quarters) — based on full-time enrollment; part time permitted

## Courses

**GEOL 204. Physical Geology. 4 Units.**
Introductory geology course that provides the student with a broad picture of geological processes operating on and within the earth. Introduction to minerals, sedimentary and igneous rocks, and fossils. Weathering, earthquakes, volcanism, erosion and sedimentation, and plate tectonics. Three class hours, one three-hour laboratory or field trip per week.

**GEOL 316. Mineralogy. 4 Units.**
Study minerals and their occurrences including crystallography and crystal chemistry, phase diagrams, and systematic classification. Mineral identification based on hand sample, optical, and other analytical techniques. Three class hours and one three-hour laboratory or field trip per week.

**GEOL 317. Igneous and Metamorphic Petrology. 4 Units.**
Introduction to classification and origin of igneous and metamorphic rocks.Study phase diagrams and processes controlling magma crystallization. Examine relationship of plate tectonics to the genesis and distribution of igneous and metamorphic rocks. Three class hours and one three-hour laboratory or field trip per week.

**GEOL 318. Sedimentary Petrology. 3 Units.**
Introduces the classification and origin of sedimentary rocks. Studies common constituents of sedimentary rocks, their classification systems, and analytical approaches, using hand samples and thin sections. One class period, and two three-hour laboratory sessions or a field trip per week. Prerequisite: GEOL 316; or consent of instructor.

**GEOL 416. Sedimentology and Stratigraphy. 6 Units.**
Focus on the sedimentary rock record through a study of rock types, depositional processes, and models. Stratigraphic nomenclature and approaches to correlation on local, regional, and global scales. Laboratory analysis of primary and diagenetic mineralogy, textures, and sedimentary structures in clastic and carbonate rocks. Field descriptions of sedimentary rocks, structures, and sequences; and field experience in interpreting depositional processes and stratigraphic relationships.

**GEOL 424. Structural Geology. 5 Units.**
Theory of stress and strain and examination of rock deformation in a framework of plate tectonics. Examples presented in field settings.

**GEOL 426. Invertebrate Paleontology. 4 Units.**
Structure, classification, ecology, and distribution of selected fossil invertebrate groups. Principles and methods involved in the study and analysis of invertebrate fossils. Three class hours and one three-hour laboratory per week.

**GEOL 427. Vertebrate Paleontology. 4 Units.**
Systematics, biology, and biogeography of ancient fossil vertebrates, with emphasis on the origins of major groups.

**GEOL 434. Introduction to GIS for the Natural Sciences (2). 2 Units.**
Principles and practice of GIS data acquisition, data editing, map making, and geodatabase management. Recommended for students beginning a research project.

**GEOL 435. GIS Spatial Analysis for the Natural Sciences (3). 3 Units.**
Advanced analysis of GIS data; statistical analysis, geographic analysis of spatial data, and methods of displaying, editing, and modeling spatial data using ArcGIS and related GIS tools. Recommended for students who have research data in hand to analyze.

**GEOL 436. Low Temperature Geochemistry. 4 Units.**
Principles of the chemistry of systems that pertain to surface geological and environmental settings. Major topics include: water quality, mineral solubility, natural systems represented by chemical equations, carbonate equilibrium systems, mineral stability plots, and oxidation-reduction systems. Prerequisite: College chemistry; consent of instructor.

**GEOL 443. Historical Geology. 4 Units.**
Overview of salient geological and paleontological features in the geological record, explaining the way they are interpreted in the formulation of models of Earth's history.

**GEOL 444. Paleobotany. 4 Units.**
Fossil plants; their morphology, paleoecology, taphonomy, classification, and stratigraphic distribution. Analyzes floral trends in the fossil record. Three class hours and one three-hour laboratory or field trip per week.

**GEOL 455. Modern Carbonate Depositional Systems. 3 Units.**
Examines modern and Pleistocene carbonate systems in the field, using these environments as models for understanding sediment production, facies development, and early diagenesis for many ancient carbonates. Presentations and readings on specific environments combined with field descriptions, mapping, analysis, and reports. Requires rigorous hiking and snorkeling in shallow water.

**GEOL 456. Field Methods of Geologic Mapping. 4 Units.**
Advanced geologic mapping of complex areas, with interpretation of their history; includes mapping of igneous, metamorphic, and sedimentary rocks. Experience in preparation of geologic reports of each mapped locality.

**GEOL 464. Science Communication Outreach. 1 Unit.**
Guided immersion into science communication outreach. Presentation of principles of communication outreach and small group work. Student teams participate in project that interacts with a specific, identified community. Undergraduate students will work with graduate students in small teams and engage collaborative planning to address a community need, then present, evaluate, and reflect on the experience. Cross-listing: ENVS 464.

**GEOL 465. Hydrogeology. 4 Units.**
Theory and geology of groundwater occurrence and flow, the relation of ground water to surface water, and the potential distribution of ground water by graphical and analytical methods. Three class hours and one three-hour laboratory per week.

**GEOL 475. Philosophy of Science and Origins. 4 Units.**
Concepts in the history and philosophy of science, and application of these principles in analyzing current scientific trends.

**GEOL 485. Seminar in Geology. 0.5 Units.**
Presentations and discussion of selected topics featuring recent developments. Members of all geology meet together.

**GEOL 486. Research and Experimental Design. 2 Units.**
Concepts, methods, and tools of research—including experimental design and data analysis.

**GEOL 487. Field Geology Studies. 1-6 Units.**
Special field study trips lasting one or more weeks. Student involvement required, including field presentations and fieldwork assignments, such as the measurement and analysis of sedimentary sections, facies profiling, paleontologic excavation, mapping, or other geological or paleontology field activity. One unit of credit per week. May be repeated for additional credit.

**GEOL 488. Topics in Geology. 1-4 Units.**
A didactic course in a specified area of earth science to cover time-sensitive subjects or topics on demand. Requires an independent study title request form that describes the specific area covered in the class and course requirements.

**GEOL 489. Readings in Geology and Paleontology. 1-4 Units.**
Focused readings and discussion of literature with course instructor in a seminar setting. Requires an independent study title request form that describes the specific area covered in the class and course requirements.

**GEOL 495. Special Projects in Geology. 1-4 Units.**
Special project in the field, laboratory, museum, or library under the direction of a faculty member. Registration indicates the specific field of the project.

**GEOL 497. Undergraduate Research. 1-4 Units.**
Credit for supervised research activities, including activities related to completion of the senior thesis. Requires an independent study title request form that explains the research and evaluation criteria.

**GEOL 510. Orientation to Graduate Geology. 1 Unit.**
Provides a platform for introducing students to skills and strategies for successfully navigating through their graduate degree and for pllanning their future professional career development.

**GEOL 512. Invertebrate Paleontology. 4 Units.**
Structure, classification, ecology, and distribution of selected fossil invertebrate groups. Considers principles and methods involved in the study and analysis of invertebrate fossils. Per week: Class three hours, plus one three-hour laboratory. Additional work required beyond GEOL 426.

**GEOL 513. Vertebrate Paleontology. 4 Units.**
Fossil vertebrates, with emphasis on the origins of major groups. Systematics, biology, and biogeography of ancient vertebrates. Additional work required beyond GEOL 427.

**GEOL 514. Paleobotany. 4 Units.**
Fossil plants, their morphology, paleoecology, taphonomy, classification, and stratigraphic distribution. Analyzes floral trends in the fossil record. Per week: three class hours and one three-hour laboratory or field trip. Additional work required beyond GEOL 444.

**GEOL 515. Sedimentology and Stratigraphy. 3 Units.**
Studies the weathering, transport, and deposition of sediments as well as the principles of stratigraphy and application of stratigraphic methods. Provides laboratory exercises and field projects to build experience with analysis of sedimentary structures and sequences, and analysis of stratigraphic relationships. Develops skills in illustrating and reporting sedimentological features observed in the field as well as stratigraphy relating to outcrops. Prerequisite: GEOL 318, 529; or consent of instructor.

**GEOL 517. Modern Carbonate Depositional Systems. 3 Units.**
Examines modern and Pleistocene carbonate systems in the field, using these environments as models for understanding sediment production, facies development, and early diagenesis for many ancient carbonates. Presentations and readings on specific environments combines with field descriptions, mapping, analysis, and reports. Requires rigorous hiking and snorkeling in shallow water. Additional work required beyond GEOL 455.

**GEOL 518. Earth Structure, Process, and History. 4 Units.**
Study of geological processes and the resulting geological record. Introduces minerals and rocks, sedimentary and igneous processes, fossils, plate tectonics, geological history, and models of earth history. Student prepares a teaching module on the topic. Open only to students in the M.S. degree program in natural sciences. Per week: class three class hours, one three-hour laboratory or field trip.

**GEOL 526. Introduction to GIS for the Natural Sciences. 2 Units.**
Principles and practice of GIS data acquisition, data editing, map making, and geodatabase management. Recommended for students beginning a research project.

**GEOL 527. Earth Materials – Advanced Mineralogy. 4 Units.**
Examines mineral groups related to student research. Advances the study of crystallography, chemical variation, microstructures, deformation, and occurrences of minerals. Develops analytical skills using optical properties, SEM/EDS, XRD, gravimetric, and FTIR. Demonstrates competence with characterization of unknown minerals through portfolio projects. Three in-class hours, and one three-hour laboratory or field trip per week. Prerequisite: GEOL 316; or consent of instructor.

**GEOL 528. Earth Materials – Advanced Igneous Petrology. 4 Units.**
Provides advanced study of the igneous rocks, using whole-rock and mineral chemistry variation, microstructures and microtextures, deformation, and tectonic settings to address processes that affected their evolution in a regional/global geological framework. Develops analytical skills using petrographic and modeling techniques to place quantitative constraints on petrologic processes. Portfolio projects demonstrate competence in the development of petrogenetic models. Prerequisite: GEOL 316; or consent of instructor.

**GEOL 529. Earth Materials – Advanced Sedimentary Petrology. 3 Units.**
Analyzes, classifies, and describes sedimentary rocks. Uses qualitative and quantitative techniques to produce illustrated reports of texture, composition, diagenesis, and porosity. One class period, and two three-hour laboratory sessions or field trip per week. Prerequisite: GEOL 316; or consent of instructor.

**GEOL 535. GIS Spatial Analysis for the Natural Sciences. 3 Units.**
Advanced analysis of GIS data; statistical analysis, geographic analysis of spatial data, and methods of displaying, editing, and modeling spatial data using ArcGIS and related GIS tools. Recommended for students who have research data in hand to analyze.

**GEOL 537. Field Geology Sedimentology and Stratigraphy. 2 Units.**
Develops field geology skills for sedimentary rock sequences as well as field measurements and descriptions of sedimentary lithologies, facies, and sequences. Applies stratigraphic approaches in the field as well as assembly and interpretation of geologic reports based on previously collected and new field data. Prerequisite or concurrent: GEOL 515; or consent of instructor.

**GEOL 538. Field Mapping and Geologic Report Writing. 4 Units.**
Teaches advanced geologic mapping of complex areas, with interpretation of their history. Explores the use of technology to collect and record field data. Explains how to incorporate published data and field measurements into figures, maps, and geologic reports. Prerequisite: GEOL 424; or consent of instructor.

**GEOL 539. Field Geology Structures and Igneous Rocks. 2 Units.**
Explores the study of structures and deformation to characterize pluton emplacement. Uses structural and petrographic data derived from systematic geological mapping, detailed petrographic descriptions, and structural characterization carried out in outcrops and rock thin sections—coupled with kinematic studies—in order to determine origin, emplacement conditions, and deformation phases of the rocks. Prerequisite or concurrent: GEOL 424; or consent of instructor.

**GEOL 545. Taphonomy. 4 Units.**
Processes that affect an organism from death until its final burial and fossilization, and utilization of this information in reconstructing ancient assemblages of organisms. Three class hours per week. One laboratory per week to study, describe, and interpret fossil assemblages of vertebrates, invertebrates, and microfossils.

**GEOL 554. Limnogeology. 4 Units.**
Ancient lake deposits, including their sedimentologic, paleontologic, mineralogic, geochemical, and stratigraphic characteristics. Investigates as analogs the depositional processes occurring in modern lakes. Laboratory and several extended field trips.

**GEOL 555. Carbonate and Evaporite Geology. 4 Units.**
Advanced course on the geology of carbonate and evaporite rocks, including: petrography, depositional systems, diagenesis, and overview of current topics of research. Includes weekly laboratory experience in the analysis of carbonate and evaporite samples and a field trip to ancient carbonate sequences.

**GEOL 556. Paleoenvironments. 3 Units.**
Venue to learn skills to distinguish and reconstruct ancient depositional environments. Applies paleontologic, sedimentologic, and geochemical data and methods to interpretation of paleoenvironments, with emphasis on organism-sediment relationships. Investigates as analogs processes, sediments, and organisms in modern depositional environments.

**GEOL 557. Paleoenvironments Field Trip. 1 Unit.**
Field-based geology that integrates with GEOL 556, Paleoenvironments. Ten days spent visiting a variety of ancient and modern depositional environments. Published observations reviewed and relived to develop a regional context and collect primary field data.

**GEOL 558. Philosophy of Science. 4 Units.**
Selected topics in the history and philosophy of science, and application of these principles in analyzing contemporary scientific trends.

**GEOL 559. Philosophy of Science and Origins. 1 Unit.**
Studies selected topics in the history and philosophy of science, and applies these principles in analyzing current scientific trends. Provides an advanced update in the topic for students who have had a similar course at the undergraduate level. Prerequisite: GEOL 475.

**GEOL 565. Analysis of Sedimentary Rocks. 4 Units.**
Provides exposure to range of analytical tools used for assessment in sedimentary geology. Tools covered include: saws and grinders, photography through microscope, point counting with optical microscope, x-ray diffraction of bulk and clays, scanning electron microscopy with EDS, magnetic susceptibility, grain size analysis, acid insoluble residues, making thin sections, MP-AES, GPS, image analysis, and error analysis. Participants will use case studies to develop skill in project design.

**GEOL 566. Clastic Sedimentary Geology. 4 Units.**
Advanced course on the geology of clastic sedimentary rocks–including: petrography, depositional systems, diagenesis, and overview of current topics of research. Includes weekly laboratory experience in the analysis and description of clastic rock samples and a field trip to ancient clastic sequences.

**GEOL 567. Stratigraphy and Basin Analysis. 4 Units.**
Addresses vertical and lateral relationships of sedimentary units and facies in the context of the development and filling of sedimentary basins within a chronostratigraphic framework. Emphasis on the impact of tectonics, sea level variations, and autogenic processes and their expression as sequences with specific stratal geometries in different basin types. Both surface (field outcrop studies) and subsurface (well logs and seismic stratigraphy) approaches to basin analysis will be covered.

**GEOL 575. Hydrogeology. 4 Units.**
Theory and geology of groundwater occurrence and flow, the relation of groundwater to surface water, and the potential distribution of groundwater by graphical and analytical methods. Three class hours and one three-hour laboratory per week.

**GEOL 588. Topics in Geology. 1-4 Units.**
A didactic course in a specified area of earth science to cover time-sensitive subjects or topics on demand. Requires an independent study title request form that describes the specific area covered in the class and course requirements.

**GEOL 594. Readings in Geology and Paleontology. 1,2 Unit.**
Focused readings and discussion of the literature with the course instructor in a seminar setting. Requires an independent study title request form that describes the specific area covered in the class and course requirements.

**GEOL 595. Readings in Limnogeology. 1 Unit.**
Readings and analysis of current and classic scientific literature dealing with modern and ancient lake environments—including geochemistry, sedimentology, biology and paleontology, and related subjects. Activities include student presentations of papers, discussion, and research proposals and reports. One extended, multiday field trip required.

**GEOL 607. Seminar in Geology. 0.5 Units.**
Presentations and discussion of selected topics featuring recent developments. Members of all geology programs meet together.

**GEOL 616. Research and Experimental Design. 2 Units.**
Concepts, methods, and tools of research, including experimental design and data analysis. Cross-listing: BIOL 616.

**GEOL 617. Proposal Writing and Grantsmanship. 2 Units.**
Develops skills in writing proposals and in acquiring funding for research. Increases understanding of the culture of research. Reviews the infrastructure of science funding and identifies individualized sources of potential funding. Presents successful proposal-writing strategies for both governmental and nongovernmental sources of funding. Emphasizes development of effective writing skills during preparation of the student's thesis or dissertation proposal.

**GEOL 618. Writing for Publication. 1 Unit.**
Explores the mechanics and processes of preparing, submitting, revising, and resubmitting a manuscript for publication in a peer-reviewed journal. Designed for students who are well along in the process of writing their first manuscript for publication. Prepares students to handle the manuscript revision process when the manuscript is returned from reviewers, as well as the final stage of resubmission to the journal.

**GEOL 658. Advanced Philosophy of Science readings (2). 2 Units.**
Reading and discussion of selected references in the philosophy of science, and the application of these concepts in the practice of scientific research and interpretation, including their influence on scientific study of origins. Best taken near the end of a student's graduate program. Two-hour class session per week.

**GEOL 664. Science Communication Outreach. 1 Unit.**
Guided immersion into science communication outreach. Principles of communication outreach and small group work presented. Student teams devise project that engages a specific, identified community. Small teams collaboratively interact with community to address a need, present findings, evaluate impact, and reflect on experience. Cross-listing: BIOL 664.

**GEOL 695. Special Projects in Geology. 1-4 Units.**
Special project in the field, laboratory, museum, or library under the direction of a faculty member. Registration indicates the specific field of the project.

**GEOL 697. Research. 1-8 Units.**
Credit for supervised research activities. Requires an independent study title request form that explains the research and evaluation criteria.

**GEOL 698. Thesis Research. 1-8 Units.**
Credit for supervised research activities and for writing of the master's thesis. Requires an independent study title request form that explains the research and evaluation criteria. Grade received does not indicate whether thesis is completed and approved.

**GEOL 699. Dissertation Research. 1-8 Units.**
Credit for supervised research activities and for writing the doctoral dissertation. Requires an independent study title request form that explains the research and evaluation criteria. Grade received does not indicate whether dissertation is completed and approved.