DEPARTMENT OF GEOLOGICAL SCIENCES (GRAD)

Contact Information
Department of Geological Sciences
Visit Program Website (http://geosci.unc.edu)

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The Department of Geological Sciences offers programs leading to the M.S. and Ph.D. degrees in geological sciences. A broad background is offered in most major areas of geoscience, with particular emphasis on hydrology, coastal processes, isotope geochemistry, geochronology, seismology, volcanology, igneous petrology, marine geology, low-temperature geochemistry, paleoclimatology, paleoceanography, paleontology, paleoecology, sequence stratigraphy, structural geology, earth surface processes, and tectonics.

Admission and General Degree Requirements
Students admitted to pursue a graduate degree in the Department of Geological Sciences normally are expected to have an undergraduate degree in traditional geology, geochemistry, geophysics, biology, chemistry, mathematics, physics, or other related interdisciplinary fields. All applicants must take the Graduate Record Examination (GRE). All foreign students whose native language is not English also must take the Test of English as a Foreign Language (TOEFL) examination.

Course requirements for incoming students will be determined by individual graduate committees, often in consultation with the director of graduate studies. Specific requirements are varied to meet the needs and career objectives of the individual.

Facilities and Research Interests
The Department of Geological Sciences occupies the 50,000 square feet of floor space in Elisha Mitchell Hall. Research equipment and facilities include two thermal ionization mass spectrometers with associated Class 100 clean labs; quadrupole ICPMS; a sediment analysis laboratory including refrigerated core storage; a laser-size particle analyzer; X-ray fluorescence spectrometer; X-ray diffractometer; field-emission electron microprobe (at Fayetteville State University, remotely operable); scanning electron microscope with X-ray analysis and c Kathodoluminescence; experimental petrology laboratory; gas chromatograph-isotope ratio mass spectrometer (in Marine Sciences); seismic reflection system; microsampling system with epifluorescence capabilities. The Department excels in advanced computational methods, and numerous high-end workstation facilities are available, including CPU-enhanced parallel processors and 4K visualization displays. Through RENCI (Renaissance Computing Institute) researchers can access, for instance, HPC and visualization to model coastal storm surge; software and cyber tools for interoperability and sharing of hydrology data and models and supercomputer clusters, such as Hatteras, a 5168-core cluster running CentOS Unix, and Blue Ridge, a 160-node cluster with a 40Gbit MPI interconnect and 20TB shared system. RENCI’s visualization includes a Social Computing Room, a 24’x24’ room that utilizes three projectors per wall, capable of visualizing at 9.5 million pixels.

Financial Aid
Approximately 11 teaching assistantships with stipends of $16,000 to $17,000 per academic year (2019–2020 stipends) are available to graduate students. In addition, all graduate students are eligible to apply for departmental summer fellowships ($7,000) research funds, and conference funds ($1,000) from a departmental endowment.

The department nominates three students to be considered by The Graduate School for nonservice fellowships; no additional application is necessary. Faculty research grants support some research assistantships. Out-of-state students are recommended for remission of out-of-state tuition costs; all students are recommended for an in-state tuition award. Most students are eligible for both and therefore are responsible only for the payment of student fees.

Master of Science
Requirements for the master of science degree are 30 semester hours (including a minimum of three hours, but no more than six hours of GEOL 993), a thesis, and a final oral examination in defense of the thesis.

Doctor of Philosophy
Many students have completed a master’s degree before being admitted to the doctoral program, but some students enter the Ph.D. program having completed only an undergraduate degree. Students admitted to the M.S. program who elect to pursue a Ph.D instead may be permitted to bypass the master’s degree after one semester of residence upon demonstration of superior scholastic performance and research potential. Recommendation by the student’s graduate committee and approval by the geological sciences faculty is required in this case.

Admission to the Ph.D. program after completing the M.S. degree in the Department of Geological Sciences requires faculty approval.

Requirements for the Ph.D. degree are a minimum of 48 semester hours of graduate credit (which may include 30 hours from the M.S. degree) and a minimum of six hours and preferably no more than 12 hours of graduate credit (which may include 30 hours from the M.S. program who elect to pursue a Ph.D. instead may be permitted to bypass the master’s degree after one semester of residence upon demonstration of superior scholastic performance and research potential. Recommendation by the student’s graduate committee and approval by the geological sciences faculty is required in this case.

Admission to the Ph.D. program after completing the M.S. degree in the Department of Geological Sciences requires faculty approval.

Requirements for the Ph.D. degree are a minimum of 48 semester hours of graduate credit (which may include 30 hours from the M.S. degree) and a minimum of six hours and preferably no more than 12 hours of GEOL 994, a written comprehensive examination and an oral comprehensive examination, a dissertation, and a final oral examination in defense of the dissertation.

Professors
Larry K. Benninger, Low-Temperature Geochemistry
Drew S. Coleman, Isotope Geochemistry, Geochronology
Jonathan M. Lees, Seismology, Volcanology
Donna M. Surge, Paleoclimate, Paleoecology, Low-Temperature Geochemistry

Associate Professors
Laura J. Moore, Coastal Geology
Tamlin M. Pavelsky, Global Hydrology
Kevin G. Stewart, Structural Geology

Assistant Professors
Xiaoming Liu, Geochemistry
Antonia Sebastian, Applied Hydrology and Water Resources

Associated Faculty
John M. Bane Jr., Physical Oceanography

Department of Geological Sciences (GRAD)
### Adjunct Appointment

Alan E. Boudreaux, Petrology, Geochemistry

### Professors Emeriti

Joseph G. Carter  
Paul Fullagar  
Allen F. Glazner, Igneous Petrology, Tectonics  
Daniel A. Textoris

### Assistant Teaching Professors

Michelle Haskin, Geoscience Education  
Joel W. Hudley, Sedimentology and Paleoclimatology  
Megan F. Plenge, Geoscience Education

## GEOL Advanced Undergraduate and Graduate-level Courses

**GEOL 403. Oceanography. 3 Credits.**  
Required preparation, major in a natural science or two courses in natural sciences. Studies origin of ocean basins, seawater chemistry and dynamics, biological communities, sedimentary record, and oceanographic history. Term paper. Students lacking science background should see MASC 101. Students may not receive credit for both MASC 101 and MASC 401.  
**Grading status:** Letter grade  
**Same as:** MASC 401, BIOL 350, ENVR 417.

**GEOL 405. Geochemistry. 3 Credits.**  
Required preparation, one introductory geology course. Introduction to the application of chemical principles to geological problems. Topics include thermodynamics, kinetics, and isotope geochemistry. Previously offered as GEOL 512/MASC 553.  
**Requisites:** Prerequisites, CHEM 102 and MATH 231; permission of the instructor for students lacking the prerequisites.  
**Gen Ed:** QI.  
**Grading status:** Letter grade  
**Same as:** MASC 455.

**GEOL 406. Introduction to Geophysics. 3 Credits.**  
Introduction to the fundamentals of global geophysics: gravity, seismology, magnetism, heat, and plate tectonics. Both shallow and deep processes are considered. Emphasis is aimed at problem solving by applying concepts. Previously offered as GEOL 515.  
**Requisites:** Prerequisites, PHYS 114, 116, or 118, and 115, 117, or 119.  
**Grading status:** Letter grade.

**GEOL 410. Earth Processes in Environmental Systems. 4 Credits.**  
Principles of geological and related Earth systems sciences are applied to analyses of environmental phenomena. The link between the lithosphere and other environmental compartments is explored through case studies of environmental issues. Three lecture hours and one laboratory hour a week.  
**Requisites:** Prerequisites, CHEM 102, GEOL 200, MATH 231, and PHYS 115 or 119; permission of the instructor for students lacking the prerequisites.  
**Grading status:** Letter grade  
**Same as:** ENEC 410, MASC 410.

**GEOL 411. Oceanic Processes in Environmental Systems. 4 Credits.**  
Principles of analysis of the ocean, coast, and estuarine environments and the processes that control these environments are applied to the analysis of environmental phenomena. Case studies of environmental issues. Three lecture hours and one laboratory hour a week.  
**Requisites:** Prerequisites, BIOL 101, CHEM 102, ENEC 222, MATH 231, PHYS 115 or 119; permission of the instructor for students lacking the prerequisites.  
**Grading status:** Letter grade  
**Same as:** ENEC 411, MASC 411.

**GEOL 412. Principles and Methods of Teaching Earth Science. 4 Credits.**  
Required preparation, any introductory geology course. This course develops the knowledge and skills teachers need to implement inquiry-based earth science instruction: conceptual knowledge of earth sciences and mastery of inquiry instructional methods. Students study inquiry in cognitive science and learning theory. This course is a requirement for the UNC-BEST program in geological sciences.  
**Gen Ed:** EE- Service Learning.  
**Grading status:** Letter grade  
**Same as:** ENEC 412.

**GEOL 415. Environmental Systems Modeling. 3 Credits.**  
This course explores principles and strategies for studying environmental phenomena, and presents methods for developing explanatory and predictive models of environmental systems, e.g., predator-prey, estuaries, greenhouse gases, and ecosystem material cycles.  
**Requisites:** Prerequisite, MATH 383; pre- or corequisite, PHYS 115 or 118, and COMP 116.  
**Grading status:** Letter grade  
**Same as:** ENEC 415, MASC 415.

**GEOL 417. Geomorphology. 3 Credits.**  
Introduction to process geomorphology with emphasis on quantitative interpretation of weathering, hill slope, fluvial, glacial, and eolian processes from topography and landscapes.  
**Requisites:** Prerequisites, GEOL 201 and MATH 231; permission of the instructor for students lacking the prerequisites.  
**Grading status:** Letter grade  
**Same as:** ENEC 417.

**GEOL 417L. Geomorphology Laboratory. 1 Credit.**  
Two laboratory hours per week.  
**Requisites:** Pre- or corequisite, GEOL 417.  
**Grading status:** Letter grade.

**GEOL 421. Archaeological Geology. 3 Credits.**  
Permission of the instructor. The application of geological principles and techniques to the solution of archaeological problems. Studies geological processes and deposits pertinent to archaeological sites, geologic framework of archaeology in the southeastern United States, and techniques of archaeological geology. Field trips to three or more sites; written reports required.  
**Repeat rules:** May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 2 total completions.  
**Grading status:** Letter grade  
**Same as:** ANTH 421.
GEOL 422. Physics of the Earth's Interior. 3 Credits.
Requisites: Prerequisites, MATH 383, and either PHYS 201 and 211 or 311 and 401.
Grading status: Letter grade
Same as: PHYS 422.

GEOL 425. Introduction to Field Geology. 3 Credits.
Introduction to geologic field methods. Includes making observations, mapping, identification of structures and features, and interpretation to solve basic geologic problems. Many field trips. Previously offered as GEOL 225.
Requisites: Prerequisites, GEOL 302, 303, and 304; permission of the instructor for students lacking the prerequisites.
Gen Ed: EE: Field Work.
Grading status: Letter grade.

GEOL 432. Palaeoclimatology. 3 Credits.
Introduction to mechanisms that drive climate. Examination of past climate reconstructions using ecological and geochemical proxies. Utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on late Quaternary.
Requisites: Prerequisite, GEOL 202 or 303; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

GEOL 433. Palaeoceanography. 3 Credits.
Origin and distribution of pelagic sediments. Review of the major Mesozoic and Cenozoic events in the world oceans. Glacial/interglacial changes in the ocean/atmosphere system.
Requisites: Prerequisite, GEOL 303 or 503; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

GEOL 435. Groundwater. 3 Credits.
Required preparation, one introductory geology course. Introduction to physics, chemistry, and geology of groundwater. Previously offered as GEOL 509.
Requisites: Prerequisite, GEOL 201; CHEM 102; MATH 231; PHYS 104 or 114 or 116 or 118; permission of the instructor for students lacking the prerequisites.
Gen Ed: QI.
Grading status: Letter grade
Same as: ENEC 435.

GEOL 436. Geochemistry of Natural Waters. 3 Credits.
Required preparation, one introductory geology course. Survey of processes affecting the compositions of streams, lakes, the ocean, and shallow ground waters. Previously offered as GEOL 510.
Requisites: Prerequisites, CHEM 102 and MATH 231; permission of the instructor for students lacking the prerequisites.
Gen Ed: QI.
Grading status: Letter grade.

GEOL 440. Principles of Seismology. 3 Credits.
Descriptive account of global seismology, earthquake distribution, and focal mechanics. Principles of geometrical optics and applications to imaging the earth's interior. Principles of seismic prospecting of hydrocarbon and geothermal reservoirs.
Requisites: Prerequisites, GEOL 200, 302; MATH 231; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

GEOL 450. Biogeochemical Processes. 4 Credits.
Principles of chemistry, biology, and geology are applied to analysis of the fate and transport of materials in environmental systems, with an emphasis on those materials that form the most significant cycles. Three lecture hours and one laboratory hour a week.
Requisites: Prerequisites, MATH 231, and PHYS 114 or 118; permission of the instructor for students lacking the prerequisites.
Gen Ed: PL.
Grading status: Letter grade
Same as: ENEC 450, MASC 450.

GEOL 460. Fluid Dynamics of the Environment. 3 Credits.
Principles and applications of fluid dynamics to flows of air and water in the natural environment. Conservation of momentum, mass, and energy applied to lakes, rivers, estuaries, and the coastal ocean. Dimensional analysis and scaling emphasized to promote problem-solving skills.
Requisites: Prerequisite, MATH 232; permission of the instructor for students lacking the prerequisite.
Gen Ed: QI.
Grading status: Letter grade.

GEOL 480. Modeling of Marine and Earth Systems. 1-3 Credits.
Mathematical modeling of dynamic systems, linear and nonlinear. The fundamental budget equation. Case studies in modeling transport, biogeochemical processes, population dynamics. Analytical and numerical techniques; chaos theory; fractal geometry.
Requisites: Prerequisite, MATH 232; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: MASC 480, ENV 480.

GEOL 483. Geologic and Oceanographic Applications of Geographical Information Systems. 4 Credits.
Required preparation, four GEOL courses or permission of the instructor. Focus is on applying GIS concepts and techniques to mining and petroleum geology, resource assessment, hydrogeology, coastal and marine geology, physical oceanography, engineering geology, and a geologic perspective on land use. Three lecture and two laboratory hours a week.
Grading status: Letter grade
Same as: MASC 483.

GEOL 485. Summer Field Course in Geology. 3 Credits.
Three-week field camp conducted in the western United States (Arizona, California, Colorado, Nevada, New Mexico, and/or Utah). Learn proper use of geology field tools and how to make a geologic map. Field interpretation of rocks and their deformation. Previously offered as GEOL 601.
Requisites: Prerequisites, GEOL 302, 303, and 304; permission of the instructor for students lacking the prerequisites.
Gen Ed: EE- Field Work.
Grading status: Letter grade.

GEOL 486. Summer Field Course in Geology. 3 Credits.
Three-week field camp conducted in the western United States (Arizona, California, Colorado, Nevada, New Mexico, and/or Utah). Learn advanced mapping skills necessary to interpret geologic history of complexly deformed rocks. Previously offered as GEOL 602.
Requisites: Prerequisites, GEOL 302, 303, and 304; permission of the instructor for students lacking the prerequisites.
Gen Ed: EE- Field Work.
Grading status: Letter grade.
GEOL 490. Topics in Earth and Environmental Sciences. 3 Credits.
Key topics and resources for high school teachers preparing to teach earth and environmental sciences. Includes lithosphere, tectonic processes, hydrosphere, atmosphere, origin of solar system and life, and environmental stewardship.
Grading status: Letter grade.

GEOL 501. Geological Research Techniques. 3 Credits.
Permission of the instructor. Theory and practice of analytical methods in geochemistry including X-ray diffraction, X-ray fluorescence, and scanning electron microscopy; introduction to electronics.
Grading status: Letter grade.

GEOL 502. Earth Surface Processes. 3 Credits.
This course will focus on the processes of soil formation, erosion, and landform evolution with an emphasis on the interaction of geomorphic processes with surface hydrology and ecosystems. (EES)
Requisites: Prerequisite, GEOG 110.
Gen Ed: PL.
Grading status: Letter grade
Same as: GEOG 440.

GEOL 503. Marine Geology. 4 Credits.
For graduate students; undergraduates need permission of the instructor. Investigates formation of the oceans, plate tectonics, carbonate reefs and platforms, sediment transport from the land to deep-sea fans, glacial-marine geology, marine records of changes in sea level and climate, and the evolution of barrier islands, estuaries, and deltas. Mandatory weekend field trip to the Southern Outer Banks.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 503.

GEOL 504. Advanced Petrology. 3 Credits.
Origin of magmas and evolution of igneous and metamorphic rocks, combined with petrographic study of selected sites.
Requisites: Prerequisite, GEOL 304.
Grading status: Letter grade.

GEOL 505. Chemical Oceanography. 4 Credits.
Graduate students only; undergraduates must have permission of the instructor. Overview of chemical processes in the ocean. Topics include physical chemistry of seawater, major element cycles, hydrothermal vents, geochemical tracers, air-sea gas exchange, particle transport, sedimentary processes, and marine organic geochemistry. Three lecture and two recitation hours per week.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 506.

GEOL 506. Physical Oceanography. 4 Credits.
For graduate students; undergraduates need permission of the instructor. Descriptive oceanography, large-scale wind-driven and thermohaline circulations, ocean dynamics, regional and nearshore/estuarine physical processes, waves, tides. Three lecture and one recitation hour per week.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 506.

GEOL 508. Global Hydrology. 3 Credits.
An introduction to methodologies and instrumentation for quantifying the movement of water in the earth system focusing on components of the hydrologic cycle.
Requisites: Prerequisites, GEOL/ENEC 324 and MATH 231; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

GEOL 511. Stable Isotopes in the Environment. 3 Credits.
Introduction to the theory, methods, and applications of stable isotopes to environmental problems. Primary focus will be on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, and nitrogen isotopes.
Requisites: Prerequisite, CHEM 102.
Grading status: Letter grade
Same as: ENEC 511.

GEOL 512. Introduction to Stable Isotopes. 3 Credits.
This course will cover the use of stable isotopes to understand the processes of soil formation, erosion, and landform evolution. It focuses on the interaction of geomorphic processes with surface hydrology and ecosystems. (EES)
Requisites: Prerequisites, GEOL 201, MATH 231; or permission of instructor.
Grading status: Letter grade
Same as: ENEC 514.

GEOL 514. Rivers and Floods. 3 Credits.
River floods are critically important in the global hydrologic cycle. While seasonal floods can be environmentally restorative, they can also have devastating socio-economic and public health consequences. Beginning with the hydrologic cycle, this course will cover concepts related to rainfall runoff and hydrologic response, flood frequency analysis, the mechanics of open channel flow, and overland and channel routing. Students will also gain experience working with real-world data and engineering software.
Requisites: Prerequisites, GEOL 201 and MATH 231; or permission of instructor.
Grading status: Letter grade
Same as: ENEC 514.

GEOL 517. Sequence and Seismic Stratigraphy. 3 Credits.
Examination of lithostratigraphic principles and the sequence stratigraphic paradigm. Students will study use of well log signature reflection attributes and reflection termination patterns to identify and correlate sequences and systems and to interpret the lithology and depositional history of subsurface stratigraphic units.
Requisites: Prerequisite, GEOL 303.
Grading status: Letter grade.

GEOL 518. Geodynamics. 3 Credits.
Required preparation, one introductory geology course. Interior of the earth deduced from seismology, gravity, heat flow, magnetism; geophysics of continents and ocean basins; age of earth.
Requisites: Prerequisites, CHEM 102; MATH 232; and PHYS 104 and 105, or 114 and 115.
Grading status: Letter grade.

GEOL 520. Data Analysis in the Earth Sciences. 3 Credits.
Required preparation, an introductory geology course numbered below 202, except first-year seminar, or permission of the instructor. Introduction to quantitative analysis in earth sciences: solid earth, atmospheres, oceans, geochemistry, and paleontology. Topics covered: univariate and multivariate statistics, testing, nonparametric methods, time series, spatial and cluster analysis, shapes.
Requisites: Prerequisites, MATH 231 and 232.
Grading status: Letter grade.

GEOL 521. Clastic Depositional Systems: Processes and Products. 3 Credits.
Examination of the use of lateral and vertical changes in sedimentary facies to identify depositional processes and environments of deposition within the terrestrial, marginal marine, shelf, and deep sea clastic depositional systems. These systems will be examined in a sequence stratigraphic framework.
Requisites: Prerequisite, GEOL 303.
GEOL 522. Physical Volcanology. 3 Credits.
Required preparation, introductory courses in geology and physics. Course is aimed at understanding the physical properties and processes controlling volcanism and magma transport. Topics covered include volcanic processes from the formation of magma in the upper mantle to violent eruption at the surface. Emphasizes dynamic processes and underlying mechanisms.
Grading status: Letter grade.

GEOL 523. Petroleum Geoscience. 4 Credits.
Students study the origin, migration, and entrapment of hydrocarbons in sedimentary basins and learn how several areas of the geosciences are integrated to locate and produce hydrocarbons. Students learn about these topics while analyzing a real subsurface data set.
Requisites: Prerequisites, GEOL 302 and 303; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

GEOL 525. Inverse Theory: Advanced Data Analysis and Geophysical Modeling. 3 Credits.
The course deals with earth science problems related to extracting model parameters from data and field observations. Details of mathematical concepts, real world examples, and practical applications associated with noisy or incomplete data are covered. Key concepts include multivariate regression, model discretization, Tikhonov regularization, and Bayesian methods.
Grading status: Letter grade.

GEOL 550. Biogeochemical Cycling. 3 Credits.
Biogeochemical cycling explores interfaces of marine, aquatic, atmospheric, and geological sciences emphasizing processes controlling chemical distributions in sediments, fresh and salt water, the atmosphere, and fluxes among these reservoirs.
Requisites: Prerequisites, ENVR 421; GEOL 405, 436, 655; MASC 440, 505; or permission of the instructor.
Gen Ed: PL, CI.
Grading status: Letter grade
Same as: MASC 550.

GEOL 552. Organic Geochemistry. 3 Credits.
Recommended preparation, CHEM 261 or MASC 505, and one additional ENVR, GEOL, or MASC course above 400. Sources, transformations, and fate of natural organic matter in marine environments. Emphasis on interplay of chemical, biological, and physical processes that affect organic matter composition, distribution, and turnover.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 552, ENVR 552.

GEOL 555. Paleobotany: An Introduction to the Past History of Plants. 3 Credits.
An introduction to the fossil record of plants, investigating how plants originated and changed through geological time to produce the modern flora. Both macrofossils and microfossils will be considered. Three lecture hours a week.
Requisites: Prerequisites, BIOL 202, and one other BIOL course above 200; corequisite, BIOL 555L; permission of the instructor for students lacking the requisites.
Gen Ed: EE- Field Work.
Grading status: Letter grade
Same as: BIOL 555.

GEOL 560. Fluid Dynamics. 3 Credits.
The physical properties of fluids, kinematics, governing equations, viscous incompressible flow, vorticity dynamics, boundary layers, irrotational incompressible flow.
Requisites: Prerequisite, PHYS 401; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: MASC 560, ENVR 452, PHYS 660.

GEOL 563. Descriptive Physical Oceanography. 3 Credits.
Observed structure of the large-scale and mesoscale ocean circulation and its variability, based on modern observations. In-situ and remote sensing techniques, hydrographic structure, circulation patterns, ocean-atmosphere interactions.
Requisites: Prerequisite, MASC 506; permission of the instructor for students lacking the prerequisite.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 563.

GEOL 567. Application of Plasma Mass Spectrometry in Earth and Environmental Sciences. 3 Credits.
This class is an introduction to one of the state-of-the-art analytical techniques in geological and environmental research - the ICP-MS (Inductively Coupled Plasma - Mass Spectrometry). Students will have hands-on experiences with ICP-MS sample preparation and analysis, and will design their own hypothesis-driven research projects to analyze major and trace elements in geological and environmental samples including water, rock, and soil.
Requisites: Prerequisite, GEOL 101, 200, or 201.
Gen Ed: EE- Mentored Research.
Grading status: Letter grade.

GEOL 580. Evolution of Earth's Surface Environment. 3 Credits.
The course combines geology, climatology, hydrology, and soil science to explore the evolution of the surface environment of the earth from the Archean to the present, including the great oxidation event and modern ocean anoxia. Students will read research papers and will be encouraged to question and debate course topics.
Grading status: Letter grade.

GEOL 590. Special Topics in Earth Sciences. 1-4 Credits.
Discussion or lab-based consideration of topical issues in earth sciences.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 8 total credits. 2 total completions.
Grading status: Letter grade.

GEOL 595. Advanced Field Seminar in Geology. 1-4 Credits.
A field course that emphasizes advanced field methods. Emphasis is placed on large-scale, detailed field work in complex structural terrains and on independent mapping that will lead to thesis/dissertation and/or publication. Previously offered as GEOL 695.
Requisites: Prerequisites, GEOL 485 and 486.
Grading status: Letter grade.

GEOL 608. Continuum Mechanics in the Earth Sciences. 3 Credits.
Applications of continuum mechanics in the earth sciences, including stress, strain, elasticity, and viscous flow. Numerical solutions to problems in heterogeneous finite strain including finite element analysis.
Requisites: Prerequisites, GEOL 302, and PHYS 114, 116, or 118.
Grading status: Letter grade
Same as: ENEC 608.
GEOL 655. Recent Advances in Non-Traditional Stable Isotope Geochemistry. 3 Credits.
This seminar will introduce students to state of the art analytical techniques, current theories, and their applications in various geological processes regarding the non-traditional stable isotopes (e.g., Li, Mg, Fe, Mo, and Cr). After introducing some basic principles and analytical techniques of these so called "non-traditional" stable isotopes, students will present and discuss recent literature in this arena.
Gen Ed: QI.
Grading status: Letter grade.

GEOL 691H. Honors. 3 Credits.
By permission of the department. For details, see geology degree requirements.
Gen Ed: EE- Mentored Research.
Grading status: Letter grade.

GEOL 692H. Honors. 3 Credits.
For details, see geology degree requirements.
Requisites: Prerequisite, GEOL 691H.
Gen Ed: EE- Mentored Research.
Grading status: Letter grade.

Graduate-level Courses
GEOL 700. Research Seminar. 1 Credit.
Required of all entering graduate students or permission of the department. A topical seminar in current research topics in the earth sciences. Presentations by selected faculty with an emphasis on in-depth, critical analysis of current research literature. Two hours a week.
Grading status: Letter grade.

GEOL 701. Graduate Seminar. 0.5-21 Credits.

GEOL 703. Sedimentary Geology I. 3 Credits.
Stratigraphic, sedimentologic, geochemical, petrologic, and paleontologic principles will be summarized. Emphasis is placed on both the techniques used in sedimentary geology and on the characteristics and processes that distinguish sedimentary environments.
Requisites: Prerequisite, GEOL 402.
Grading status: Letter grade.

GEOL 704. Sedimentary Geology II. 3 Credits.
Continuation of GEOL 703.
Requisites: Prerequisite, GEOL 703.
Grading status: Letter grade.

GEOL 705. Advanced Petrology I. 3 Credits.
Application of thermodynamics, phase equilibria, thermobarometry, radiogenic and stable isotope geology, and geochemical modeling to the study of igneous and metamorphic rocks and crustal evolution.
Requisites: Prerequisites, CHEM 102, GEOL 304, MATH 233, and PHYS 105.
Grading status: Letter grade.

GEOL 706. Advanced Petrology II. 3 Credits.
Continuation of GEOL 705.
Requisites: Prerequisite, GEOL 705.
Grading status: Letter grade.

GEOL 707. Stratigraphic Micropaleontology: Mesozoic Calcareous Nannofossils. 4 Credits.

GEOL 708. Stratigraphic Paleontology: Cenozoic Calcareous Nannofossils. 4 Credits.

GEOL 710. Advanced Coastal Environmental Change. 3 Credits.
Focuses on biological-physical couplings that shape coastal environments (i.e. coastal 'ecomorphodynamics') and determine how these environments change with climate and land use. Environments include: barrier islands, open ocean coastlines, and tidal wetlands. Grading based on presentations, participation, and a research proposal.
Requisites: Prerequisites, GEOL 417, 502, or 503; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade
Same as: MASC 730, ENEC 710.

GEOL 711. Advanced Mineralogy. 3 Credits.

GEOL 712. Isotope Geochemistry. 3 Credits.
Survey of isotopic studies in geology; geochronology, crustal evolution, heat flow, paleotemperatures, origin of ore deposits.
Requisites: Prerequisites, CHEM 102, GEOL 301, 303, and 304.
Grading status: Letter grade.

GEOL 804. Advanced Igneous Petrology. 4 Credits.

GEOL 805. Igneous Geochemistry. 4 Credits.

GEOL 806. Metamorphic Petrology. 4 Credits.

GEOL 809. Tectonophysics. 3 Credits.
Fundamental physical processes necessary for an understanding of plate tectonics; stress and strain in solids; elasticity and flexure; heat transfer; gravity; mantle rheology and convection.
Requisites: Prerequisites, MATH 383, PHYS 201, and 211; Permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

GEOL 851. Seminar in Stratigraphy. 1-15 Credits.

GEOL 852. Seminar in Paleoclimatology. 1-15 Credits.

GEOL 853. Seminar in Paleontology. 1-15 Credits.

GEOL 854. Seminar in Continental Margins. 0.5-21 Credits.

GEOL 855. Seminar in Sedimentology. 1-15 Credits.

GEOL 856. Seminar in Isotope Geology. 3 Credits.
Introduction to the theory, methods and applications of stable isotopes to low- and high-temperature problems. Primary focus will be on the origin, natural abundance, and fractionation of carbon, hydrogen, and oxygen isotopes.
Grading status: Letter grade.

GEOL 857. Seminar in Geochemistry. 1-15 Credits.

GEOL 858. Seminar in Petrology. 1-15 Credits.

GEOL 859. Seminar in Economic Geology. 1-15 Credits.

GEOL 860. Seminar in Volcanology. 3 Credits.
All aspects of volcanism will be covered including seismology, geochemistry, deep structure, volcanic products and hazards. Readings of original papers will be stressed.
Grading status: Letter grade.
GEOL 861. Seminar in Geophysics. 0.5-21 Credits.
Develop explanatory and predictive models of the earth's climate. Introductory level and focused on modeling past climate with the hope of understanding its future. A thorough discussion of current global warming/climate change issues, including the science, history, and controversy, are the main topics of the last third of the course.
Grading status: Letter grade.

GEOL 862. Seminar in Seismology. 3 Credits.

GEOL 863. Seminar in Structural Geology. 1-15 Credits.

GEOL 864. Seminar in Tectonics. 3 Credits.
The goal of this seminar is to examine the Cretaceous to Eocene tectonics of the western United States to evaluate the putative flat slab processes responsible. Geologic research on the Laramide Orogeny predates plate tectonic theory, and the explosion of subsequent research warrants a reevaluation of existing theory.
Grading status: Letter grade.

GEOL 900. Research in Geology. 1-9 Credits.

GEOL 993. Master's Research and Thesis. 3 Credits.

GEOL 994. Doctoral Research and Dissertation. 3 Credits.