Introduction
The study of earth's dynamic systems is a field that has seen major advances over the last few decades. Geologists investigate diverse systems that play a large role in controlling the environment at the earth's surface. Examples include earthquakes, volcanoes, glaciers, landslides, rivers, and shorelines. Earth processes play a critical role in making our planet habitable, and geologists are constantly in demand to guide communities and nations in their search for resources such as clean drinking water and extractable energy and minerals, or in decisions regarding development in fragile coastal regions or in seismically active areas. The Department of Geological Sciences provides students with a solid training in earth science so that they can advance in highly satisfying careers as professional geologists.

Most students planning to do graduate work or to become professional geologists should follow the B.S. program. However, the flexibility of the B.A. program may be advantageous to students with interest in, for example, environmental studies, education, or law.

Advising
All majors and minors have a primary academic advisor in Steele Building. Students are strongly encouraged to meet regularly with their advisor and review their Tar Heel Tracker each semester. The department's director of undergraduate studies works with current and prospective majors by appointment. Departmental academic advising is particularly important for those majors who are considering going on to graduate school. Further information on courses, undergraduate research opportunities, the honors program, careers, and graduate schools may be obtained from the department's Web site.

Facilities
The Department of Geological Sciences houses several laboratory facilities that are available for undergraduate students to use for research. Many students are introduced to the laboratory facilities through coursework. Laboratories include

1. a thermal ionization mass spectrometer for isotope and geochronology research;
2. a scanning electron microscope laboratory for image analysis, element mapping, and semi-quantitative chemical analysis;
3. an X-ray fluorescence spectrometer for chemical analysis of geological materials;
4. an X-ray diffractometer for rapid mineral identification;
5. a direct current plasma spectrometer for analysis of major and minor elements in sample solutions;
6. equipment for geophysical research and imaging, including portable broadband seismic stations, infrasonic microphones, a gravimeter, and equipment for ship-borne reflection seismology;
7. a sediment analysis laboratory including a coulometer, settling tube, and laser particle size counter;
8. chemical and counting laboratories for quantifying natural and artificial radioactivity at environmental levels;
9. a paleoclimate/paleoecology laboratory equipped for high-resolution microsampling of carbonate samples for geochemical analysis.

Graduate School and Career Opportunities
Geologists commonly are employed by private industry, public and private schools, colleges and universities, and consulting firms (e.g., hydrology, environmental geology, engineering geology, petroleum geology, and mineral exploration). Geology graduates also can find jobs with federal or state geological surveys or with other federal/state environmental or energy firms. Some federal/state agencies prefer geologists with at least a master’s degree. A doctoral degree usually is required for employment at colleges and universities.

Majors
• Geological Sciences Major, B.S.—Earth Science Concentration (http://catalog.unc.edu/undergraduate/programs-study/geological-sciences-major-bs-earth-science-concentration)
• Geological Sciences Major, B.S.—Environmental Geology Concentration (http://catalog.unc.edu/undergraduate/programs-study/geological-sciences-major-bs-environmental-geology-concentration)
• Geological Sciences Major, B.S.—Geochemistry Concentration (http://catalog.unc.edu/undergraduate/programs-study/geological-sciences-major-bs-geochemistry-concentration)
• Geological Sciences Major, B.S.—Paleobiology Concentration (http://catalog.unc.edu/undergraduate/programs-study/geological-sciences-major-bs-paleobiology-concentration)

Minor
• Geological Sciences Minor (http://catalog.unc.edu/undergraduate/programs-study/geological-sciences-minor)

Graduate Programs
• M.S. in Geological Sciences (http://catalog.unc.edu/graduate/schools-departments/geological-sciences)
• Ph.D. in Geological Sciences (http://catalog.unc.edu/graduate/schools-departments/geological-sciences)
Professors
Larry K. Benninger, Drew S. Coleman, Allen F. Glazner, Jonathan Lees, José A. Rial.

Associate Professors
Louis R. Bartek, Laura Moore, Tamlin M. Pavelsky, Kevin G. Stewart, Donna Surge.

Assistant Professor
Xiaoming Liu.

Affiliated Faculty
John M. Bane Jr., Christopher S. Martens.

Adjunct Professor
Alan Boudreau.

Adjunct Associate Professor
Antonio B. Rodríguez.

Research Assistant Professor
Michael John Willis.

Lecturers
Joel Hudley, Melissa O. Hudley.

GEOL—Geological Sciences

Undergraduate-Level Courses

GEOL 70. First-Year Seminar: One Billion Years of Change: The Geologic Story of North Carolina. 3 Credits.
A field-based course focused on the geologic story of North Carolina. Includes local field trips and weekend trips to the coast and mountains
Gen Ed: PL.
Grading status: Letter grade.

GEOL 71. First-Year Seminar: Bones Back to Life. 3 Credits.
Get hands-on experience with the reconstruction of vertebrate fossils. Learn the paleontology of the Carolinas and beyond.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 72. First-Year Seminar: Field Geology of Eastern California. 3 Credits.
This seminar provides a hands-on introduction to active geologic and environmental processes in eastern California, including active volcanoes, earthquake-producing faults, and extreme climate change.
Gen Ed: PL, EE-Field Work.
Grading status: Letter grade.

GEOL 72H. First-Year Seminar: Field Geology of Eastern California. 3 Credits.
This seminar provides a hands-on introduction to active geologic and environmental processes in eastern California, including active volcanoes, earthquake-producing faults, and extreme climate change.
Gen Ed: PL, EE-Field Work.
Grading status: Letter grade.

GEOL 73. First-Year Seminar: Global Warming and the Future of the Planet. 3 Credits.
Global warming is the most important environmental problem of the 21st century. This seminar explores geologic history of global warming, its physical principles, and prospects for future societies.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 74. First-Year Seminar: Geology of Climate Change. 3 Credits.
Examination of the problem of natural versus human-induced climate change from the perspective of the geologic record of earth history. Field trips to coast, Piedmont, and Blue Ridge.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 75. First-Year Seminar: Waste in the Environment. 3 Credits.
Origins and effects of waste in the environment. Introduces natural wastes and ecosystem recycling, but focuses on case studies of generation, environmental impacts, and remediation of anthropogenic wastes.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 76. First-Year Seminar: Energy Resources for a Hungry Planet. 3 Credits.
Discussions are centered on the most pressing issues of our time: environmental deterioration and construction of a sustainable (livable) world during and after the depletion of traditional energy resources.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 77. First-Year Seminar: Volcanoes and Civilization: An Uneasy Coexistence. 3 Credits.
Volcanoes provide a breathable atmosphere, a habitable climate, and precious ores, but they have the potential to destroy civilization. This seminar will explore the uneasy coexistence of volcanoes and civilization.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 79. First-Year Seminar: Coasts in Crisis. 3 Credits.
An investigation of the geologic evolution and function of coastal environments, the recent effects of coastal development and engineering, and an examination of existing coastal management strategies and the tensions between coastal development and the desire to preserve natural environments.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 89. First-Year Seminar: Special Topics. 3 Credits.
Special topics course. Content will vary each semester.
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.

GEOL 101. Introductory Geology. 3 Credits.
Major geologic events: earthquakes, volcanic activity, mountain formation, plate tectonics, and erosion. Landscape development by glaciers, streams and groundwater, ocean currents and waves, wind. Not open to students with credit in or currently enrolled in GEOL 105, 109, or 111. Optional laboratory: GEOL 101L. PX credit for GEOL 101+101L.
Gen Ed: PX.
Grading status: Letter grade.
GEOL 101L. Introductory Geology Laboratory. 1 Credit.
Study of common minerals and rocks. Use of topographic and geologic maps to illustrate geologic processes. Two laboratory hours a week.
Requisites: Pre- or corequisite, GEOL 72, 101, 105, 109, 110 or 159.
Grading status: Letter grade.

GEOL 103. The Marine Environment. 3 Credits.
Introduction to marine sciences emphasizing physical, chemical, biological, and geological phenomenon in oceanic and coastal environments. Human use of, and impact on, marine resources. Science majors should take MASC 401. Students may not receive credit for both MASC 101 and MASC 401.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 101.

GEOL 105. Violent Earth. 3 Credits.
Earth is changing catastrophically through volcanoes, earthquakes, hurricanes, and meteoric impacts. Explore the causes and effects of these phenomena and their impact on human development. Not open to students with credit in or currently enrolled in GEOL 101, 109, or 111. Optional laboratory: GEOL 101L. PX credit for GEOL 105+101L.
Gen Ed: PX.
Grading status: Letter grade.

GEOL 108. Our Energy and Climate Crises: Challenges and Opportunities. 4 Credits.
Students quantify global depletion of energy resources and accompanying environmental degradation, discovering the profound changes in attitudes and behavior required to adjust to diminished fossil fuels and modified climate.
Gen Ed: PL, GL.

GEOL 109. Earth, Climate, and Life through Time. 3 Credits.
Study of the solid earth and plate tectonics. Evolution of the atmosphere and oceans. Climate change. Origin of life, evolution and mass extinctions. Not open to students with credit in or currently enrolled in GEOL 101, 105, or 110. Optional laboratory: GEOL 101L. PX credit for GEOL 109+101L.
Gen Ed: PX.
Grading status: Letter grade.

GEOL 110. Earth and Climate for Science Majors. 3 Credits.
Interactions between Earth systems. Topics include plate tectonics, climate change, history of life, and biogeochemical cycles. This course is restricted to science majors only. Not open to students with credit in or currently enrolled in GEOL 101, 105, or 110. Optional laboratory: GEOL 101L. PX credit for GEOL 110+101L.
Gen Ed: PX.
Grading status: Letter grade.

GEOL 159. Prehistoric Life. 3 Credits.
Fossils and the origin and evolution of life, including micro- and macroevolution, mass extinctions, the evolution of dinosaurs and humans, and scientific perspectives on multicultural creationism. Optional laboratory, GEOL 101L. PX credit for GEOL 159 + 101L.
Gen Ed: PX.
Grading status: Letter grade
Same as: BIOL 159.

GEOL 190. Special Topics in Geological Sciences at an Introductory Level. 3 Credits.
An undergraduate seminar course that is designed to be a participatory intellectual adventure on an advanced, emergent, and stimulating topic within a selected discipline in geological sciences. This course does not count as a credit towards geological sciences majors.
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.

GEOL 200. The Solid Earth. 3 Credits.
An introduction to the solid earth, and with GEOL 201 is an overview of earth systems for students continuing in geological, environmental, and other sciences. Topics include synthesis of the elements, formation of the solar system and earth, plate tectonics, earth materials, internal energy, magnetism, geochemical cycles, and earth resources.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 201. Earth's Surface: Processes, Landforms, and History. 3 Credits.
This course focuses on the biological, chemical, and physical processes that shape the surface of the earth. Major points of emphasis will include earth's climate, the global water cycle, geomorphic processes and the landforms they create, sedimentology and depositional environments, and elements of earth history recorded by earth surface processes.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 202. Earth Systems History. 3 Credits.
Required preparation, one introductory geology course numbered below GEOL 202, except first-year seminar. History of the earth (including its oceans, atmosphere, and life forms) as deciphered from the geologic record. Birth of continents/oceans; evolution and extinction of life forms; the changing global environment.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 204. Planetary Geology: Meteorites and Asteroids. 3 Credits.
Required preparation, one introductory geology course numbered below GEOL 202, except first-year seminar. Effects and probable effects of meteorite and asteroid impacts on earth and other planets: craters, new meteorites, and tektites; giant sea waves; reduction of species and extinction of organisms.
Gen Ed: PL.
Grading status: Letter grade.

GEOL 206. Environmental Geology. 3 Credits.
Required preparation, one introductory geology course numbered below GEOL 202, except first-year seminar. Environmental and human problems connected with uses of earth materials and with geological processes. Mineral and water resources, land-use planning, and engineering geology.
Grading status: Letter grade
Same as: ENEC 211.

GEOL 213. Earth's Dynamic Systems. 3 Credits.
Grading status: Letter grade
Same as: ENEC 213.
GEOL 215. Energy Resources. 3 Credits.
Required preparation, one geology course numbered below GEOL 202, except first-year seminar. Considers the distribution, extraction, economics, and demand for mineral resources. Treats the impact of the mineral industry on industrial and preindustrial economies, economic factors, maldistribution and depletion of resources, and the environmental impact of the mineral extraction industry.
Grading status: Letter grade.

GEOL 221. Geology of North America. 3 Credits.
Required preparation, one geology course numbered below GEOL 202, except first-year seminar. General introduction to the geologic evolution of North America. Provides students with an understanding and appreciation of diverse natural regions of the United States and Canada. Selected national parks serve as case studies of regional geologic history.
Gen Ed: EE-Field Work.
Grading status: Letter grade.

GEOL 223. Geology of Beaches and Coasts. 3 Credits.
Required preparation, one introductory geology course numbered below GEOL 202, except first-year seminar. Introduction to coastal processes, including waves, tidal currents, tectonics, climate, and human activity, and their influence on barrier islands, beaches, dunes, marshes, and estuaries. Involves a field trip to the Outer Banks of North Carolina.
Grading status: Letter grade
Same as: MASC 223.

GEOL 225. 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.
Requisites: Prerequisites, GEOL 101/101L.
Grading status: Letter grade.

GEOL 301. Earth Materials: Minerals. 4 Credits.
Minerals in sedimentary, igneous, and metamorphic environments: their properties, occurrence, and uses. Methods of identifying minerals, including use of optical properties. Three lecture and three laboratory hours a week.
Requisites: Prerequisite, GEOL 101 or 110; pre- or corequisite, CHEM 101; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

GEOL 310. Coastal Environmental Change. 3 Credits.
An exploration of the large-scale evolution of coastal environments, including relevance of geologic setting, wave and sediment transport processes, the evolution of beach and barrier island morphology, and issues of coastal environmental management.
Requisites: Prerequisite, GEOL 101, 105, or 110; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

GEOL 324. Water in Our World: Introduction to Hydrologic Science and Environmental Problems. 3 Credits.
This introductory course will cover two broad themes: the physical processes of the hydrologic cycle and how human use (and abuse) of freshwater resources can lead to major environmental problems.
Gen Ed: PX.
Grading status: Letter grade
Same as: ENEC 324.

GEOL 324L. Water in Our World Laboratory. 1 Credit.
Students will conduct laboratory and field experiments to reinforce the topics covered in ENEC/GEOL 324. PX credit for ENEC/GEOL 324 + 324L.
Requisites: Pre- or corequisite, ENEC/GEOL 324.
Grading status: Letter grade
Same as: ENEC 324L.

GEOL 390. Special Topics in Geology. 1-4 Credits.
Permission of the department. Topics and instructors vary from semester to semester. Course may be repeated.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

GEOL 390H. Special Topics in Geology. 1-4 Credits.
Permission of the department. Topics and instructors vary from semester to semester. Course may be repeated.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

GEOL 395. Undergraduate Research in Geology. 1-4 Credits.
Permission of the instructor. Research in geology under the supervision of a selected instructor. Approved learning contract required. May be repeated up to four times for a maximum of 12 credits.
Repeat rules: May be repeated for credit. 12 total credits. 4 total completions.
Grading status: Letter grade.

GEOL 396. Independent Study in Geology. 1-4 Credits.
Permission of the instructor. Independent study under the supervision of a selected instructor. Learning contract required. May be repeated up to four times for a maximum of 12 credits.
Repeat rules: May be repeated for credit. 12 total credits. 4 total completions.
Grading status: Letter grade.

Advanced Undergraduate and Graduate-level Courses

GEOL 401. Structural Geology. 4 Credits.
Introduction to the mechanical behavior and dynamic evolution of the earth's crust through the study of deformed rocks. Includes weekend field trip to western North Carolina.
Requisites: Prerequisite, GEOL 101, 105, 109, or 110.
Grading status: Letter grade.

GEOL 402. Sedimentology and Stratigraphy. 4 Credits.
Introduction of principles involved in description and classification of sedimentary rocks and stratigraphic units as well as stratigraphic correlation. Students will be introduced to relationships of processes, depositional environments, and sedimentary facies.
Requisites: Prerequisites, GEOL 101 or 110, and GEOL 301.
Grading status: Letter grade.

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, ENV 417.
GEOL 404. Petrology and Plate Tectonics. 4 Credits.
Studies of the origin and evolution of igneous and metamorphic rocks, including microscopic, X-ray, and field methods; volcanology; plate-tectonic interpretation of rock sequences. Three lecture and three laboratory hours a week.
Requisites: Prerequisite, GEOL 301; permission of the instructor for students lacking the prerequisite.
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 213, 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 417.

GEOL 417L. Geomorphology Laboratory. 1 Credit.
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 101 or 110, and MATH 231; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade
Same as: MASC 431.

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 431. Micropaleontology. 4 Credits.
An in-depth study of the biostratigraphy, paleoecology, and taxonomy of various microfossil groups (i.e., foraminifera, ostracodes, conodonts, coccoliths, radiolaria, diatoms, acritarchs, dinoflagellates, etc.) dependent upon individual student objectives. Three lecture and three laboratory hours a week.
Requisites: Prerequisite, GEOL 478 or MASC 440; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: MASC 431.
GEOL 432. Paleoclimatology. 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 402; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

GEOL 433. Paleoceanography. 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 402 or 503; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

GEOL 434. Marine Carbonate Environments. 4 Credits.
Permission of the instructor. Chemical and biological origins of calcium carbonate, skeletal structure, and chemo-mineralogy, preservation, sedimentation, and early diagenesis are studied in deep and shallow environmental settings to understand skeletal genesis, limestone origin, and carbonate facies variability. Field trip to Florida, Bahamas, or Bermuda. Laboratory exercises; research report.
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 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 101, 213, 401; 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, CHEM 251 or 261, MATH 231, and PHYS 115 or 119; 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: QL.
Grading status: Letter grade.

GEOL 478. Invertebrate Paleontology. 4 Credits.
Introduction to the principles, methods of analysis, and major controversies within paleontology. Examination of the fossil record and its application to problems in evolutionary biology, paleoecology, paleoclimatology, and general earth history.
Requisites: Prerequisite, GEOL 159 or BIOL 101; permission of the instructor for students lacking the prerequisites.
Gen Ed: PX.
Grading status: Letter grade
Same as: BIOL 478.

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, ENVR 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 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, GEGO 110.
Grading status: Letter grade
Same as: GEGO 440.

GEOL 503. Marine Geology. 4 Credits.
For graduate students; undergraduates need permission of the instructor. Investigates formation of ocean basins, coastal and fluvial processes, sediment transport, plate tectonics, petrography of marine rocks, ocean chemistry, oceanic biogeochemical cycles, application of geochemical proxies in paleoceanographic reconstructions, macroevolutionary patterns of marine biota, global oceanic change. Mandatory weekend fieldtrip.
Gen Ed: PL.
Grading status: Letter grade
Same as: MASC 503.
GEOL 504. Advanced Petrology. 4 Credits.
Origin of magmas and evolution of igneous and metamorphic rocks, combined with petrographic study of selected sites and individual examples. Two lecture and six laboratory hours a week.
Requisites: Prerequisite, GEOL 404.
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 505, ENV R 505.

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 507. Rhythms in Global Climate and the Stratigraphic Record. 3 Credits.
An overview of the mechanisms of cyclic climate forcing and a review of the geologic evidence for these climate rhythms, with a particular emphasis on the Milankovitch orbital cycles.
Requisites: Prerequisite, GEOL 402.
Grading status: Letter grade.

GEOL 508. Applied 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. Emphasis is divided between analytical aspects and field procedures.
Requisites: Prerequisites, GEOL 101 or 110, MATH 231, PHYS 105; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

GEOL 509. Groundwater. 3 Credits.
Introduction to physics, chemistry, and geology of groundwater.
Requisites: Prerequisites, CHEM 102; GEOL 101, 105, 109, or 110; MATH 231; PHYS 104 or 114 or 116; Permission of the instructor for students lacking the prerequisites.
Gen Ed: QI.
Grading status: Letter grade.

GEOL 510. Geochemistry of Natural Waters. 3 Credits.
Survey of processes affecting the compositions of streams, lakes, the ocean, and shallow ground waters.
Requisites: Prerequisites, CHEM 102; GEOL 101, 105, 109, or 110; MATH 231; Permission of the instructor for students lacking the prerequisites.
Gen Ed: QI.
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. Geochemistry. 3 Credits.
Introduction to the application of chemical principles to geological problems. Topics include thermodynamics, kinetics, and isotope geochemistry.
Requisites: Prerequisites, CHEM 102; GEOL 101, 105, or 110; and MATH 231; permission of the instructor for students lacking the prerequisites.
Gen Ed: QI.
Grading status: Letter grade
Same as: MASC 553.

GEOL 514. River Systems of East Coast North America. 3 Credits.
Junior or senior status. Analysis of 23 rivers from St. Lawrence to the Everglades, from headwaters to oceanic terminus of turbidite fan. Focus on stream processes, geologic development, hydrology, utilization history, ecology, and planning.
Requisites: Prerequisites, GEOL 101 or 110, and 211 or 417.
Grading status: Letter grade.

GEOL 515. 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.
Requisites: Prerequisites, PHYS 116 or 118, and 117 or 119.
Grading status: Letter grade.

GEOL 517. Sequence and Seismic Stratigraphy. 3 Credits.
Examination of lithostratigraphic principles and the sequence stratigraphic paradigm. Students will study use of variation 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 402.
Grading status: Letter grade.

GEOL 518. Geodynamics. 3 Credits.
The interior of the earth deduced from seismology, gravity, heat flow, magnetism; geophysics of continents and ocean basins; age of earth.
Requisites: Prerequisites, CHEM 102; GEOL 101 or 110; 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.
Prepared requirement, 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 402.
Grading status: Letter grade.

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 101, 301, 401, and 402; 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 510, 512, 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 prerequisites.
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 301; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: MASC 560, ENV 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 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 601. 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.
Requisites: Prerequisites, GEOL 301, 401, 402, and 404; permission of the instructor for students lacking the prerequisites.
Gen Ed: EE-Field Work.
Grading status: Letter grade.

GEOL 602. Summer Field Course in Geology. 3 Credits.
Prerequisites: GEOL 301, 401, 402, and 404; permission of the instructor for students lacking the prerequisites. 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.
Gen Ed: EE-Field Work.
Grading status: Letter grade.
GEOL 608. Continuum Mechanics in the Earth Sciences. 3 Credits.
Required preparation, introductory geology course numbered below GEOL 202, except first-year seminar, or permission of the instructor.
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, MATH 231; PHYS 114 or 118.
Grading status: Letter grade
Same as: ENEC 608.

GEOL 655. Physical Geochemistry. 3 Credits.
An introduction to physical geochemistry and chemical thermodynamics with special emphasis on geological applications. Three lecture hours a week.
Requisites: Prerequisites, CHEM 102 and MATH 232; permission of the instructor for students lacking the prerequisites.
Gen Ed: QL.
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.

GEOL 695. 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.
Requisites: Prerequisites, GEOL 601 and 602.
Grading status: Letter grade.