The Department of Earth Sciences offers the master of science degree in Earth sciences with options in geology, ocean mapping, and a specialization in geochemical systems. The department also offers the master of science degree in hydrology, and a master of science and a Ph.D. in Oceanography. A Ph.D. in Earth and environmental sciences is offered through the Natural Resources and Earth System Science Program (http://catalog.unh.edu/graduate/programs-study/natural-resources-earth-systems-science). Students may also pursue a graduate certificate in Ocean Mapping, offered in partnership with the Center for Coastal and Ocean Mapping. Graduate students in the department may conduct research with faculty members in the Department of Earth Sciences; the Institute for the Study of Earth, Oceans, and Space; and the Center for Coastal and Ocean Mapping.

The M.S. Geology option is intended for students with interests in petrology, mineralogy, structural geology, tectonics, geophysics, sedimentology, glacial geology, paleoclimate, glaciology, hydrogeology, stratigraphy, paleontology, low- or high-temperature geochemistry, and isotope geochemistry.

The M.S. Ocean Mapping option is intended for students with interests in hydrography and hydrographic survey technology.

The M.S. Geochemical Systems Specialization is intended for students with interests in all aspects of geochemistry: bedrock, sediment, water, ice, and air with particular emphasis on interpreting and modeling the interaction of these media (e.g., biogeochemistry, air quality, and climate change).

The M.S. in Hydrology is intended for students with interests in fluvial processes, global-scale hydrology, groundwater hydrology, hydroclimatology, surface-water hydrology, water quality, and quantitative hydrology.

Admission Requirements
An applicant to the M.S. program is expected to have completed one year of calculus and at least four semesters of college chemistry, physics, and/or biology; and to have an undergraduate degree or equivalent in geology, chemistry, physics, mathematics, engineering, or the biological sciences. Applicants must submit current scores (within five years) from the general test of the GRE. Students lacking some background in a particular area may be admitted provided they are prepared to complete courses, without graduate credit, in which they may be deficient.

The program of study a student wishes to follow and the student’s undergraduate major determine the level of preparation necessary. The preparation of each student is determined before the beginning of the first semester in residence in order to plan the course of study. Each entering student is assigned an academic adviser to assist in planning a program of study.

Degree Requirements
Students in the M.S. programs are required to complete the core curriculum for their respective areas and complete either the thesis or non-thesis option.
ESCI 826 - Igneous and Metamorphic Petrology
Credits: 4
This course focuses on the origin and evolution of igneous and metamorphic rocks from field, petrographic mineral chemistry, experimental, and theoretical studies. Igneous systems include volcanic and plutonic suites, with emphasis on meraulogic records of magma chamber systematics. Metamorphic systems include pelitic, maflc, and calc-silicate rocks, with special emphasis on closed- and open-system reactions, mult-systems, reaction space, and pressure-temperature-time paths. Prereq: ESCI 614; adequate calculus, chemistry, and physics. Field trips. Special fee. Lab.

ESCI 831 - Geodynamics
Credits: 4
Application of quantitive methods to geologically motivated problems, focusing on lithospheric deformation, topography, and fluid flow. Students acquire geophysical and geochemical techniques used to address dynamics in the Earth system. Includes biweekly recitation sessions for working through problems sets and facilitating discussions of relevant papers from the literature. Prereq: one year each of physics, calculus, chemistry or permission.

ESCI 834 - Geophysics
Credits: 4
The structure of the solid Earth, including the continental and oceanic lithosphere and the deep interior as revealed by investigations of seismic waves, the Earth's gravitational and magnetic fields, heat flow, and earthquakes. Prereq: ESCI 401; one year of calculus; one year of college physics; or permission. Special fee. Lab.

ESCI 835 - Earthquakes and Faulting
Credits: 4
This course provides an introduction to the principles of brittle faulting and earthquake mechanics. We discuss classic theory and current topics in earthquake science based on observations from laboratory experiments, seismology, geodesy, and geology (exhumed faults). Prereq: Structural geology or permission.

ESCI 841 - Geochemistry
Credits: 4
Course focuses on the application of chemical principles to solve problems in the Earth sciences. Students learn the chemical tools of thermodynamics and kinetics, element partitioning, conservation of mass, and isotope geochemistry. Explore geochemical properties/ processes in the deep Earth and the Earth surface, atmosphere and marine systems, and cosmo-chemistry and investigate the interactions between these components of the Earth system. Lab. Prereq: one year each chemistry, calculus.

ESCI 845 - Isotope Geochemistry
Credits: 4
Course focuses on the application of radiogenic, radioactive and stable isotopes to improve students’ knowledge about the processes and timescales relevant to the formation of the planet and solar system, the evolution of the Earth system and interactions in the hydrosphere and biosphere. Topics include geochronology, tracer applications, Earth surface applications, as well as applications in the hydrosphere and biosphere. Systems discussed include the classic radiogenic systems (K-Ar, Rb-Sr, Sm-Nd, Lu-Hf and U-Th-Pb), traditional (H, C, N, O) as well as nontraditional (e.g., Mg, Ca, Fe) stable isoUrte systems, and radioactive isotopes (e.g., radiocarbon). Course consists of lecture, where students are exposed to these applications, and a lab section to work through any questions on the homework assignments, discuss relevant papers from the literature, and carry out a project. Special fee. Lab. Prereq: one year each chemistry and calculus.

ESCI 847 - Aqueous Geochemistry
Credits: 4
The chemical processes that determine the composition of aquatic systems such as rivers, lakes, groundwater and the ocean. The goal is to quantitatively understand the behavior of inorganic species such as carbon dioxide, nutrients, trace metals and inorganic pollutants in natural waters. Topics include, acid-based equilibria, carbonate chemistry, reduction-oxidation reactions, organic complexation and mineral precipitation and dissolution. Lab. Prereq: 1 year of college calculus and/or chemistry or geochernistry.

ESCI 850 - Biological Oceanography
Credits: 4
Biological processes of the oceans, including primary and secondary production, trophodynamics, plankton diversity, zooplankton ecology, ecosystems and global ocean dynamics. Field trips on R/V Gulf Challenger and to the Jackson Estuarine Laboratory. Prereq: one year of biology or permission of instructor. (Also offered as ZOOL 850, EOS 850.) Special fee. Lab. (Not offered every year.)

ESCI 852 - Chemical Oceanography
Credits: 3
This course investigates the physical and biogeochemical processes that determine the composition of seawater. Topics include biological effects on chemistry, ocean nutrient cycles, air-sea gas exchange, radiogenic and stable isotopes as tracers of ocean processes, sediment and trace-metal chemistry. Prereq: one year of college chemistry and calculus or permission.

ESCI 854 - Sedimentology
Credits: 4
This course focuses on modern sedimentary processes and ancient sedimentary records through the examination, identification, and interpretation of sediments and sedimentary rocks. Topics such as sediment transport mechanisms, depositional environments, and time in sedimentary records will provide a strong framework for any student studying Earth processes and sedimentary systems. Special fee.

ESCI 856 - Geotectonics
Credits: 3
The geological record of plate tectonics past and present. The first part of the course focuses on modern tectonic settings with an emphasis on plate geometries, geodynamical processes, and sedimentary products. The second part of the course focuses on reconstructing ancient tectonic settings with an emphasis on methodology (paleomagnetism, basin analysis, provenance) and case studies (e.g. India-Asia collision). Field trip. Prereq: ESCI 614 or ESCI 631 or permission. Special fee.

ESCI 858 - Introduction to Physical Oceanography
Credits: 3
Descriptive treatment of atmosphere-ocean interaction; general wind-driven and thermo-haline ocean circulation; waves and tides; continental shelf and near-shore processes; instrumentation and methods used in ocean research. Simplified conceptual models demonstrate the important principles. Prereq: calculus based physics, introduction to oceanography; or permission.

ESCI 859 - Geological Oceanography
Credits: 4
Major geological features and processes of the ocean floor; geological and geophysical methods; composition of the earth, sedimentary processes, plate tectonics and paleoceanography.
ESCI 860 - Paleooceanography  
Credits: 3  
This course introduces the basic principles of paleooceanography, such as the preservation of ocean history in sediment archives and the analysis/interpretation of paleooceanographic data. The course focuses on the capabilities and limitations of paleooceanographic techniques, and empowers students to critically assess the strengths and weaknesses of results presented in scientific journals. Topics include Milankovitch cycles, faunal assemblages, temperature and circulation proxies, linear and non-linear responses to climate forcings, abrupt climate events, atmospheric teleconnections and monsoons. Prereq: Calculus and one year of college physics. (Also offered as OE 871.)

ESCI 864 - Spectral Analysis of Geophysical Time Series Data  
Credits: 4  
This course considers basic exploratory techniques and in-depth spectral analysis for estimation with geophysical time series data, including calculations of confidence intervals and significance testing. This course prepares students for interpreting time series data with science and engineering applications. Topics include sampling theory, filtering, statistics, probability, spectral analysis, and empirical orthogonal functions. Students gain experience in code-writing for the analysis of time series data. Prereq: Calculus.

ESCI 865 - Paleoclimatology  
Credits: 3  
Course reviews the study of past changes in the Earth’s climate system. Main discussion topics include astronomical theories of ice ages, Quaternary dating methods, Antarctic and Greenland ice core records, greenhouse gases, marine-based climate proxies, glacial mega-floods, and linkages between ocean circulation and abrupt climate change. Emphasis on climate variability during the Quaternary period (the last approximately 1.8 million years), a time interval dominated by cycles of global glaciation. Lectures include discussion of recent and emerging scientific papers in order to keep pace with the latest findings in paleoclimatic research.

ESCI 866 - Volcanology  
Credits: 4  
Provides a comprehensive overview of volcanic processes and their influences on planetary evolution and modern-day Earth systems. Lectures discuss the generation and properties of magma, tectonic setting of volcanism, eruption styles, volcanic landforms and products, monitoring of active volcanoes, volcanic hazards, and volcanism on other planets. Laboratory topics include modeling volcanic processes, hand-sample observation, topographic map interpretation, volcanogaphical data analysis, and two afternoon field trips. As volcanology is a rapidly developing field of active research, the course incorporates discussions of recent and emerging scientific papers from the literature and student-led updates of ongoing volcanic activity. Prereq: one year of calculus and one Earth Science course or permission. Special fee. Lab.

ESCI 867 - Geodesy and Positioning for Ocean Mapping  
Credits: 4  
The science and technology of acquiring, managing, and displaying geographically-referenced information; the size and shape of the earth, datums and projections; determination of precise positioning of points on the earth and the sea, including classical terrestrial-based methods and satellite-based methods; shoreline mapping, nautical charting and electronic charts. Prereq: one year of calculus and one year of college physics. (Also offered as OE 871.)

ESCI 872 - Applied Tools for Ocean Mapping  
Credits: 2  
A review course on research tools commonly used in ocean mapping. The course focuses on teaching problem solving skills, note merely the application of tools. The course consists of modules addressing the use of: IVS Fledermaus; GeoMappApp, GIS, Google Earth, Matlab as well as the effective library research and use of Wikis. Prereq: two terms of single variable calculus. Cr/F.

ESCI 874 - Integrated Seabed Mapping Systems  
Credits: 4  
Overview of typical applications that involve mapping the sediment-water interface in the ocean and adjacent waters. Emphasis on defining the task-specific resolution and accuracy requirements. Fundamentals of acoustics relevant to seabed mapping. Progressions through typical configurations involving single beam, sidescan, phase differing and multibeam systems. Integration of asynchronous 3D position, orientation and sound speed measurements with sonar-related acoustic travel times and angles. Analysis of impact of offsets, mis-alignments and latency in all integrated sensors. Prereq: two terms each of college calculus and physics. Pre- or Co-req: MATH 831 or equivalent material.

ESCI 875 - Fundamentals of Ocean Mapping II  
Credits: 4  
The second of two courses covering the principles and practices of hydrography and ocean mapping. In this course the following topics are covered: Ancillary Sensor Integration; System Calibration; Verification and Field QA/QC; Water Levels (Tides); Mapping Standards; Survey Planning; Execution and Reporting; Terrain Analysis; Optical Remote Sensing; Data Presentation; Seafloor Characterization; Electronic Navigational Charts; Hydrography for Nautical Charting, Product Liability and contracts; and the United Nations Common Law of the Sea (UNCLOS). Prereq: OE 874/ESCI 874, two terms each of college calculus and physics. Pre or Co-req: MATH 831 or equivalent material.

ESCI 877 - GIS for Earth & Environmental Sciences  
Credits: 4  
Geospatial technologies provide insight into spatial and temporal aspects of environmental and earth systems. Students will master basic skills of a geographical information system. Weekly laboratory exercises will build upon a foundation of conceptual knowledge and data processing skills. Focus on applied research questions and projects will be addressed. The course will use the open source program QGIS. Additional work will develop programing skills using the python language. Programming background is not required but beneficial. Prereq: Undegraduate Science Course.
ESCI 878 - Remote Sensing Earth & Environmental Sciences
Credits: 4
Remote sensing provides insight to spatial and temporal aspects of environmental and Earth systems. Students will examine digital image processing techniques, different sensor and platform technologies, and new trends and frontiers in remote sensing science. Weekly laboratory exercises build upon conceptual knowledge, data processing skills, and development of programming skills. Applied research questions and projects will use Google Earth Engine. Hyperspectral, lidar, and unmanned aerial systems will be presented. Prereq: Undergraduate Science Course.

ESCI 895 - Topics
Credits: 1-4
Study on an individual or group basis in geologic, hydrologic, or oceanographic problems, under members of the graduate staff. Topics include: geochemistry, geomorphology, geophysics; glaciology; groundwater, structural, and regional geology; crystallography; mineralogy; petrology; thermodynamics; ore deposits; earth resource policy; paleontology; sedimentation; stratigraphy; water resources management; chemical, physical, and geological oceanography; earth systems; earth science teaching methods. Prereq: permission of staff concerned. May be repeated.

ESCI 896 - Topics
Credits: 1-4
Study on an individual or group basis in geologic, hydrologic, or oceanographic problems, under members of the graduate staff. Topics include: geochemistry, geomorphology, geophysics; glaciology; groundwater, structural, and regional geology; crystallography; mineralogy; petrology; thermodynamics; ore deposits; earth resource policy; paleontology; sedimentation; stratigraphy; water resources management; chemical, physical, and geological oceanography; earth systems; earth science teaching methods. Prereq: permission of staff concerned. May be repeated. Special fee on some topics.

ESCI 897 - Colloquium
Credits: 0
Presentation of recent research in the earth sciences by guest speakers and department faculty. May be taken four times. Cr/F.

ESCI 898 - Directed Research
Credits: 2
Research project on a specified topic in the Earth Sciences, guided by a faculty member. Cr/F.

ESCI 899 - Master's Thesis
Credits: 1-6
May be repeated up to a maximum of 6 credits. Cr/F.

ESCI 906 - Advanced Fate and Transport in the Environment
Credits: 3
Mathematically rigorous introduction and analysis of the basic processes controlling the migration and transformation of chemicals in the environment at sub-geophysical scales, including advection, diffusion, dispersion, and retardation. Examples are drawn from surface water, groundwater, oceans, and the atmosphere, with a focus on rivers and streams. Prereq: Multidimensional calculus.

ESCI 972 - Hydrographic Field Course
Credits: 4
A lecture, lab, and field course on the methods and procedures for the acquisition and processing of hydrographic and ocean mapping data. Practical experience in planning and conducting hydrographic surveys. Includes significant time underway (day trips and possible multi-day cruises) aboard survey vessel(s). Prereq: Introduction to Ocean Mapping; Geodesy and Positioning for Ocean Mapping; or permission. (Also listed as OE 972.)

ESCI 973 - Seafloor Characterization
Credits: 3
Remote characterization of seafloor properties using acoustic (echo sounders, sub-bottom profilers, side-scan, multi-beam and interferometric sonars) and optical (video and laser linescanner) methods. Models of sound interaction with the seafloor will be explored as well as a range of possible geologic, geotechnical, morphologic, acoustic, and biologic descriptors. Prereq: permission. (Also listed as OE 973.)

ESCI 993 - Advanced Seminar
Credits: 1
Focused seminar in a discipline of earth sciences: earth, ocean, atmosphere, or hydrology. May be repeated up to a maximum of 4 credits.

ESCI 994 - Advanced Seminar
Credits: 1
Focused seminar in a discipline of earth sciences: earth, ocean, atmosphere, or hydrology. May be repeated up to a maximum of 4 credits.

ESCI 995 - Advanced Topics
Credits: 1-4
Advanced work on an individual or group basis. Prereq: permission. May be repeated.

ESCI 996 - Advanced Topics
Credits: 1-4
Advanced work on an individual or group basis. Prereq: permission. May be repeated.

ESCI 997 - Seminar in Earth Sciences
Credits: 1
Readings, discussion, and presentation of recent investigations in the earth sciences. Required of all M.S. students in Earth Sciences. Cr/F.

ESCI 998 - Proposal Development
Credits: 1
Introduction to research in the earth sciences and development of thesis and directed research proposals. Required of all M.S. students in Earth Sciences.

ESCI 999 - Doctoral Research
Credits: 0
Cr/F.

Faculty
See https://ceps.unh.edu/faculty/earth-sciences for faculty.