Geosciences (GEO)

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Degrees awarded: M.S. in Geosciences; Ph.D. in Geosciences

As the core discipline examining Earth's natural processes and materials, Geosciences boasts unparalleled diversity. Spurred by urgent scientific and social questions, ranging from environmental concerns to the origin and evolution of the planet itself, the Geosciences are experiencing remarkable growth, with excellent career opportunities. The Geosciences encompass many disciplines including geochemistry, geology, and geophysics, and its interdisciplinary nature fosters natural links not only with chemistry and physics, but also with biology, engineering, environmental science, health fields, and materials science. Developments in technology and new innovative approaches have transformed graduate study in many areas within Geosciences, and students participate in research utilizing state-of-the-art instrumentation and facilities.

Graduate students may choose among degree programs with emphasis in different areas in Geosciences. Ph.D. and M.S. thesis-based programs are offered with concentrations in areas including crystal chemistry, geochemistry, mineral and rock physics, petrology, sedimentary geology, and seismology and tectonics (described in more detail below). There is also a non-thesis M.S. program in hydrogeology focused primarily on training professionals in environmentally related fields. Also offered is an M.A. in Teaching Earth Science, which leads to provisional certification for teaching earth science in secondary schools of New York State.

The Department of Geosciences occupies a modern, well-equipped building that houses extensive experimental and analytical labs, faculty and graduate student offices, numerous computers and workstations, a machine shop, an electronics support group, and the Geosciences Resource Room. The Long Island Groundwater Research Institute (LIGRI), the Marine Sciences Research Center (MSRC), the Mineral Physics Institute, and nearby Brookhaven National Laboratory offer additional support and laboratory facilities for graduate student research. In particular, the National Synchrotron Light Source (NSLS) at Brookhaven offers unparalleled opportunities for faculty and graduate students to perform unique experiments requiring high-intensity X-rays and is only 20 miles away.

Areas of Emphasis in Graduate Study and Research

The Department's philosophy has been to pursue excellence by concentrating its research initiatives in specific areas of the Geosciences. Graduate students benefit from greater focus and also enjoy close interaction with faculty members. A distinctive aspect of graduate study in the Department of Geosciences is the opportunity for collaborative research, often involving several faculty members. The Department's extensive state-of-the-art computers, laboratory facilities, and modern instrumentation have helped to foster a well-earned reputation for observational, experimental, and multifaceted approaches to Geosciences research. Cooperative programs with other departments, nearby institutions, and national laboratories provide access to unique facilities (e.g., NSLS).

Seismology, Tectonics, and Shallow Surface Geophysics

A primary focus in seismology and tectonics is the determination of detailed three-dimensional earth structure, from the core to the surface, and related studies on the dynamics that drives mantle convection, deformation of the lithosphere, and plate tectonics in general. Particular emphasis is placed on interdisciplinary research and collaboration, where inferences made from geodetic, geodynamic, and seismological investigations are integrated with findings from the fields of geochemistry, mineral and rock physics, and petrology. Areas of specific focus in seismology include anisotropy and attenuation, core-mantle boundary structure, earthquake source parameter studies, inner core structure, outer core structure, strong ground motion studies, theoretical studies on seismic wave propagation, and upper mantle structure. Investigations in tectonophysics include the coupling between mantle convection and lithospheric dynamics; the development of the kinematics, mechanics, and seismicity within plate boundary deformation zones; and the inference of mantle flow beneath the lithosphere. Current projects involve using earthquake and space geodetic data to infer the deformation fields and employing analog, analytical, and numerical modeling to understand surface geodynamical observations, ranging from geoid, topography, plate motions, and surface deformations in the global and regional scales to the partitioning of strain and tectonic implications at geometrically complex plate margins. All of these projects emphasize the use of integrated geodetic, seismic, structural, and field data to understand the composition, dynamics, and structure of the Earth's interior, as well as the driving forces for plate movements and deformations. The topics in shallow surface geophysics include field geophysical surveys of glaciotectonic deformation of Long Island sediments using electrical resistivity, ground-penetrating radar, seismic reflection, and refraction as well as borehole geophysics.

Mineral and Rock Physics

Research in these fields focuses on the investigation of the structure and composition of the Earth, geophysical properties of Earth materials, and the mechanical behavior of the crust and mantle. An important emphasis is the study of high-pressure and high-temperature phases and assemblages, particularly those of relevance to the mantle. *In situ* measurement of elastic properties, compressibility, and determination of crystal structure complement studies of high-pressure phase relations for constraining models for Earth's mantle and equations of state for mantle phases. Specific projects include determination of ultrasonic wave velocities of minerals and rheological determination of the strength of minerals at the pressure and temperature

conditions of the Earth's mantle to depths greater than 500 km. Research initiatives in these areas are closely linked to the activities of the Mineral Physics Institute at Stony Brook and the NSF Consortium for Materials Properties Research in Earth Sciences (COMPRES). Facilities available in the Department of Geosciences and the Mineral Physics Institute include equipment for ultrasonic interferometry, Brillouin spectroscopy, and multi-anvil apparatus for experiments at high pressure and temperature; these are all integrated with synchrotron X-ray sources at the NSLS. Complete single-crystal and powder X-ray diffraction facilities and transmission electron microscopy and electron diffraction are available. Another important area of study is rock physics, fluid flow, and earthquake mechanics. Experimentally and theoretically based, this program focuses on brittle fracture, frictional instability, hydromechanical behavior, mechanical compaction of porous rock, and strain localization. The rock mechanics laboratory includes a triaxial press, an acoustic emission system, and permeameters.

Crystal Chemistry and Crystallography

The Department has a strong background in the study of Earth materials at the atomic and molecular level, and in using the results of these studies to interpret the properties of materials constituting Earth from crust to core. Two centers of excellence, the Center for Environmental Molecular Sciences (CEMS) and the Mineral Physics Institute (MPI), concentrate on the behavior of upper crustal and Earth's interior, respectively. Both employ a wide range of structural probes, some located in the Department and others located at national and international synchrotron X-ray and neutron facilities. Within the Department, extensive facilities for single-crystal and powder X-ray diffraction, with capabilities for *in situ* high-temperature and high-pressure studies exist. Projects emphasize crystal structure studies on carbonates, hydroxides, oxides, silicates, and sulfides, including characterization of phase transitions, ordering phenomena, and ion exchange. Convenient access to the Brookhaven National Laboratory and the National Synchrotron Light Source provides opportunities for unique experiments requiring a high-intensity X-ray source. Other projects utilize X-ray absorption spectroscopy to examine local structure in minerals and neutron diffraction for studies of hydrous phases. Many of the Department's faculty are actively engaged in the design and construction of the next generation of beamlines required for high pressure and environmental investigations. These facilities are being designed with the requirements of the Stony Brook and wider national and international user base in mind. This work is complemented by electron diffraction using the Department's transmission electron microscope.

Geochemistry

There are broad opportunities for graduate study and research in many areas of geochemistry. Major initiatives exist in aqueous and hydrothermal geochemistry, geochemistry of mineral/fluid interfaces, isotope and trace-element geochemistry, and theoretical and experimental geochemistry of mineral-melt systems. All programs have a strong experimental foundation, and many integrate experimental work with field studies.

Specific areas of research utilizing trace elements and radiogenic isotopes include evolution of Archean and Phanerozoic crust and geochronology of lithologic assemblages. These integrate with petrologic studies of sedimentary, metamorphic, and igneous terranes throughout the world. Research involving the chemistry and structure of sulfide and carbonate mineral surfaces are among the programs in low-temperature aqueous geochemistry; these include emphasis on geocatalysis, crystallization, and trace element incorporation mechanisms, as well as the role of sulfides in the origin of life. Field-related studies focus on fluid chemistry in active hydrothermal systems. Research on silicic melts combines theoretical and experimental approaches for characterizing speciation and crystal-melt equilibria, and also for examining nucleation and growth. Closely related experimental studies focus on phase equilibria, solid-solution models, and the development of geothermometers and geobarometers, including applications in field studies.

Experimental and analytical work makes use of the Department's electron microprobe, transmission electron microscope, thermal ionization mass spectrometers, FT-IR, Mössbauer lab, DCP and ion chromatography labs, X-ray diffraction facilities, and three synthesis and experimental petrology labs. Additional work uses facilities in other Stony Brook departments, including NMR spectrometers located in the Department of Chemistry, as well as facilities at nearby Brookhaven National Laboratory, including the NSLS.

Petrology

Opportunities for graduate study and research in petrology range from atomic-scale investigations, for example, dealing with the structure of glasses, to global questions regarding the relationships of magmatic suites to large-scale mantle and crustal processes. Projects include spectroscopic and quantum chemical approaches for examining mechanisms of volatile dissolution and crystal nucleation in melts and experimental investigations of the effects of pressure, temperature, and volatile composition on stabilities of minerals and melts, with corresponding development of thermodynamic models. Field and laboratory work are integrated in some studies. Experiments are being applied to Martian meteorites.

This work is supported by experimental facilities that contain controlled-atmosphere gas-mixing furnaces, cold-seal bombs, piston-cylinder apparatus, internally heated pressure vessels, as well as multi-anvil apparatus for experiments at high temperature and pressure conditions. Analytical facilities include an electron microprobe, a transmission electron microscope, thermal ionization mass spectrometers, a Mössbauer lab, and X-ray diffraction facilities.

Sedimentary Geology

Research initiatives in sedimentary geology at Stony Brook integrate geochemistry with field, petrologic, and stratigraphic studies. Trace element and isotopic studies of terrigenous sedimentary rocks provide information on their provenance, age, and composition, which yield insight to broader issues of crustal evolution, including sediment subduction, growth of continental crust and the sedimentary mass, and recycling of sedimentary rocks. Carbonate rocks and their diagenesis are another important area of research that utilizes a wide range of approaches. Petrography is combined with microanalytical techniques for trace elements and both stable and radiogenic isotopes to reconstruct

the diagenetic environments and the physicochemical characteristics of paleohydrologic systems. Emphasis is also placed on the quantitative modeling of rock-water interaction. A strong component of fieldwork is common for studies of both clastics and carbonates. Analytical facilities include the Department's electron microprobe, optical and cathodoluminescence petrography and electron microscopy facilities, a mass spectrometry lab, a Mössbauer lab, DCP and ion chromatography labs, X-ray diffraction facilities, and a variety of facilities at the NSLS.

Planetary Science

Graduate research opportunities are available in the field of planetary science, including planetary geochemistry and petrology, planetary spectroscopy, planetary geophysics, and astrobiology with current focus on Mars and the Earth's moon. Several faculty and students have been actively involved in planetary missions, including Mars Global Surveyor, Mars Exploration Rovers, and Mars Odyssey. Projects are available to evaluate geological, chemical, spectroscopic, and geophysical data that have been returned from these and other missions. Planetary science research is also supported by an assortment of experimental and analytical facilities. A recently installed infrared spectroscopy laboratory supports experimental and analytical studies in emission and reflectance spectroscopy of Mars and lunar analog materials as well as investigations of the fundamental infrared spectral properties of a wide variety of minerals. High pressure-high temperature experimental laboratories (see details under Petrology and Mineral and Rock Physics) may be used for evaluating the origin and history of igneous rocks from terrestrial planets and rocky satellites. Low-temperature and hydrothermal experimental laboratories are available for the study of Martian near-surface aqueous processes and for investigating issues related to astrobiology. Experimental laboratories are also supported by a broad array of analytical facilities (see details under Crystal Chemistry and Crystallography, Geochemistry and Sedimentary Geology).

Hydrogeology

The non-thesis M.S. program with a concentration in hydrogeology is designed to give those with a B.S. degree in physical sciences a solid foundation of theoretical and practical graduate training emphasizing the physical and geochemical aspects of hydrogeology. Coursework and a final research project totaling 30 graduate credits are arranged to accommodate working professionals, with most courses taught in the evenings. This is a part-time degree program. A formal thesis is not required. Coursework includes groundwater hydrology, aqueous geochemistry, rock and soil physics, numerical hydrology, statistics and probability, and organic contaminant hydrology. Final research projects are arranged individually with faculty supervisors and are designed to give students experience in field, laboratory, or theoretical approaches.

Admission

For admission to the Graduate Program in Geosciences, the following, in addition to the Graduate School requirements, are required:

A. A bachelor's degree in one of the earth or space sciences or in biology, chemistry, physics, mathematics, or engineering;

B. A minimum average of B for all undergraduate coursework and a B average for courses in the sciences;

C. Results of the Graduate Record Examination (GRE) General Test;

D. Acceptance by both the Department and the Graduate School.

In special cases, a student not meeting requirements A and B may be admitted on a conditional basis. Upon admission, the student will be informed of the requirements that must be satisfied for termination of this status.

Distinguished Professors

Lindsley, Donald H., *Emeritus*, Ph.D., 1961, Johns Hopkins University: Application of phase equilibrium studies of silicate and oxide minerals to metamorphic and igneous petrology.

Weidner, Donald J., Ph.D., 1972, Massachusetts Institute of Technology: Structure of the Earth's interior as revealed by seismic waves and laboratory determinations of physical properties.

Distinguished Service Professors

Hanson, Gilbert N., Ph.D., 1964, University of Minnesota: Application of radiometric and geochemical methods to petrologic and tectonic problems.

Liebermann, Robert C., Ph.D., 1969, Columbia University: Mineral physics; elastic and anelastic properties of rocks and minerals and their applications to the Earth's interior.

Professors

Davis, Daniel M., *Graduate Program Director*, Ph.D., 1983, Massachusetts Institute of Technology: Quantitative geophysical modeling of fold and thrust belts; geodynamic modeling of the state of stress in the lithosphere.

Holt, William E., Ph.D., 1989, University of Arizona: Seismotectonics; kinematics and dynamics of crust and mantle deformation; earthquake source parameter studies.

McLennan, Scott M., Ph.D., 1981, Australian National University: Geochemistry of sedimentary rocks; sedimentary petrology.

Nekvasil, Hanna, Ph.D., 1986, Pennsylvania State University: Experimental and thermodynamic investigations of mineral/melt equilibria in silicic magmas.

Parise, John, Ph.D., 1980, James Cook University of North Queensland: Synthesis and characterization of zeolites for use as selective catalysts; characterization using normal X-ray and neutron diffraction techniques; investigation of crystallizing gels using small-angle neutron scattering; structural modeling of silicates.

Reeder, Richard J., Ph.D., 1980, University of California, Berkeley: Low-temperature geochemistry; mineralogy; crystal chemistry.

Schoonen, Martin A.A., *Interim Dean of Stony Brook Southampton*, Ph.D., 1989, Pennsylvania State University: Kinetics and thermodynamics of low-temperature and hydrothermal water-rock interaction; theoretical geochemical modeling; geochemistry of natural waters.

Wong, Teng-fong, Ph.D., 1980, Massachusetts Institute of Technology: Experimental rock physics; fault mechanics.

Associate Professors

Oganov, Artem R., Ph.D., 2002, University College, London: Computational mineral physics.

Phillips, Brian, Ph.D., 1990, University of Illinois at Urbana-Champaign: Aqueous geochemistry; NMR spectroscopy; mineralogy and structural chemistry of silicates and other oxides.

Rasbury, E. Troy, *Undergraduate Program Director*, Ph.D., 1998, Stony Brook University: Sedimentary geochemistry; geochronology; chronostratigraphy.

Wen, Lianxing, Ph.D., 1998, California Institute of Technology: Mantle rheology and dynamics; seismic structures of the Earth's mantle; new techniques for calculating viscous flow and seismic wave propagation.

Assistant Professor

Glotch, Timothy, Ph.D., 2004, Arizona State University: Planetary geology, remote sensing, Martian surface mineralogy.

Research Assistant Professor

Rogers, Andrea Deanne, Ph.D., 2005, Arizona State University: Remote sensing, planetary surface processes, GIS.

Lecturer

Stidham, Christiane Wilson, Ph.D., 1999, University of California, Berkeley: Geophysics.

Affiliated Faculty

Distinguished Professor

Aller, Robert C.,[1] Ph.D., 1977, Yale University: Marine geochemistry; early marine diagenesis.

Distinguished Service Professor

Krause, David W.,[2] Ph.D., 1982, University of Michigan: Vertebrate paleontology; mammalian evolution, including primates.

Professors

Bokuniewicz, Henry J.,[1] Ph.D., 1976, Yale University: Marine geophysics.

Chen, Jiuhua, Ph.D., 1994, Institute of Materials Structure Science, KEK: Mineral physics; mantle petrology; application of synchrotron radiation to earth sciences.

Cochran, J. Kirk,[1] Ph.D., 1979, Yale University: Marine geochemistry; use of radionuclides as geochemical tracers; diagenesis of marine sediments.

Flood, Roger D.,[1] Ph.D., 1978, Massachusetts Institute of Technology, Woods Hole Oceanographic Institution: Marine geology; sediment dynamics; continental margin sedimentation.

Harbottle, Garman,[3] Ph.D., 1949, Columbia University: Nuclear chemistry; archeology.

Associate Professor

Forster, Catherine A.,[2] Ph.D., 1990, University of Pennsylvania: Vertebrate paleontology; systematics; functional morphology.

Research Associate Professors

Li, Baosheng,[4] Ph.D., 1996, Stony Brook University: Mineral physics; elasticity of minerals; high-pressure research.

Vaughan, Michael T.,[4] Ph.D., 1979, Stony Brook University: Experimental geophysics; crystallography; synchrotron X-ray studies.

Assistant Professor

O'Leary, Maureen,[2] Ph.D., 1997, Johns Hopkins University: Vertebrate paleontology; phylogenetic systematics; mammalian evolution.

1) Marine Sciences Research Center

2) Department of Anatomical Sciences

3) Brookhaven National Laboratory

4) Mineral Physics Institute

Degree Requirements

The Department of Geosciences offers programs leading to the M.A.T., M.S., and Ph.D. degrees in the Geosciences. The Master of Arts in Teaching degree in Earth Science is a non-thesis degree for which all requirements can be completed in three semesters.

The M.S. degree with concentration in Hydrogeology is a non-thesis M.S. with most courses offered at times appropriate for working professionals.

The M.S. degree in Geosciences with thesis is typically not a terminal degree. Many students seeking Ph.D. candidacy first earn an M.S. degree.

Students become candidates for the Ph.D. in Geosciences by completing preparatory work leading to successful completion of the Ph.D. preliminary examination. Students are urged to obtain a more detailed description of procedures from the *Geosciences Graduate Handbook*.

Final responsibility for adhering to degree requirements and meeting all deadlines rests solely with the student.

Requirements for the Ph.D. Degree in Geosciences

Advancement to Ph.D. candidacy is gained after the successful completion of the Ph.D. preliminary examination. The examination is the culmination of an evaluative process that begins when the student arrives at Stony Brook. In particular, the faculty seek evidence of scientific creativity, originality, vigor, and flexibility, along with the basic background knowledge, skills, and critical faculties needed to carry out advanced independent research in the student's chosen field. The minimum residence requirement is two consecutive semesters of graduate study. There is no language requirement.

A. Course Requirements

Course requirements are flexible and are determined in consultation with the student's academic advisory committee at the beginning of studies. Academic advisory committees are assigned to students at the time of their arrival at Stony Brook, and the composition of the committee may be changed at the student's request, with the approval of the graduate program director. During their first two years in the program, students generally take one to three courses per semester. In addition, they participate in appropriate formal and informal seminars. During their first fall semester, all students must take GEO 500, Geosciences Research Seminar. In addition, all students must register for GEO 696, Geoscience Colloquium, and GEO 697, Geoscience Seminar, each semester, and GEO 600, Practicum in Teaching, at least once.

Among the courses offered are:

GEO 503 Mineral Equilibria

GEO 507 Petrogenesis

GEO 514 Physical Hydrogeology

GEO 515 Geohydrology

GEO 517 Crystal Chemistry

GEO 518 Carbonate Sediments

GEO 519 Geochemistry of Natural Waters

GEO 521 Isotope and Trace Element Geology

GEO 524/MAR 524 Organic Contaminant Hydrology

GEO 526 Low-Temperature Geochemistry

GEO 533 Geochemistry of the Solid Earth

GEO 550 Global Tectonics

GEO 551 Physics of the Earth I

GEO 552 Physics of the Earth II

GEO 556 Solid-State Geophysics

GEO 564/AMS 562 Numerical Hydrology

GEO 573 Hydromechanical Behavior of Geomaterials

A number of other courses are offered periodically according to student demand, either in a formal classroom setting or as Directed Studies (GEO 585). These include the following courses:

GEO 505 Experimental Petrology Laboratory

GEO 506 Theoretical Petrology

GEO 508 Rock-Forming Minerals

GEO 522 Planetary Sciences

GEO 528 Carbonate Geochemistry

GEO 531 Crystalline Solids

GEO 532 Solid-State Geochemistry

GEO 535 Regional Structure and Tectonics

GEO 542 Inverse Theory

GEO 562/MAR 562 Early Diagenesis of Marine Sediments

GEO 567 Sedimentary Rocks and Crustal Evolution

GEO 570 Earthquake Mechanics

GEO 571 Mechanics of Geologic Materials

GEO 572 Advanced Seismology

Specialized, advanced seminars are offered periodically by various faculty members. These include the following courses:

GEO 603 Topics in Petrology

GEO 605 Topics in Sedimentary Geology-Paleontology

GEO 607 Topics in Geophysics

GEO 609 Topics in Mineralogy and Crystallography

B. Research Projects

Each student must complete two individual research projects with separate faculty members as part of the requirements leading up to the Ph.D. qualifying exam. One of these projects can be an M.S. thesis. The requirements for each of these papers are determined by the individual professors with whom the research is carried out. When working on such a project, students register for either GEO 590 or 599 Research, after consultation with the appropriate professor. A research paper or M.S. thesis completed before arriving at Stony Brook may substitute for one of the two research papers required before orals, if it is approved for that purpose by the graduate committee.

C. Ph.D. Preliminary Examination

The preliminary examination consists of the preparation and oral defense of a thesis proposal. There are three separate steps in this procedure: (1) submission of a proposal abstract to the graduate committee, who then selects an examining committee, (2) submission of the thesis proposal to the examining committee, and (3) oral defense of the proposal.

D. Thesis Proposal Abstract

A one-page document stating the most essential aspects of the student's proposed thesis, the thesis proposal abstract must be signed by three faculty members before being given to the graduate committee. One of the three faculty members must be identified as a potential sponsor, meaning that he or she is tentatively willing to be the student's thesis advisor. This implies no commitment, either on the part of the professor or the student.

Upon receipt of the abstract, the graduate committee selects the members of the student's Ph.D. preliminary examination committee and sets a deadline (usually six weeks) for the submission of the thesis proposal to the examination committee. This committee is to consist of five scientists holding Ph.D. degrees who are experts in fields related to the proposal, at least four of whom must be members of the Department.

E. Thesis Proposal

The Ph.D. thesis proposal specifies the scientific rationale for the proposed thesis work, the relevant work done thus far, and the techniques and effort required to reach the research objective. When the thesis proposal is completed, copies are given to each member of the examination committee. Within a week of receiving the proposal, the examination committee will meet to determine whether or not the thesis proposal is defensible. If it is not deemed defensible, the student is informed as to whether a resubmittal will be permitted. If the thesis proposal is deemed acceptable, the examination committee sets a date for the Ph.D. preliminary examination.

F. Oral Preliminary Examination

The student gives a short public presentation of the thesis proposal, after which there is a closed oral examination. Although much of the questioning inevitably focuses on the proposed thesis work, any topic in the geosciences and related fields may be covered in the questioning. At the end of the examination, the student and any others present who are not part of the preliminary examination committee are excused. The committee will then judge whether the student has demonstrated the ability to conceive, plan, and carry out original research.

The examination committee has a range of options open to it. It may vote to deny Ph.D. candidacy, either with or without a second opportunity to pass the Ph.D. preliminary examination. It may vote to accept the proposal, but fail the student on other grounds. In doing so, the examination committee may either bar a second opportunity to take the exam, require specific remedial actions, or schedule a second opportunity to take the examination. The committee has the option to vote to reconvene to re-evaluate its decision, based upon actions the student has taken in response to the examination committee's recommendations.

The examination committee may also vote to pass the student contingent upon changes in or rewriting of the proposal. It is free to establish any mechanism it deems necessary to affirm whether or not its requirements have been met. All decisions must be agreed to by a majority vote and must be conveyed in writing to the graduate program director and to the student.

When the graduate program director has been informed by the chair of the examination committee that the student has passed the Ph.D. preliminary examination, the Department recommends to the Graduate School that the student be advanced to Ph.D. candidacy.

G. Teaching Requirement

All graduate students must register for GEO 600, Practicum in Teaching, at least once, as outlined in Course Requirements on the preceding page.

H. Dissertation

The Ph.D. dissertation is the document summarizing the original scientific research in recognition of which the Ph.D. candidate seeks the doctoral degree. The University has very specific rules about the format of the thesis, but the nature of its scientific content is at the discretion of the student, his or her advisor(s), and the Ph.D. thesis defense committee. In many cases, the thesis consists of a linked set of published or soon-to-be-published scientific papers.

When informed by the student's advisor that the thesis is ready to be defended, the graduate committee selects a Ph.D. thesis defense committee. The defense committee consists of five or six members, a majority of whom must be members of the Department. One defense committee member, other than the thesis advisor, is appointed as committee chair by the graduate committee. Within two weeks of receiving the thesis, the defense committee chair polls the committee members to ascertain that the thesis is actually defensible. If it is, the defense committee chair formally schedules the oral defense.

I. Ph.D. Thesis Oral Defense

The student makes a public presentation of the major results of the thesis. There is then a closed session, during which the student is examined primarily, but not exclusively, on the dissertation topic. The committee has the option of voting to accept the thesis, reject it,

or accept it with revisions. If the thesis is accepted with required revisions, the committee will decide the mechanism for determining compliance with its requirements. Voting is by majority.

Requirements for the M.S. Degree in Geosciences with Thesis

The M.S. in Geosciences with thesis is typically a nonterminal degree completed by some students before seeking Ph.D. candidacy. All requirements for the M.S. degree must be completed within a period of three years after entry. There are no residence or language requirements.

A. Course Requirements

Students must successfully complete a program of 30 graduate credits, including a minimum of 18 credits in approved academic courses. A student must achieve a 3.0 overall grade point average in all graduate courses taken at Stony Brook to receive a degree.

B. M.S. Thesis

An M.S. thesis proposal of no more than two pages must be submitted to the graduate committee at the end of the first year. The proposal must be signed by two faculty members, one of whom must be designated as a potential sponsor of the research and research advisor. After the proposal has been accepted, the student may proceed with the preparation of the M.S. thesis.

When the M.S. thesis is nearing completion, the student's advisor asks the graduate committee to appoint a defense committee. This committee consists of three experts in the field who hold Ph.D.s, at least two of whom must be members of the program faculty. Within two weeks of receiving the thesis, the defense committee decides whether the thesis is defensible. If it is, then an oral thesis defense is scheduled.

The M.S. thesis defense consists of a short public presentation of the major results of the thesis. This is followed by a closed examination that may cover any topic within the student's general field of study, but generally concentrates upon the thesis topic. The thesis defense committee may vote to accept the thesis, return it to the student for revisions, or reject it outright.

Requirements for the M.S. Degree with Concentration in Hydrogeology

The non-thesis M.S. with a concentration in Hydrogeology requires a total of 30 credits. Of these 30 credits, at least 21 credits must be in the required and approved courses and at least six credits must be in approved research. A minimum overall grade point average of B is required. Students are required to complete the four core courses in category A; one course from category B (if a student is deficient in either writing or communication skills, computer programming, or statistics); and one, two, or three courses from category C. There are no residence or language requirements.

Category A

GEO 515 Geohydrology

GEO 564/AMS 562 Numerical Hydrology

GEO 526 Low-Temperature Geochemistry

GEO 519 Geochemistry of Natural Waters

Category B

AMS 576 Statistical Methods for Social Scientists

EST 588 Technical Communication for Management and Engineering

Category C

GEO 573 Hydromechanical Behavior of Geomaterials

GEO 521 Isotope and Trace Element Geology

GEO 524/MAR 524 Organic Contaminant Hydrology

EST 593 Risk Assessment

EST 595 Principles of Environmental Systems Analysis

EST 596 Simulation Models for Environmental Waste Management

EST 597 Waste Management: Systems and Principles

CEY 503 Environmental Law

CEY 509 Man, Environment, and Health

Research

In addition to formal coursework, the curriculum for the M.S. with concentration in Hydrogeology includes a minimum of six credits of research, either GEO 590 or 599, after consultation with the appropriate professor. This research is to be carried out over a period of two or more semesters, and will be designed through a mutual consultation between the student and one or more members of the participating faculty. The purpose of the research is to give the student experience at solving hydrogeological problems. It may utilize field, laboratory, or theoretical approaches. The program of research will culminate in a written report to be approved by three designated faculty.

Requirements for the M.A.T. Degree in Earth Science

The Master of Arts in Teaching Earth Science leads to provisional certification for teaching earth science in secondary schools in New York State. It also prepares the student for the examination for permanent certification. There is no residence requirement. Students must complete at least one year of college-level study of a foreign language.

Students in the M.A.T. program must register through the School of Professional Development.

A. Formal Coursework

Students are required to complete with an average grade of B or higher 15 credits in earth science courses and 27 credits in pedagogical courses and teaching experience. The Departmental M.A.T. advisor, in consultation with the student, will determine a set of earth science courses for the M.A.T. degree in Earth Science.

B. Recommendation of the Department for the M.A.T.

When all program requirements are completed, the Departmental M.A.T. advisor will consult with the director of the Science Education Program to determine whether all state-mandated education courses have been completed. If they conclude that all requirements have been met, they will inform the Associate Dean of the School of Professional Development that the requirements for provisional certification have been fulfilled and recommend to the Dean of the Graduate School that the M.A.T. degree should be granted.

C. Time Limit

Although full-time students can complete all requirements for the

M.A.T. degree within three semesters, part-time students will require additional time to complete the degree requirements.

Courses

ESS 501 Foundations of Earth Science
We consider in depth the scientific concepts that are included in the Earth Science curriculum taught in New York State. This course is team-taught by an experienced Earth Science teacher and University faculty with expertise in astronomy, meteorology, and the geosciences.
Prerequisite: Earth Science teacher, Earth Science education student, or permission of instructor.
Fall, every year, 3 credits, ABCF grading

ESS 502 An Earth Systems Perspective on Long Island's Future
Each time this course is offered we will study in great detail the reasons for given Earth system constraint and the consequences for Long Island's natural and developed areas. Such a constraint might be peak production of oil, groundwater pollution, global climate change, etc. This evening seminar course is repeatable by permission only.
3 credits, ABCF grading
May be repeated for credit

ESS 511 Pine Barrens Sustainability
The ecologically diverse Long Island Pine Barrens region provides a habitat for a large number of rare and endangered species, but faces challenges associated with protection of a natural ecosystem that lies in close proximity to an economically vibrant urban area that exerts intense development pressure. In this course we will consider the interaction of the ecological, developmental, and economic factors that impact the Pine Barrens and the effectiveness of decision support systems in promoting sustainability of the Pine Barrens.
3 credits, ABCF grading

ESS 600 Practicum in Teaching
For M.A.T. Earth Science students.
Fall, spring, or summer, 0-3 credits, S/U grading

GEO 500 Geosciences Research Seminar
Meetings in which first-year graduate students and undergraduates with senior standing learn about the research activities of the Geosciences faculty.
Fall, 0 credit, S/U grading

GEO 502 GIS for Geologists
A practical introduction to geographic information system software. Participants learn to use direct measurement and mathematical techniques to compute the location of features and gain practical experience in rendering imagery and tabular geographic data as layers on maps. The course consists of two three-hour sessions per week for the first five weeks of semester, which include fieldwork, lectures, demonstrations, and software-based analysis of data. This course meets with GEO 588 (Geological Field Methods for Earth Science Teachers) for the first five weeks of the semester. Students may not take GEO 502 and GEO 588 for credit.
Fall, every year, 1 credit, ABCF grading

GEO 503 Mineral Equilibria
Covers the basics of the application of the principles of chemical thermodynamics to the resolution of geochemical and petrological problems. Begins with the first law and continues through phase transitions, properties of fluids, definitions of fugacity, and activity of major and trace elements in fluids and molten solutions; configurational entropies; models quantifying nonideal mixing in solid solutions. Additional topics include interpretation of calorimetric studies and/or solubilities of minerals in aqueous solutions.
Prerequisites: Physical chemistry and thermodynamics or permission of instructor
Fall, alternate years, 3 credits, ABCF grading

GEO 505 Experimental Petrology Laboratory
The course is designed to give the student experience in some or all of the following techniques of experimental petrology: evacuated silica-glass tube experiments, one-atmosphere quenching experiments (with and without controlled atmospheres), 1- to 5-kbar hydrothermal systems (using oxygen buffers where necessary), gas-media experiments up to 7 kbar, and solid-media, piston-cylinder experiments.
Requirements: Completion of a project involving several of the above techniques; written report
Prerequisite: Permission of instructor
Spring, alternate years, 1 credit, ABCF grading

GEO 506 Theoretical Petrology
Theory of phase diagrams, Schreinemaker's rules, heterogeneous equilibria, experimental systems of petrologic interest, and properties of solutions.
Prerequisites: Metamorphic and igneous petrology and physical chemistry or thermodynamics, or permission of instructor
Spring, 3 credits, ABCF grading

GEO 507 Petrogenesis
Discussion of the origin and evolutionary history of selected types of igneous and metamorphic rocks by integrating the principles of heterogeneous phase equilibria, trace-element and isotopic geochemistry, crystal chemistry, and geologic occurrence.
Fall, 3 credits, ABCF grading

GEO 508 The Rock-Forming Minerals
Study of the crystal chemistry, intracrystalline cation distribution (homogeneous equilibria) stability, and paragenesis of the rock-forming minerals. Special emphasis is placed on amphiboles, feldspars, micas, and pyroxenes.
Fall, 3 credits, ABCF grading

GEO 511 Computer Programming for the Geosciences
An introduction to object-oriented programming in Java for geoscience students. Participants are required to develop interactive programs to serve as educational or research tools pertaining to topics within the geosciences. These programs, or applets, include a graphical user interface that enables users to control parameters and observe results. The applets are posted on the Web.
Prerequisite: Geosciences graduate standing
Spring, 3 credits, ABCF grading

GEO 514 Introduction to Physical Hydrogeology
Surface hydrology. Principles of groundwater flow. Well hydraulics. Geology of groundwater occurrence. Water quality and groundwater contamination. Hydrologic site evaluation.
Spring, 3 credits, ABCF grading

GEO 515 Geohydrology
Dynamics of fluids in porous media. Fundamentals of physical hydrogeology. Quantitative analysis of regional groundwater system and well hydraulics. Introduction to numerical simulation techniques. Hydrodynamic dispersion and basic concepts of contaminant transport.
Spring, 3 credits, ABCF grading

GEO 517 Crystal Chemistry
The structure/property/composition relationships in solids. An introduction to the common structure types and how they illustrate principles useful in understanding more complex solid-state materials. Applications of modern scattering techniques to the study of solids, particularly earth materials, are also included.
Fall, 3 credits, ABCF grading

GEO 518 Carbonate Sediments
An intensive study of the formation, deposition, lithification, and diagenesis of carbonate sediments. Lectures and seminars emphasize principles of carbonate deposition, facies relationships, and chemistry. Laboratories emphasize binocular and petrographic analysis of recent and ancient carbonates.
Spring, alternate years, 4 credits, ABCF grading

GEO 519 Geochemistry of Natural Waters
A comprehensive quantitative treatment of the processes controlling the chemistry of polluted and unpolluted surface and groundwaters. Topics covered include thermodynamics and kinetics of water-rock interaction; mineral solubility; chemical speciation; redox reactions; adsorptions; carbonate chemistry; and speciation, mobility, and toxicity of metal ions. Based on a knowledge of these processes, the chemical composition of a wide variety of surface and groundwaters is interpreted. Water-quality criteria and their application are also discussed.
Spring, 3 credits, ABCF grading

GEO 520 Glacial Geology
History of glaciation on earth, formation and dynamics of glaciers and ice sheets; processes of glacial erosion and deposition; and the nature of glacial sediments and landforms particularly relating to the development of Long Island.
Prerequisite: Physical geology
Spring, 3 credits, ABCF grading

GEO 521 Isotope and Trace Element Geology
Application of radiogenic isotopes and trace elements to the petrogenesis of igneous,

metamorphic, and sedimentary systems including water-rock interaction in diagenetic and hydrothermal systems. Evaluation of radiogenetic techniques for determining the ages of rocks and minerals.
Spring, alternate years, 3 credits, ABCF grading

GEO 522 Planetary Sciences
The chemical, physical, and petrologic properties of meteorites are reviewed. These data and data for the moon and the terrestrial planets are used to form a picture of the origin, chemical evolution, and accretion of planetary material.
Fall, 3 credits, ABCF grading

GEO 524 Organic Contaminant Hydrology
There are a host of chemical, biological, and physical processes that affect the transport and fate of organic chemicals in natural waters. This course concerns understanding these processes and the structure-activity relationships available for predicting their rates. The major focus of this class is on contaminant hydrology of soil and aquifer environments, and includes the principles behind remediation and containment technologies. This course is offered as both MAR 524 and GEO 524.
Prerequisite: GEO 526 or MAR 503 or permission of instructor
Spring, 3 credits, ABCF grading

GEO 526 Low-Temperature Geochemistry
Fundamental principles of chemical thermodynamics and kinetics, including isotope effects, as they pertain to geochemical processes occurring in surface and near-surface environments. Consideration is also given to mass transfer process and reaction pathways.
Fall, 3 credits, ABCF grading

GEO 528 Carbonate Geochemistry
Examination of the mineralogical and chemical characteristics of the rock-forming carbonates with emphasis on stabilities in the geological environments. Includes study of phase relations; trace and minor element chemistries; and mechanisms of growth, dissolution, and replacement. Use of current research techniques as applied to carbonate minerals.
Fall, alternate years, 3 credits, ABCF grading

GEO 531 Crystalline Solids
Principles of symmetry, single-crystal, and powder X-ray diffraction techniques and elements of crystal structure determination are considered. Use of crystallographic data in the study of mineral systems. Laboratory in diffraction techniques includes extensive use of digital computers.
Fall, alternate years, 3 credits, ABCF grading

GEO 532 Solid-State Geochemistry
The application of crystallographic techniques to problems in mineral chemistry. Concepts of the crystalline state, order-disorder, atom radii, chemical bonding, atom coordination, solid solutions, and physical properties of minerals. Emphasis on silicate and sulfide crystal structures.
Fall, alternate years, 3 credits, ABCF grading

GEO 533 Geochemistry of the Solid Earth
A brief overview of basic principles of geochemistry, including origin of the elements, geochemical and cosmochemical classification of the elements, and a geochemical perspective of the periodic table. This is followed by an examination of the compositions and chemical interactions among the major geochemical reservoirs of the solid earth, including core, upper and lower mantles, oceanic and continental crust, and the sedimentary shell of the Earth.
Prerequisite: Graduate standing or permission of instructor
Spring, even years, 3 credits, ABCF grading

GEO 535 Regional Structure and Tectonics
Formation and development of continental crust in Phanerozoic mountain belts. The structure and origin of ocean crust, magmatic arcs, and continental margin sequences are studied using geophysical, geochemical, and geologic data from ancient and modern examples.
Fall, alternate years, 3 credits, ABCF grading

GEO 540 Solid Earth Geophysics
An overview of solid earth geophysics. Topics include earthquake and exploratory seismology, gravity, magnetics, geochronology, and heat flow. There is an emphasis on how all of these techniques shed light on the nature of the Earth's interior and dynamics.
Prerequisite: Physical geology, undergraduate physics, and calculus
Fall, 3 credits, ABCF grading

GEO 542 Inverse Theory
Introduction to the basic concepts of inverse theory and its application to the study of the internal structure of the Earth and related problems.
Fall, alternate years, 3 credits, ABCF grading

GEO 543 Stratigraphy
The history and practice of defining units of layered rocks and interpreting their spatial relationships. Topics include the basis for the geologic time scale, lithostratigraphic versus chronostratigraphic units, biostratigraphy, magnetostratigraphy, facies patterns and Walther's law, subsurface stratigraphy, and the application of stratigraphy to geological problems. One three-hour laboratory per week. Laboratory work emphasizes practical techniques in stratigraphy.
Prerequisite: GEO 546 or undergraduate mineralogy and petrology
Fall, 4 credits, ABCF grading

GEO 546 Mineralogy and Petrology
An introduction to mineralogy and petrology, including crystallography, crystal chemistry, mineral identification, and the processes that govern the formation of igneous and metamorphic rocks. Two three-hour laboratories per week.
Prerequisite: Undergraduate physical geology and one year of undergraduate chemistry
Spring, 4 credits, ABCF grading

GEO 549 Structural Geology
Principles of structural geology, including the recognition and the mechanics of crustal structural features. Topics include folding and faulting, stress and strain, and the nature of brittle and ductile lineations and foliations in the crust. One three-hour laboratory per week.
Prerequisite: Undergraduate physical geology
Spring, 4 credits, ABCF grading

GEO 550 Global Tectonics
Geological, geochemical, and geophysical evidence related to the concepts of plate tectonics and mantle convection. Kinematics and dynamics of plate motions. Origin of first-order crustal structures of continents and ocean basins. Geochemical and thermal evolution of the Earth.
Spring, 3 credits, ABCF grading

GEO 551 Physics of the Earth I
Study of the internal structure and properties of the Earth as revealed by field and laboratory investigations. Topics include the rotation and figure of the Earth, gravity anomalies, solid-earth tides, geomagnetism and paleomagnetism, electromagnetic induction, and heat flow and the Earth's present and past thermal states. May be taken independently of GEO 552.
Fall, 3 credits, ABCF grading

GEO 552 Physics of the Earth II
Study of the Earth's structure and properties based on evidence from seismology and high-pressure geophysics. Topics include fundamental principles of elastic wave theory, body and surface wave propagation in layered media, earthquake source mechanisms, free oscillations of the Earth, and rheological properties of the Earth's interior. May be taken independently of GEO 551.
Fall, alternate years, 3 credits, ABCF grading

GEO 556 Solid-State Geophysics
Application of lattice dynamics and equations of state of solids to studies in high-pressure, high-temperature geophysics. Reviews experimental data from physical acoustics, static and shock wave compression, and theoretical results from finite strain and atomistic models.
Prerequisites: GEO 551 and 552 or permission of instructor
Spring, 3 credits, ABCF grading

GEO 562 Early Diagenesis of Marine Sediments
The course treats qualitative and quantitative aspects of the early diagenesis of sediments. Topics include diffusion and adsorption of dissolved species; organic matter decomposition and storage; and diagenesis of clay materials, sulfur compounds, and calcium carbonates. The effects of bioturbation on sediment diagenesis are also discussed. This course is offered as both MAR 562 and GEO 562.
Prerequisite: Permission of instructor
Fall, alternate years, 3 credits, ABCF grading

GEO 564 Numerical Hydrology
Numerical solution methods for the equations of incompressible flow in porous media with special emphasis on groundwater flow. Finite difference and finite element methods for steady-state and transient flows-boundary conditions, range of validity and stability of the numerical schemes, and numerical artifacts. The approach is hands on, with example problems being computed. This course is offered as both GEO 564 and AMS 562.
Prerequisite: AMS 526 or permission of instructor
Fall, alternate years, 3 credits, ABCF grading

GEO 567 Sedimentary Rocks and Crustal Evolution
An examination of major and trace elements and isotopic composition of terrigenous sedimentary rocks within a framework of tracing the composition and evolution of the continental crust. Emphasis is placed on interpreting sedimentary compositions in terms of provenance and sedimentary history (e.g., weathering, diagenesis, recycling). Relationships between sediment composition and tectonic setting is also examined.
Spring, 3 credits, ABCF grading

GEO 570 Earthquake Mechanics
A survey of fundamental mechanics aspects of earthquake rupture; reviews concepts of fracture mechanics, elastodynamics, and experimental rock mechanics. Topics include state of stress in the lithosphere, theoretical models of earthquake instability, energetics of faulting, representation of dynamic elastic field generated by earthquakes, and relation of seismic signals to the kinematics and dynamics of seismic source.
Prerequisite: GEO 552 or permission of instructor
Spring, alternate years, 3 credits, ABCF grading

GEO 571 Mechanics of Geologic Materials
Elastic, thermal, and anelastic properties of geological materials. The course emphasizes a thermodynamic characterization of these properties including irreversible thermodynamics and nonhydrostatic thermodynamics. Specific applications to the Earth's environment are discussed.
Prerequisites: GEO 551, 552, or permission of instructor
Fall, alternate years, 3 credits, ABCF grading

GEO 572 Advanced Seismology
Course is intended to expose the student to topics that are at the forefront of current seismological research. Examples include wave propagation in heterogeneous media, earthquake source studies, tsunami generation, and seismic network data analysis.
Prerequisite: GEO 552
Fall, alternate years, 3 credits, ABCF grading

GEO 573 Physics of Rocks
Fundamentals of the physical properties of rock in relation to seismology, hydrogeology, geophysical prospecting and geotechnical engineering. Topics include: composition, pore structure and fabric of rocks; elasticity, anelasticity and plasticity; seismic velocity and anisotropy; poroelasticity; electrical, magnetic, and hydraulic transpost properties.
Fall, alternate years, 3 credits, ABCF grading

GEO 581 Coastal Engineering Geology
Concepts of the mechanics of earth materials and the physics of surficial processes with applications to the coastal environment and engineering. This course is also offered as MAR 581.
Prerequisites: Enrollment in MESP or OEN program, or permission of instructor
Fall, 3 credits, ABCF grading

GEO 585 Directed Studies
Special studies directed by various faculty members.
Fall, spring, and summer, 1-3 credits, ABCF grading

GEO 588 Geological Field Methods for Earth Science Teachers
Geologic mapping techniques, geochemical analytical approach, and hydrological methodologies applied in the field to examples on Long Island. These approaches are designed for developing research projects for secondary students in earth science.
Prerequisite: Permission of instructor
Summer, 3 credits, ABCF grading

GEO 589 Research for Earth Science Teachers
This course is intended to provide earth science teachers or students in the M.A.T. in Earth Science program an opportunity to obtain research experience. A written report is required.
Prerequisite: Permission of instructor
Summer, 1-3 credits, ABCF grading

GEO 590 Research Project
Independent research
Fall, spring, and summer, 1-12 credits, ABCF grading
May be repeated for credit

GEO 599 Research
Independent research for those students established in a research group.
1-12 credits, S/U grading
May be repeated for credit

GEO 600 Practicum in Teaching
Fall and spring, 0-3 credits, S/U grading
May be repeated for credit

GEO 603 Topics in Petrology
Fall and spring, 1-3 credits, ABCF grading
May be repeated for credit

GEO 604 Topics in Planetary Science
1-3 credits, ABCF grading
May be repeated for credit

GEO 605 Topics in Sedimentary Geology–Paleontology
Fall and spring, 1-3 credits, ABCF grading
May be repeated for credit

GEO 607 Topics in Geophysics
Fall and spring, 1-3 credits, ABCF grading
May be repeated for credit

GEO 609 Topics in Mineralogy and Crystallography
Fall and spring, 1-3 credits, ABCF grading
May be repeated for credit

GEO 696 Geoscience Colloquium
A weekly series of research seminars presented by visiting scientists as well as by the faculty. Required every semester of all geoscience graduate students.
Fall and spring, S/U grading
May be repeated for credit

GEO 697 Geoscience Seminar
Presentation of preliminary research results and current research problems by students and faculty. Required every semester of all geoscience graduate students.
Fall and spring, 0 credit, S/U grading
May be repeated for credit

GEO 698 Geoscience Special Seminar
A weekly series of specialized seminars in which graduate students and faculty discuss specific topics within the subgroups of geology. Research is reviewed, theses are discussed.
Fall and spring, 0 credit, S/U grading
May be repeated for credit

GEO 699 Dissertation Research On Campus
Independent research for Ph.D. degree. Open only to candidates for the Ph.D. who have passed the preliminary examination.
Prerequisite: Advancement to candidacy (G5); major portion of research must take place on SB campus, at Cold Spring Harbor, or at Brookhaven National Lab
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

GEO 700 Dissertation Research Off Campus–Domestic
Prerequisite: Must be advanced to candidacy (G5); major portion of research will take place off campus, but in the U.S. and/or U.S. provinces (Brookhaven National Lab and Cold Spring Harbor Lab are considered on campus); all international students must enroll in one of the graduate student insurance plans and should be advised by an International Advisor
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

GEO 701 Dissertation Research Off Campus–International
Prerequisite: Must be advanced to candidacy (G5); major portion of research will take place outside the U.S. and/or U.S. provinces; domestic students have the option of the health plan and may also enroll in MEDEX; international students who are in their home country are not covered by mandatory health plan and must contact the Insurance Office for the insurance charge to be removed; international students who are not in their home country are charged for the mandatory health insurance (if they are to be covered by another insurance plan, they must file a waiver by the second week of classes; the charge will only be removed if the other plan is deemed comparable); all international students must receive clearance from an International Advisor
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

GEO 800 Summer Research
0 credit, S/U grading
May be repeated for credit