Earth Sciences

This section presents the requirements for programs in:
- M.Sc. Earth Sciences
- M.Sc. Earth Sciences with Collaborative Specialization in Chemical and Environmental Toxicology
- Ph.D. Earth Sciences
- Ph.D. Earth Sciences with Collaborative Specialization in Chemical and Environmental Toxicology

Program Requirements

**M.Sc. Earth Sciences (5.0 credits)**

Requirements:
1. 1.5 credits in course work, 0.5 credit of which may be at the senior undergraduate level
2. 3.5 credits in:
3. A pre-defence public lecture, preceding the oral examination, based on the thesis research
4. 0.0 credits in: participation in the OCGC Seminar Series. Each student gives a presentation of one lecture (open to all members of the OCGC) describing the candidate’s research study within 16 months of the candidate’s registration in the M.Sc. program.

Total Credits 5.0

**M.Sc. Earth Sciences with Collaborative Specialization in Chemical and Environmental Toxicology (5.0 credits)**

Requirements:
1. 0.5 credit in:
   - BIOL 6402/ Principles of Toxicology
   - CHEM 5708 [0.5]
   - or BIOL 6403 [0.5] Ecotoxicology
   - or CHEM 5705 [0.5] Ecotoxicology
2. 0.5 credit in:
   - BIOL 6405/ Seminar in Toxicology
   - CHEM 5805 [0.5]
3. 0.5 credit in additional course work
4. 3.5 credits in:
5. A pre-defence public lecture, preceding the oral examination, based on the thesis research
6. 0.0 credit: participation in the OCGC Seminar Series. Each student gives a presentation of one lecture (open to all members of the OCGC) describing the candidate’s research study within 16 months of the candidate’s registration in the M.Sc. program.

Total Credits 5.0

**Ph.D. Earth Sciences (1.0 credit)**

Requirements:
1. 1.0 credit of course work at the graduate level. Additional courses may be prescribed by the thesis advisory committee

Total Credits 1.0

**Ph.D. Earth Sciences with Collaborative Specialization in Chemical and Environmental Toxicology (1.0 credit)**

Requirements:
1. 0.0 credits in:
   - ERTH 6909 [0.0] Ph.D. Thesis (a research thesis on a topic in toxicology supervised by a faculty member of the Collaborative Program in Chemical and Environmental Toxicology, defended at an oral examination before an examination board that includes an external examiner)
2. A pre-defence public lecture, preceding the oral examination, based on the thesis research
3. 1.0 credit in:
   - BIOL 6402 [0.5] Principles of Toxicology
   - CHEM 5708 [0.5] Principles of Toxicology
   - BIOL 6405 [0.5] Seminar in Toxicology
   - CHEM 5805 [0.5] Seminar in Toxicology
4. 0.0 credits in:
   - ERTH 6908 [0.0] Ph.D. Comprehensive Examination (Conducted by the thesis advisory committee. Includes the presentation of a thesis proposal)
5. 0.0 credit in: participation in the OCGC Seminar Series. Each student gives a presentation of one lecture (open to all members of the OCGC) describing the candidate’s research study within 16 months of the candidate’s registration in the Ph.D. program.
6. Fulfilment of residence requirement: at least four terms of full-time study

Total Credits 1.0

**Regulations**

See the General Regulations section of this Calendar.
A grade of B- or higher is required for each course counted towards the Master's degree.

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See the General Regulations section of this Calendar.

**Admission**

The requirement for admission to the program is an Honours B.Sc. degree, with at least high honours standing, in geology or a related discipline.

**Admission**

The requirement for admission to the Ph.D. Program is an M.Sc. degree in Earth Sciences or a related discipline. A grade of B- or higher is required for each course to be counted.

**Earth Sciences (ERTH) Courses**

**ERTH 5001 [0.5 credit] (GEO 5301)**

Seminars in Earth Sciences I
One-term modular courses covering a spectrum of Earth Science topics and current research problems, ranging from the geology and geophysics of the solid Earth, to its surface environment and crustal resources. Course complements ERTH 5002.
Precludes additional credit for Students may not take a module for credit that is offered by their supervisor, but may do so with the permission of the OCGC Director. A minimum of four modules offered per term, three must be completed to obtain course credit. Choice of modules must be approved by the OCGC Director.

**ERTH 5002 [0.5 credit] (GEO 5302)**

Seminars in Earth Sciences II
One-term modular courses covering a spectrum of Earth Science topics and current research problems, ranging from the geology and geophysics of the solid Earth, to its surface environment and crustal resources. Course complements ERTH 5001.
Precludes additional credit for Students may not take a module for credit that is offered by their supervisor, but may do so with the permission of the OCGC Director. A minimum of four modules offered per term, three must be completed to obtain course credit. Choice of modules must be approved by the OCGC Director.

**ERTH 5104 [0.5 credit] (GEO 5114)**

Mineralogy
An advanced course covering selected topics in mineralogy, such as crystallography, crystal chemistry, crystal structure, mineralogy of rock-forming mineral groups, and instrumental methods in mineralogical research, such as use of electronic optical instruments, spectroscopy, and X-ray crystallography; seminar presentations and practical exercises.

**ERTH 5105 [0.5 credit] (GEO 5115)**

Thermodynamics, Kinetic Theory, and Metamorphic Petrology
Phase equilibria, phase diagrams, and the kinetics of mineral reactions; mass transfer; regional and global aspects of metamorphic petrogenesis. Course may include one or two weeks of field-based instruction with costs borne by students.
Includes: Experiential Learning Activity

**ERTH 5202 [0.5 credit] (GEO 5122)**

Advanced Igneous Petrology
Integrates physical and chemical processes with the dynamics of magmatic systems to understand igneous processes. Course may involve a field trip with costs to be paid by students.
Includes: Experiential Learning Activity

**ERTH 5204 [0.5 credit] (GEO 5124)**

Geology and Geochemistry of Ore Deposits
An advanced course in ore deposits examining aspects of their geology, geochemistry, and exploration. Topics will be selected from a range of different deposit types, including hydrothermal and magmatic ore deposits, as well as laboratory and field examination of different ores and their host rocks.
Includes: Experiential Learning Activity

**ERTH 5206 [0.5 credit] (GEO 5306)**

Hydrothermal Ore Deposits
Advanced economic geology course on hydrothermal ore deposits including geology and geochemistry, physical and chemical controls on mineralization, recognition and characterization of ore-fluid reservoirs, nature of large-scale fluid flow and alteration, and applications to exploration.

**ERTH 5301 [0.5 credit] (GEO 5131)**

Siliciclastic Sedimentology
Origin and significance of physical sedimentary processes and structures. Analysis of ancient siliciclastic depositional environments in a facies model and sequence stratigraphic framework. Course involves lectures, seminars and field excursions.
Includes: Experiential Learning Activity
ERTH 5305 [0.5 credit] (GEO 5135)  
**Carbonate Sedimentology**  
Aspects of modern depositional systems, dynamic facies models, sequence stratigraphy, mineralogy, and diagenesis of carbonate sediments. The practical part of the course will consist of a field-laboratory project that integrates various techniques in carbonate sedimentology (mapping, petrography, staining, cathodoluminescence, fluorescence, SEM).  
Includes: Experiential Learning Activity

ERTH 5306 [0.5 credit] (GEO 5136)  
**Paleobiology**  
Extinctions, micro- and macro-evolutionary processes, long-term trends and cycles in the Phanerozoic; functional morphology; application of invertebrates to biostratigraphy, paleoceanography and paleoecology. May include one or two weeks of field-based instruction with costs borne by the student.

ERTH 5307 [0.5 credit] (GEO 5137)  
**Evolutionary Developmental Biology**  
This course explores the mechanistic basis of organismic evolution from genetic, morphogenetic and epigenetic perspectives, within a phylogenetic context of living and extinct vertebrates.  
Includes: Experiential Learning Activity

ERTH 5308 [0.5 credit] (GEO 5138)  
**Advanced Micropaleontology**  
Paleobiology, biostratigraphy and paleoecology of microfossils in the context of paleoceanography, paleoecology and paleoclimatology. Course may involve a field trip with costs to be paid by students.  
Includes: Experiential Learning Activity

ERTH 5403 [0.5 credit] (GEO 5143)  
**Environmental Isotopes and Groundwater Geochemistry**  
Geochemistry and environmental isotopes in studies of groundwater dynamics, age and contaminant hydrogeology. Environments from shallow groundwater and surface water to deep crustal brines are examined. Low temperature aqueous geochemistry and mineral solubility with emphasis on the carbonate system.

ERTH 5405 [0.5 credit] (GEO 5145)  
**Radioisotope Geochemistry Methods**  
Overview of the basic principles of radiochemistry and examination of the occurrence, sources and production of radionuclides in the earth system that have been used extensively in environmental and geochemical studies. Discussion of and practice using the key methods of radionuclide detection.

ERTH 5407 [0.5 credit] (GEO 5147)  
**Aqueous Inorganic Geochemistry and Modelling**  
Covers concepts in aqueous geochemistry including ion hydration and hydrolysis, aqueous activity, complexation, mineral solubility, carbonate system, redox, adsorption/surface complexation and reaction kinetics. Bi-weekly assignments provide an introduction to equilibrium geochemical modelling.

ERTH 5409 [0.5 credit]  
**Reactive Transport Modelling**  
Introduction to the theory of numerical models and application of reactive transport models in hydrogeology. Focus will be on development of appropriate conceptual models of flow, transport and bio- and geochemical reactions and simulation of these conceptual models using reactive transport codes.

ERTH 5414 [0.5 credit] (GEO 5144)  
**Isotope Mapping and Provenance Applications**  
Isotopes are used to trace provenance of organic and inorganic materials. This course will discuss how traditional isotope systems vary in the environment at different spatiotemporal scales and how mapping their variations can solve problems in hydrology, climatology, ecology, and archeology.  
Includes: Experiential Learning Activity

ERTH 5501 [0.5 credit] (GEO 5151)  
**Precambrian Geology**  
Geology of the main Archean cratons and Proterozoic belts with emphasis on North America. Formation of the Earth, composition and evolution of the crust and mantle during the first 4 billion years of Earth’s history, from its formation to the end of the Proterozoic.  
Includes: Experiential Learning Activity

ERTH 5503 [0.5 credit] (GEO 5153)  
**Computer Techniques in the Earth Sciences**  
A practical course for mapping; quantitative analysis, integration and modeling of spatial data related to geosciences and engineering applications using a combination of GIS, statistical and geostatistical analysis techniques.  
Includes: Experiential Learning Activity  
Prerequisite(s): permission of the Department.

ERTH 5505 [0.5 credit] (GEO 5155)  
**Climate Change**  
Considers climate changes and their driving mechanisms over a broad range of timescales based on observations from geological archives and more recent instrumented evidence. Future climate projections and their accuracy are also considered.  
Includes: Experiential Learning Activity
ERTH 5507 [0.5 credit] (GEO 5157)
Tectonic Processes Emphasizing Geochronology and Metamorphism
Applications of empirical, analytical and quantitative techniques to problems in regional geology and crustal tectonics; orogenic processes; heat and metamorphism; isotopic geochronology as applied to thermal history.

ERTH 5600 [0.5 credit] (GEO 5160)
Chemistry of the Earth
An examination of the composition of the mantle and crust in selected tectonic settings, such as subduction zones and hot spots. Topics may include how geochemical data constrain geodynamic settings of study areas.

ERTH 5603 [0.5 credit] (GEO 5163)
Stable Isotope Geochemistry

ERTH 5609 [0.5 credit] (GEO 5169)
Radiogenic Isotope Geochemistry
Radiogenic isotope systematics applied to the solid Earth and their use to understand various geological processes. Evolution of large-scale isotopic reservoirs throughout Earth’s history. Application of different radiometric dating techniques, assessment of geochronological data, models and interpretations.

ERTH 5701 [0.5 credit] (GEO 5171)
Physics of the Earth
The physics and dynamics of the solid Earth: seismology; gravitational and magnetic fields, thermal state. Geophysical constraints on the structure and composition of the interior. Geodynamic processes. Also offered at the undergraduate level, with different requirements, as ERTH 4801, for which additional credit is precluded.

ERTH 5703 [0.5 credit] (GEO 5173)
Structural Geology
Deformation processes and the analysis of geological structures at all scales.

ERTH 5704 [0.5 credit] (GEO 5174)
Tectonics
Dynamic and geological aspects of plate tectonics throughout Earth history.

ERTH 5707 [0.5 credit] (GEO 5177)
Engineering Seismology
Seismological topics with engineering applications. Characterization of seismicity and seismic sources (areas and faults). Seismic hazard analysis. Empirical and theoretical modeling of strong ground motion in time and frequency domain.

ERTH 5708 [0.5 credit] (GEO 5178)
Earthquake Signal Processing
Theoretical and practical aspects of earthquake signal processing, seismic instrumentation, instrument response and application of spectral analysis and response spectra.

ERTH 5901 [0.5 credit] (GEO 5191)
Research Topics in Earth Sciences
Directed reading/field/laboratory studies unrelated to thesis research, under the guidance of directors other than the thesis supervisor. A written proposal including research plan, deliverables, and evaluation, must be submitted for departmental approval prior to registration. Written report required.
Includes: Experiential Learning Activity

ERTH 5903 [0.5 credit] (GEO 5193)
Field Studies
Field investigations of geological problems, unrelated to thesis research, under the guidance of directors other than the thesis supervisor. Minimum of fifteen days field work. A written proposal including research plan, deliverables, and evaluation must be submitted for departmental approval prior to registration.
Includes: Experiential Learning Activity

ERTH 5906 [0.0 credit] (GEO 5193)
M.Sc. Geoscience Seminar
Participation in the Geoscience Seminar Series.

ERTH 5907 [0.0 credit] (GEO 5193)
Ph.D. Geoscience Seminar
Participation in the Geoscience Seminar Series.

ERTH 5909 [3.5 credits] (GEO 7999)
M.Sc. Thesis
A thesis proposal must be approved by the research advisory committee by the end of the first year of registration.
Includes: Experiential Learning Activity

ERTH 6908 [0.0 credit] (GEO 9998)
Ph.D. Comprehensive Examination
The Comprehensive Examination involves a thesis proposal and oral examination in three different areas of specialization. Students will receive a grade of Satisfactory or Unsatisfactory. This exam is taken within the first twelve months of registration in the program.

ERTH 6909 [9.0 credits] (GEO 9999)
Ph.D. Thesis
A thesis proposal must be approved by the research advisory committee by the end of the first year of registration.
Includes: Experiential Learning Activity