# Earth Sciences

This section presents the requirements for programs in:

- M.Sc. Earth Sciences
- M.Sc. Earth Sciences with Specialization in Chemical and Environmental Toxicology
- Ph.D. Earth Sciences
- Ph.D. Earth Sciences with 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 Specialization in Chemical and Environmental Toxicology (5.0 credits)

**Requirements:**

1. 0.5 credits in:
   - BIOL 6402/6403/6405/7085
   - CHEM 5705
2. 0.5 credit in:
   - BIOL 6405/CHEM 5805 Seminar in Toxicology
3. 0.5 credits 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 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

### Ph.D. Earth Sciences (10.0 credits)

**Requirements:**

1. 1.0 credit of course work at the graduate level. Additional courses may be prescribed by the thesis advisory committee
2. 9.0 credits in:
   - ERTH 6909 [9.0] Ph.D. Thesis (defended at an oral examination before an examination board that includes an external examiner)
3. A pre-defence public lecture, preceding the oral examination, based on the thesis research
4. 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.
5. Fulfilment of residence requirement: at least four terms of full-time study

Total Credits 10.0

### Ph.D. Earth Sciences with Specialization in Chemical and Environmental Toxicology (10.0 credits)

**Requirements:**

1. 9.0 credits in:
   - ERTH 6909 [9.0] 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
5. Fulfilment of residence requirement: at least four terms of full-time study

Total Credits 10.0

## 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.

**Regulations**
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.

**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 5105)**  
**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**  
Advanced aspects of geology, geochemistry, genesis, and exploration of ore deposits. Laboratory and field examination of different ore deposit types 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 5215 [0.5 credit] (GEO 5115)**  
**Natural Hazards in Canada - Risk and Impact**  

Also listed as IPIS 5505.

Also offered at the undergraduate level, with different requirements, as ERTH 4815, for which additional credit is precluded.

**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.

ERTH 5307 [0.5 credit]  
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  
Lectures two hours a week and a laboratory three hours a week.

ERTH 5308 [0.5 credit]  
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 5309 [0.5 credit] (GEO 5139)  
Glacial and Periglacial Geology  
An examination of various sedimentary environments associated with glacial and periglacial processes and their significance for mineral exploration and environmental geochemistry. Study of cold climate non-glacial conditions and the development of permafrost and permafrost-related features, including the effect of groundwater flow on permafrost distribution.

ERTH 5402 [0.5 credit] (GEO 5142)  
Environmental Geoscience  
A study-seminar course in which students will examine, in depth, certain environmental problems, including geological hazards, mineral and energy consumption and environmental degradation. The relation between development and the environment will be considered.

ERTH 5403 [0.5 credit] (GEO 5143)  
Environmental Isotopes and Groundwater Geochemistry  
Stable environmental isotopes (18O/2H/13C/34S/15N) in studies of groundwater origin and flow, and geothermal studies. Groundwater dating techniques involving tritium and radio-carbon, and exotic radioisotopes (e.g., 36Cl/39Ar/85Kr). Low temperature aqueous geochemistry and mineral solubility with emphasis on the carbonate system. Some applications to paleoclimatology will be discussed.

ERTH 5406 [0.5 credit] (GEO 5146)  
Techniques of Groundwater Resources Evaluation  
Governing groundwater flow equations, initial and boundary conditions; simple numerical solutions (spreadsheets); complex numerical solutions (commercial software); and analytical solutions. Applications: aquifer response test analysis, capture zone analysis, groundwater flow modeling, water budgeting, and aquifer vulnerability assessment.

ERTH 5501 [0.5 credit] (GEO 5151)  
Precambrian Geology  
Geology and tectonic history of the Canadian Shield, emphasizing modern four-dimensional interpretations (2D mapping, depth, time); comparison and correlation with other Precambrian shields; global Precambrian tectonic evolution through review of continental reconstructions; Precambrian mineral deposits; field trips and research projects.  
Includes: Experiential Learning Activity
ERTH 5503 [0.5 credit] (GEO 5153)  
Computer Techniques in the Earth Sciences  
A practical course in the application of computer techniques in the acquisition and interpretation of geoscientific data. Topics may include: remote sensing and geographic information systems; geostatistical analysis techniques; analysis and modeling of geoscientific data.  
Includes: Experiential Learning Activity  
Prerequisite(s): permission of the Department.

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  
Nucleosynthesis; chemical differentiation of the Earth. Evolution of large-scale isotopic reservoirs. Isotopic tracers (143Nd/144Nd, 87Sr/86Sr, common Pb). Geochronology; fundamentals and application of Sm/Nd, Rb/Sr, U/Pb, K/Ar and Lu/Hf methods. Evolution of the solid Earth from the isotopic perspective.

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 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. Written report required.  
Includes: Experiential Learning Activity

ERTH 5903 [0.5 credit] (GEO 5193)  
M.Sc. Geoscience Seminar  
Participation in the Geoscience Seminar Series.

ERTH 5906 [0.0 credit] (GEO 5193)  
M.Sc. Geoscienti 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, Unsatisfactory or Pass with Distinction. 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