

Earth Sciences

- **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**

M.Sc. Earth Sciences

About the Program

Established in 1982, the Ottawa-Carleton Geoscience Centre, a joint initiative of Carleton University and the University of Ottawa, offers programs leading to the degrees of M.Sc. and Ph.D. in Earth Sciences. The Centre houses modern instrumental facilities open to students at both campuses, and research activity includes most areas of the Earth Sciences. The campuses are fifteen minutes apart by complimentary inter-university transport and within a short distance of most federal facilities.

The size of the Centre's research faculty and its location in the nation's capital offer unique opportunities for collaborative research over a broad range of disciplines. Of particular note is the Centre's close collaboration with the Geological Survey of Canada and the Canadian Museum of Nature. Graduate students are enrolled in the university where their faculty supervisor holds an appointment but can take courses or use research facilities at both universities. Students draw from a program of courses in English or French and may pursue their research in either language.

Academic 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.

Admission Requirements

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.

Program Requirements

M.Sc. Earth Sciences (5.0 credits)

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|--|-----|
| 1. 1.5 credit in course work, 0.5 credit of which may be at the senior undergraduate level | 1.5 |
| 2. 3.5 credits in: | 3.5 |
| ERTH 5909 [3.5] M.Sc. Thesis (defended at an oral examination) | |
| 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 M.Sc. program. | |

Total Credits **5.0**

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

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|--|------------|
| 1. 0.5 credit in: | 0.5 |
| BIOL 6402/ Principles of Toxicology
CHEM 5708 [0.5]
or BIOL 6403/ Ecotoxicology
CHEM 5705 [0.5] [0.5] | |
| 2. 0.5 credit in: | 0.5 |
| BIOL 6405/ Seminar in Toxicology
CHEM 5805 [1.0] | |
| 3. 0.5 credit in additional course work | 0.5 |
| 4. 3.5 credits in: | 3.5 |
| ERTH 5909 [3.5] M.Sc. Thesis | |
| 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

About the Program

Established in 1982, the Ottawa-Carleton Geoscience Centre, a joint initiative of Carleton University and the University of Ottawa, offers programs leading to the degrees of M.Sc. and Ph.D. in Earth Sciences. The Centre houses modern instrumental facilities open to students at both campuses, and research activity includes most areas of the Earth Sciences. The campuses are fifteen minutes apart by complimentary inter-university transport and within a short distance of most federal facilities.

The size of the Centre's research faculty and its location in the nation's capital offer unique opportunities for collaborative research over a broad range of disciplines. Of particular note is the Centre's close collaboration with the Geological Survey of Canada and the Canadian Museum of Nature. Graduate students are enrolled in the university where their faculty supervisor holds an appointment but can take courses or use facilities at both universities. Students draw from a program of courses in English or French and may pursue their research in either language.

Academic Regulations

See the General Regulations section of this Calendar.

Admission Requirements

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.

Program Requirements

Ph.D. Earth Sciences (10.0 credits)

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

ERTH 6908 [0.0]	Ph.D. Comprehensive Examination (Conducted by the thesis advisory committee. Includes the presentation of a thesis proposal and involves three areas of geoscience specialization chosen by the student's advisory committee and approved by the Director of the Ottawa-Carleton Geoscience Centre)	
2. 9.0 credits in:		9.0
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		0.0
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.		0.0
5. Fulfilment of residence requirement: at least four terms of full-time study		0.0
Total Credits		10.0
Ph.D. Earth Sciences with Specialization in Chemical and Environmental Toxicology (10.0 credits)		
1. 9.0 credits in:		9.0
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:		1.0
BIOL 6402 [0.5] Principles of Toxicology or CHEM 5708 [0.5] Principles of Toxicology		
BIOL 6405 [1.0] Seminar in Toxicology or CHEM 5805 [1.0] Seminar in Toxicology		
4. 0.0 credit in:		0.0
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.		0.0
6. Fulfilment of residence requirement: at least four terms of full-time study		0.0
Total Credits		10.0

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. A minimum of four modules offered per term, three must be completed to obtain course credit. 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. Choice of modules must be approved by the OCGC Director. Course complements EARTH 5002.

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. A minimum of four modules offered per term, three must be completed to obtain course credit. 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. Choice of modules must be approved by the OCGC Director. Course complements EARTH 5001.

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]

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.

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.

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.

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]**Natural Hazards in Canada - Risk and Impact**

Overview of natural hazards and severe weather phenomena in Canada. Notions of risk, return period, and probability of occurrence of natural disasters. Impact on society and infrastructure. Mitigation policies and strategies.

Precludes additional credit for IPIS 5515.

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.

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).

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 paleolimnology.

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.

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, paleolimnology and paleoclimatology. Course may involve a field trip with costs to be paid by students.

Lectures, seminars and/or laboratory five hours a week.

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 (^{18}O , ^2H , ^{13}C , ^{34}S , ^{15}N) in studies of groundwater origin and flow, and geothermal studies. Groundwater dating techniques involving tritium and radio-carbon, and exotic radioisotopes (e.g., ^{36}Cl , ^{39}Ar , ^{85}Kr). 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 5407 [0.5 credit] (GEO 5147)**Geochemistry of Natural Waters**

Aqueous speciation, solubility of metals, minerals and gas, reaction kinetics and equilibria. Chemistry and dynamics of groundwaters and hydrothermal fluids.

ERTH 5408 [0.5 credit] (GEO 5148)**Theory of Flow and Contaminant Transport in Geological Materials**

Development of governing groundwater flow equations and solute transport equations from first principles, and application of principles in case studies. Topics may include forces and potentials, fluids, geological materials, contaminants, case studies.

Prerequisite(s): undergraduate hydrogeology or instructor's permission.

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.

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.

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**

Mechanisms of isotope fractionation in nature; physical and chemical isotope fractionation, kinetic isotope effects. Variation of stable isotope ratios (hydrogen, carbon, oxygen and sulphur) in nature. Preparation techniques of natural samples for isotope analysis. Applications of stable isotopes to study magma genesis, ore genesis, nature of water and formation fluids and sedimentary environments.

ERTH 5609 [0.5 credit] (GEO 5169)**Radiogenic Isotope Geochemistry**

Nucleosynthesis; chemical differentiation of the Earth. Evolution of large-scale isotopic reservoirs. Isotopic tracers ($^{143}\text{Nd}/^{144}\text{Nd}$, $^{87}\text{Sr}/^{86}\text{Sr}$, 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.

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]**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.

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.

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.

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.

Summer session: some of the courses listed in this Calendar are offered during the summer. Hours and scheduling for summer session courses will differ significantly from those reported in the fall/winter Calendar. To determine the scheduling and hours for summer session classes, consult the class schedule at central.carleton.ca

Not all courses listed are offered in a given year. For an up-to-date statement of course offerings for the current session and to determine the term of offering, consult the class schedule at central.carleton.ca