GEOLOGICAL SCIENCES AND GEOLOGICAL ENGINEERING

Departmental Facilities

The department is located in stately Miller Hall and its modern Bruce Wing. There are excellent study collections, including more than 70,000 volumes and 20,000 maps housed in the university's Douglas Library. We are also proud of our superb mineralogical, petrological, sedimentological and paleontological collections.

In addition to the standard tools related to the Earth Sciences, the department is home to numerous high-end laboratory and computational facilities. Among these facilities are the following:

- A new electron microprobe and scanning electronic microscope with mineral analyser facilities for the determination of the chemical composition of micron-scale areas on mineral samples. Training courses are regularly provided for interested graduate students.
- X-ray diffraction facilities that include a new Xpert Pro Philips powder diffractometer with an X'celerator area detector and 15-sample chamber magazine. The diffractometer is equiped with an environmental chamber which allows diffraction experiments under a wide range of pressures and temperatures.
- Fluid inclusion facilities including two new Linkham cooling-heating stages and digital imaging, allowing for investigation of fluid inclusion at temperatures between 180°C and 1500°C.
- The Queen's University 40Ar/39Ar geochronology laboratory contains an 8 W Ar-ion laser and Modifications Inc. resistance furnace coupled to an MAP 216 mass spectrometer, yielding 40Ar/39Ar ages with typical precisions of ± 0.5%. The laser can be used in both spot-dating and step-heating modes to maximise the isotopic age information from the samples.
- The department is home to the Queen's Facility for Isotope Research (www.queensu.ca/geol/qfir/facilities/qfir-stable-isotope-lab (http://www.queensu.ca/geol/qfir/facilities/qfir-stable-isotope-lab/)), an ultra-modern and diverse geochemical laboratory capable of analysing the isotopic composition of a wide range of elements in almost any material. The equipment includes a MAT 252 Delta XP and a new MAT 253 isotope ratio mass spectrometers plus a full suite of peripheral tools such as gas chromotographs, elemental analyzers and a gas bench. There are also two complementary Inductive Coupled Plasma Spectrometer (ICPMS) systems, complete with two inniegan Elements, ICPOES, a Thermo X and a Finnegan Neptune multicollector.All can be interfaced with our 193, 213 or femtosecond laser systems for ablation to analyze trace element compositions on a scale of 10 micrometers.
- The Rose Geocomputation Laboratory in the Department of Geological Sciences and Geological Engineering provides computational resources. The lab is equipped with 6 PC workstations with GIS, CAD, programming, and geological modeling software. Network file servers allow data and project work to be shared and seamlessly moved between work locations. Funded by a generous donation from Mike and Sue Rose, alumni of the Department, the Lab has continuing funding to remain state-of-the-art for future generations of students.
- A 20,000g centrifuge is available for experimental tectonic modelling. This facility is unique in Canada, and, to the best of our knowledge, is one of only three in the world that are used for scaled modelling of tectonic processes.
- There is a state of the art Geomechanics Computation Laboratory with research and design analysis software including comprehensive packages from RocScience, Mine Modelling, Itasca and others. This suite of analysis tools is used for engineering design analysis and can also be applied to geomechanical analysis of earth processes. There is also a new and complementary laboratory-scale multi-channel full-waveform acoustic emission system from ESG Inc., intended for use with conventional rock-testing apparatus.
- The Earth Systems Information Laboratory is the teaching computing lab for the Department of Geological Sciences and Geological Engineering. With 50+ computers, screen projection for presentations or software demonstrations, access to network file servers, and scanning and printing facilities, the Lab can handle full lab classes as needed. Geophysical, geological, GIS and CAD software are available for student use on all computers.
- Microstructural Laboratory: The microstructural laboratory consists of two high-end petrographic microscopes (Leica M420 macroscope with high-quality 6:1 Apozoom objective, and a Nikon E600 polarizing microscope up to 100x), both linked to a QIcam 12bit monochrom high resolution digital camera operated by a Compix Image processing and Analysis (IPA) software. This software can isolate mineral populations, and perform several quantitative measurement tasks on captured images. The laboratory also has a standard Leitz petrographic microscope equipped with a 5-axis Leitz

Universal stage for crystallographic preferred orientation measurements.

Financial Assistance

The Department of Geological Sciences and Geological Engineering guarantees minimum stipends for its funding-eligible students. The minimum for students completing a master's two year research program is $21,000 per annum. For Ph.D. students the minimum is $23,000. Both minimum stipends are effective as long as the student is within terms of support. Actual financial support may be higher in many cases, depending on external awards student may have received. The one-year master's students receive no financial assistance.

Fields of Graduate Study and Research

Research in the Department of Geological Sciences and Geological Engineering is offered in five fields of study.

- Field I - Economic Geology and Mineral Exploration
- Field II - Petrology and Structural Geology
- Field III - Sedimentology, Sedimentary Geochemistry and Paleobiology
- Field IV - Geophysics and Geochronology
- Field V - Applied Geoenvironmental Sciences and Geotechnique

The Department provides opportunities for a broad range of major subfields in the earth sciences, including mineralogy, petrology, structural geology, stratigraphy, sedimentology, paleontology, geochemistry, geophysics, environmental and economic geology. In geological engineering there are particular strengths covering hydrogeology, environmental geochemistry, geomechanics, hazard mitigation and earth-structure interaction.

Members of the department's staff often collaborate, giving graduate students exciting opportunities for multidisciplinary research under co-supervision.

Among the broad areas in which recent graduate research projects have been concentrated are: integrated geochronological and metallogenic studies of parts of the Canadian Shield and the Cordillera of North and South America, genesis of mineral deposits in all geological settings and their application to exploration models, tectonics of the Canadian Cordillera and the Canadian Shield, environmental studies in the Canadian arctic as well as other parts of North America, integrated sedimentological/geochemical/paleobiological studies of modern and ancient carbonate and siliciclastic depositional systems, the early evolution of animals and their ecosystems, exploration geochemistry, and theoretical to observational studies in both exploration and earthquake seismology. Geological Engineering projects have focussed on fundamental properties of hydrostratigraphic units, analysis and design protocols for tunnelling near surface and at great depth, stability of large natural and cut slopes, and geomechanical risk assessment for mining.

The Master of Science in Applied Geology (Non-Research Pattern II and III)

The Master of Science in Applied Geology is a one-year program leading to enhanced knowledge in Mineral Exploration/Resource Geology or Geological Engineering.

Students interested in engineering geology may also wish to investigate the GeoEngineering Centre (www.geoeng.ca (http://www.geoeng.ca/)), a collaboration with the Queen's Civil and Mining Engineering departments and with the Royal Military College.

Faculty

Head
Remenda. V.H.

Coordinator of Graduate Studies
Leybourne, M.

Professor
Braun, A., Dalrymple, R.W., Diederichs, M.S., Fotopoulos, G., Godin, L., Hutchinson, D.J, James, N.P., Jamieson, H.E., Narbonne, G.M., Olivo, G.R., Pufahl, P.

Associate Professor
Hanes, J.A., Layton-Matthews, D.,Leybourne, M., Remenda, V.H.

Assistant Professor
Day, J., Harrison, A., Spencer, C., Steel, E., Vriens, B.

Professor Emeritus
Clark, A.H., Dalrymple, R., Dixon, J., Farrar, E., Helmstaedt, H.,Peterson, R.C., Price, R.A..

Cross-Appointed Faculty
Bevan, G., McKinnon, S., Vlachopoulos, N.

Continuing Adjunct
Harrap, R.

Adjunct (Group 1) Professor
Franklin, J.M., Martindale, W., Parsons, M., Pratt, R.G., Schulze, D.

Adjunct (Group 1) Associate Professor

Doggett, M.D., Gehling, J.G.

Adjunct (Group 1) Assistant Professor
Archibald, D.A., Bone, Y., Camacho, A., Hiatt, E.E., Kellett, D., McClenaghan, M.B., Peter, J., Pratt, A., Pufahl, P., Snyder, D.

Programs of Study

Master of Science (M.Sc): Regular two-year research program and one-year non-research program in Applied Geology.

Master of Applied Science (M.A.Sc.): Master's program in applied sciences (engineering).

Doctor of Philosophy (Ph.D.): Geological science and applied science programs available.

Master of Earth and Energy Resources Leadership (MEERL): A professional Master's degree, 20 months in duration, 20% residential and 80% online, intended to be completed while students remain employed.

All applicants are accepted under the general regulations of the School of Graduate Studies and Postdoctoral Affairs.

- Geological Sciences and Geological Engineering - Doctor of Philosophy (https://queensu-ca-public.courseleaf.com/graduate-studies/programs-study/geological-sciences-engineering/geological-sciences-geological-engineering-phd/)
- Geological Sciences and Geological Engineering - Master of Science (https://queensu-ca-public.courseleaf.com/graduate-studies/programs-study/geological-sciences-engineering/geological-sciences-geological-engineering-ms/)

Some of the courses listed below are offered each year, some are offered either in alternating years, or on demand, and depend partly on student enrolment. Please check the Departmental website for further information. The cost of field trips, including transportation, accommodation and food (when it is supplied), will be borne by the student. Subsidies will be provided by the Department when funding permits. A list of the estimated field trip fees for each course is provided on the departmental web page. These fees are subject to change, and will be finalized by June 1 each year. Field trip fees will be payable by the due dates listed in the table. GEOL 800, 803-812, 817, and 838 are all 1.5 credit units courses. GEOL 898, 899 and 999 are 6.0 credit units. All other courses are 3.0 credit units.

APSC 810 Teaching and Learning in Engineering
This course is an introduction to learning principles and effective teaching in engineering, intended to prepare for roles like teaching assistant, university course instruction, or training in engineering industry. The course includes relevant theories of teaching and learning with practical elements like classroom management, designing sessions and assessments, signature engineering teaching approaches, and using digital pedagogies.

APSC 812 AI Ethics and Society
This course investigates the ethical implications of Artificial Intelligence (AI) as a social, technological and cultural phenomenon. Given the increasing use of intelligent systems for decision-making and autonomous control, it is essential that designers and developers are aware of the ethical and social implications that AI can have. The course materials will examine fundamental ethical principles related to the application of AI and investigate its influence in a number of industries including self-driving vehicles, healthcare, law and defense. The course will also examine the delicate balance between innovations in AI versus regulation, privacy, and individual rights. This course is graded on a Pass/Fail basis.

APSC 877 Engineering Project Management
The course will examine the essential skills and knowledge required for effective engineering project management. The foundational principles of project management including integration, scope, cost, time, human resources, stakeholders and procurement are examined. The course will be delivered online.
Exclusions: MECH 896, APSC 223

APSC 888 Engineering Innovation and Entrepreneurship
This course will help learners from across engineering develop an entrepreneurial mindset capable of turning problems into opportunities. Learners will investigate the relationships between innovation and industrial dynamics, and seek to understand the fundamental forces that drive the science and technology industries' evolution and industry life cycles.
EXCLUSION: CHEE 410

APSC 896 Engineering Leadership
The course is designed to develop a range of leadership skills essential for engineering professional practice. Students will explore their own leadership abilities and develop their competencies in areas such as managing conflict, team dynamics and developing others. The course content will be presented through lectures, case studies, panel discussions and other active learning activities. Fall. P. Hungler

GEOL 800 Foundations of Geosciences
The course will consist of three, seminar-based sections, each worth 1/3 of 1.5 credit units: (1) Principles of scientific methodology in the Geosciences: will provide an overview of the scientific method and tools for effective scientific communication. Professional practice and ethical aspects

will also be discussed. (2) Mathematical methods for Geosciences: will provide a foundation in numerical methods and mathematical analysis. Topics include spatial statistics, probability, linear regression, and an introduction to numerical modeling techniques. (3) Experimental/ Analytical Techniques in Geosciences: will provide an overview of analytical techniques and equipment available to geoscientists. Intended as an introduction to more advanced "methods" modules, this last section will provide a fundamental knowledge of the theory and operation of instruments and techniques available to members of our department. Staff.

GEOL 802 Graduate Field School
Graduate field school held in several regions of the world consisting of field trips to selected areas of geological interest, emphasizing relationships between local and regional geological environments and their natural resources and hazards, in the context of the tectonic evolution of the area visited. Students are expected to research background on areas to be visited and must produce one or more substantial reports and present one or more seminars. Extra fees may apply to cover the cost of travel. Field excursions in the fall, winter and/or beginning of summer term. Field trip costs will be finalized by September, when the detailed trip plan is presented to interested students. In previous years, the maximum cost of the trip has been $3000 / student. Funding from thesis supervisors may be available to help offset these costs. Staff.

GEOL 803 Basin Analysis and Economics Deposits
A review of the tectonic origin and filling of various types of sedimentary basins, followed by an examination of the diagenesis of siliciclastic, carbonate and organic sediments, and the implications for the occurrence of hydrocarbons and mineral deposits. (1.5 credit units). PREREQUISITE: GEOL 238 or equivalent; GEOL 365 or equivalent

GEOL 804 Focused Topics in Geological Engineering
This course consists of a short and focused exploration of a pre-approved topic in engineering geology removed from the thesis research. The course may be hosted at Queen's or offsite under the co-supervision of the designated departmental instructor. Course delivery may vary from special lecture series to supervised field/lab course. Deliverables would include a self-directed report and presentation. Field trip fee may apply. (1.5 credit units).
PREREQUISITE: Permission of the instructor.

GEOL 805 Focused Topics in Applied Geology
This course consists of a short and focused exploration of a pre-approved topic in applied geology removed from the thesis research.The course may be hosted at Queen's or offsite under the co-supervision of the designated departmental instructor. Course delivery may vary from special lecture series to supervised field/lab course. Deliverables would include a self-directed report and presentation. Field trip fee may apply. (1.5 credit units)
PREREQUISITE: Permission of the instructor.

GEOL 806 Applications of Scanning Electron Microscopy and Microprobe Analysis
The theory and practical aspects of the techniques of Scanning Electron Microscopy and the Electron microprobe. A project is required where the student employs these techniques to study a material of their choice. (1.5 credit units)
PREREQUISITE: Permission of the instructor.
EXCLUSION: GEOL 452

GEOL 807 Applications of X-ray Powder Diffraction and Mineral Spectroscopy
The theory and practical aspects of the techniques of X-ray powder diffraction and mineral spectroscopy. Techniques include Vis-infra-red spectroscopy, Raman spectroscopy and Mossbauer spectroscopy. A project is required where the student employs these techniques to study a material of their choice. (1.5 credit units)
PREREQUISITE: Permission of the instructor.
EXCLUSION: GEOL 452

GEOL 808 Visualization in the Geosciences
An introduction to 3d visualization of natural sciences data with a focus on methods relevant to geological engineering, mineral exploration, and geoscience research. Perception, representation, and analytical methods. Design tools and data integration methods. Temporal analysis of natural sciences data. LiDAR data analysis. Global and local models. Virtual worlds. (1.5 credit units)
PREREQUISITE: GEOL/GEOE 463 or GEOL 855 or Permission of the instructor

GEOL 809 Mine Waste Geochemistry
This course will expose students to the concepts and the current practice of mine waste management including acid mine drainage, neutral-pH metal leaching, secondary mineral precipitates, prediction and permitting, site remediation, etc. Those who complete this course will have a comprehensive understanding of the nature of mining environmental impact, the scientific principles behind the interaction between mine waste and the surface environment, and the tools (including speciation software) that professionals use to predict, control, remediate and regulate metal mining activities. (1.5 credit units)
PREREQUISITE: Permission of the instructor.
EXCLUSION: GEOL 835

GEOL 810 Microtectonics and orogenic systems

Mechanisms of brittle and ductile deformation, strain, rheology, and deformation mechanisms applied to geological structures and rock fabrics, with an emphasis on microstructural development of fabrics, flow paths and vorticity analysis. Applications to problems in continental tectonics studies.(1.5 credit units)
PREREQUISITE : Permission of the instructor.
EXCLUSION: GEOL 481, GEOL 816.

GEOL 811 Introduction to GIScience
An overview of the major themes, approaches, and methods of geographic information science and related GIS software tools. Spatial analysis, fundamentals of cartography, and fundamentals of data management. Students will gain exposure at a level appropriate for effectively managing and using spatial data for graduate level projects.(1.5 credit units)
PREREQUISITE : Permission of the instructor.
EXCLUSION: GEOL 463, GPHY 243

GEOL 812 Resources and Sustainability
This course addresses the major challenges of mineral exploration and mining industries in providing well-being for people and ecosystems; includes discussions of the global distribution of, and demand for, water, energy and mineral resources, and the major geological, technological, economic, environmental, social and governance issues. It involves 20 h of lectures and discussion of papers and it culminates with the presentation of comprehensive seminar and report by the participants. (1.5 credit units)

GEOL 813 Rock Engineering- Concepts and Case Histories
Overview of development of rock engineering; discussion of acceptability criteria for engineering design; site characterization techniques and objectives; rockmass classification methodology and property determination; analysis of structural instability; assessment of stress; design of underground structures in weak rock; rock support design; risk management for rock engineering. Three hour lecture, two hours tutorial. Fall. Instructor: D. Jean Hutchinson.
PREREQUISITE: Rock Mechanics course or permission of the instructor.

GEOL 815 Topics in Tectonics
A seminar-based course focussing on advanced concepts in structural geology and Tectonics. Topics may include flow concepts applied to ductile deformation, description and interpretation of microstructural fabrics, subduction processes, fluid and faulting, modelling approaches to Tectonic problems, and exhumation processes of metamorphic rocks. Far field effects such as lithosphere rheology, climate, and erosion will also be discussed. Three hour lectures; Winter. L. Godin.
PREREQUISITE: Permission of the instructor.

GEOL 816 Structural Analysis
Mechanisms of brittle and ductile deformation applied to geological structures and rock fabrics. Emphasis is on structures in fold and thrust belts, fracture and vein analysis, and studies of superposed deformation. (Offered jointly with GEOL 481, but extra assignments are given.) Two hours lecture, 1 hour tutorial; 2 hours lab; Winter. L. Godin.

GEOL 817 Presenting Science
This course covers key theoretical principles and practical applications for presenting science. Students will learn about different types of presentations and means for presenting scientific data based on their target audience. It should be emphasized that the “science” component of this course is also critically important and therefore students are expected to select their presentation topics according to their scientific discipline. (1.5 credit units)
PREREQUISITE: Permission of the instructor.

GEOL 822 Metallogeny in Mineral Exploration
The major geological environments considered from a plate tectonic perspective, and their associated ore deposits: approaches to the definition of the characteristics of ore deposit types, with particular emphasis on the role of theories of ore genesis in defining geological criteria for area selection in mineral exploration. (May be offered jointly with GEOL 422, depending on enrolment.) Three hours lecture, three hours seminar, seminar/laboratory; Fall. G.R. Olivo, Coordinator.

GEOL 835 The Environmental Impact of Mining
This course will expose students to the concepts and the current practice of mine waste management including acid mine drainage, neutral-pH metal leaching, secondary mineral precipitates, prediction and permitting, site remediation, etc. Students who complete this course will have a comprehensive understanding of the nature of the environmental impact of mining on ecological and human health, the scientific principles behind the interaction between mine waste and the surface environment, and the tools that professionals use to predict, control, remediate and regulate metal mining activities. Offered as full course or module. The course includes a three-day workshop, six 2-hour laboratory sessions and a three-day field trip. Winter. H. Jamieson. Field trip fees are approximately $100.

GEOL 838 Basin Analysis and Economic Deposits
A review of the tectonic origin and filling of various types of sedimentary basins, followed by an examination of the diagenesis of siliciclastic, carbonate and organic sediments, and the implications for the occurrence of hydrocarbons and

mineral deposits. (1.5 credit units) PREREQUISITE: GEOL 238 or equivalent; GEOL 365 or equivalent

GEOL 839 The Geochemistry of Fluids Associated With Economic Ore Deposits
Basic principles of litho- and aqueous-geochemistry. New principles involving stable and radiogenic isotope geochemistry will follow. The hydrologic cycle will be examined from a geochemical perspective, leading to discussion of hydrothermal fluids and ore deposits associated with hydrothermal alteration. Phase equilibrium, mineral stability, oxidation-reduction reactions, isotope geochemistry, and other characteristics of hydrothermal fluids. The origin and chemical compositions of magmatic and metamorphic fluids. (Portions of the course are given jointly with GEOL 465.) Three hours lecture, three hours laboratory.

GEOL 840 Problems in Geology
An investigation of selected geological problems. Staff. Offered on demand.

GEOL 841 Special Topics in Geology & Geological Engineering I
A course unit composed of two modules on topics in the geological sciences and geological engineering. Each module will consist of a workshop, short course or extended field trip, as approved by the Department. The unit will be completed within two years. Specific modules offered during each academic year will be announced on the department's web site in September or, in exceptional circumstances, as opportunities arise. Modules taken for GEOL 851 are not eligible. Staff.

GEOL 843 Problems in Geological Engineering
An investigation of selected geological engineering problems. Staff. Offered on demand.

GEOL 847 Topics in Paleontology
An investigation of selected paleontological problems. Seminar weekly plus a project and a major essay. G.M. Narbonne. Offered on demand.

GEOL 849 Economic Guidelines for Exploration Planning

The course develops those evaluation skills which enable exploration geologists and engineers to translate their technical knowledge and expertise into economic planning criteria. Cost, risk, and return characteristics of mineral exploration; introduction to economic evaluation; cash flow and time value concepts; discounted cash flow methods; mining taxation considerations; sensitivity and risk analysis techniques; exploration economics and strategies; evaluation of exploration projects; exploration planning issues, financial statement analysis. Lectures in the fall term and in December during the intensive course on Economic Guidelines for Mineral Exploration. Fall. M. Doggett.

GEOL 851 Special Topics in Geology & Geological Engineering II
A course unit composed of two modules on topics in the geological sciences and geological engineering. Each module will consist of a workshop, short course or extended field trip, as approved by the Department. The unit will be completed within two years. Specific modules offered during each academic year will be announced on the department's web site in September or, in exceptional circumstances, as opportunities arise. Modules taken for GEOL 841 are not eligible. Staff.

GEOL 853 Methods of Geological Data Analysis
A broad base of digital and analog methods will be used to examine the collection, correction, and analysis of geologic data. Field data collection using GPS and handheld computers will lead to a discussion of field data semantics, Geographic Information Systems technology, and the acquisition and distribution of data across the Internet. Manipulation of air photo and remotely sensed imagery will lead to a discussion of state of the art geologic sensing systems including Radar and Hyperspectral methods. The underlying theme of the labs and assignments will be the application of these techniques to resource and environmental assessment. (Offered jointly with GEOL 463.) Two hours lecture, three hours laboratory; Fall. R.M. Harrap.

GEOL 859 Advanced Applied Geophysics
This course emphasizes theory and practise of advanced applied geophysical methods and the applications in engineering and science. Design of geophysical surveys considering the intrinsic limitations and sources of uncertainty.
Prerequisites: GEOE 319 or permission of the instructor.

GEOL 862 Resources and Sustainability
This course addresses the role of mineral exploration and mining industries in providing wellbeing for people and ecosystems; includes discussions of the global distribution of, and demand for, water, energy and mineral resources, and the major geological, technological, economic, environmental, social and governance issues. It culminates with the design of solutions based on sustainable management. 3 hours, 1 hour tutorial: including lectures, panel discussions and seminars. Winter. G.R. Olivo.

GEOL 866 Isotopes and the Environment
A course for advanced students in the fields of biology, chemistry, geography or geology in the principles of stable isotope and radiogenic isotope systematics in natural processes. Emphasis will be placed on the use of isotopes

in tracing elemental cycles, biological cycles and hydrologic cycles and how some isotopes can be used to place constraints on the timing of specific events within these cycles. (Offered jointly with GEOL 466.) Three hours lecture, two hours laboratory;
PREREQUISITE: CHEM 112 (or equivalent), or permission of instructor.

GEOL 873 Applied Numerical Analysis for Rock Engineering
Course focuses on a comprehensive suite of numerical analysis techniques suited to geotechnical design of rock structures and analysis of rockmass stability in natural and engineered settings. Finite element, finite difference, discrete/distinct element and boundary element methods are all discussed with hands-on application workshops using state-of-the-art geomechanics software. Analytical models and pre- and post- processing techniques suited to typical rock engineering problems are developed through assignments. Strength criteria and non-linear inelastic constitutive models for continuum plasticity, brittle fracture and discontinuum deformation are explored in detail. Projects involving real case histories are undertaken to highlight the application of and engineering judgment associated with numerical analysis for problems involving rockmasses. 2 hours lecture, 2 hours lab; Winter. M.S. Diederichs.

GEOL 875 Exploration and Environmental Geochemistry

Principles of rock-water interaction and element migration in the near surface environment applied to environmental and exploration geochemistry. Students learn field and analytical techniques, evaluate and interpret geochemical data, and design solutions related to geochemical hazards to human health, environmental impacts of mining, and formulation of strategies for detecting mineral deposits. Field trip fee: $50
PREREQUISITE: Permission of the instructor
EXCLUSION: GEOL 475, GEOL 865 and GEOL 885

GEOL 878 Terrigenous Clastic Sedimentology
Detailed examination of depositional processes and external controls on the facies organization and sequence stratigraphy of fluvial, coastal, shelf and deep-marine environments. Introduction to sedimentary basin types. Required extended field trip during term. Three hours lecture, three hours lab; Fall. R.W. Dalrymple.
PREREQUISITE: GEOL 238 or permission of the instructor.

GEOL 879 Satellite Geophysics and Applications
Theory and application of observing geophysical fields from space-borne platforms. Orbital mechanics, signal propagation, uncertainty will be addressed. Current missions including radar and laser altimetry, gravimetry and magnetometry, and synthetic aperture radar. Applications in science and engineering (site investigation, geodynamics, ocean and ice, natural resources) through student projects.

GEOL 882 Petrogenesis of Carbonate Rocks
The alteration of carbonate sediments in different diagenetic environments leading to the formation of limestone and dolomite. Topics addressed will include biological and chemical modification, cementation, neomorphism, porosity evolution and karst. Emphasis to be on rock-water interactions as revealed through petrography as well as trace element and isotope geochemistry. Three hours; seminars, selected lectures and laboratories; Fall. N. James.
PREREQUISITE: GEOL 368 or permission of instructor.

GEOL 883 Carbonate Facies Dynamics
Principles of carbonate facies models as derived from modern environments and ancient successions. Assessment of current trends in modelling and the temporal response of carbonate systems to intrinsic and extrinsic controls. Three hours, seminar; fall. N. James.
PREREQUISITE: GEOL 368 or permission of instructor.

GEOL 884 Satellite Positioning
Principles and applications of space-based systems for geo-spatial data acquisition with particular focus on Global Navigation Satellite Systems and Geodetic Satellite Missions. Applications for small to mid-scale engineering problems and larger scale Earth monitoring systems. PREREQUISITE: Permission of the instructor.

GEOL 888 Geological Evolution of North America
An advanced course discussing the principles of earth evolution as exemplified by North America. The holistic approach illustrates the way in which geodynamics, geochemistry, sedimentation, paleo-biology and oceanography are used to unravel the history of the continent. (Offered jointly with GEOL 488.) Three hours lecture; five day field trip; Fall. N. James, and R. Harrap.
PREREQUISITE: A geology core program or permission of the instructor.

GEOL 889 Exploration Seismology
Theory of elastic waves and seismic processing methods. Application of seismic reflection and refraction methods to oil and gas exploration. Hands-on experience in seismic data processing using leading-edge software systems.
PREREQUISITE: Permission of the instructor.

GEOL 898 Master's Project (Non-Research)

GEOL 899 Master's Thesis Research

GEOL 978 Topics in Clastic Sedimentology
An investigation of selected problems related to sediment transport and deposition, environmental dynamics, external

controls on sedimentation, and sequence stratigraphy of clastic sediments. Seminar weekly. R.W. Dalrymple. Offered on demand.

GEOL 999 Ph.D. Thesis Research