Introduction

Thank you for your interest in graduate degree programs in the Department of Earth and Atmospheric Sciences at the University of Alberta.

We hope that this brochure and our web site www.ualberta.ca/eas will provide you with information to help you to make a decision about submitting an application. Specific questions can be sent by mail, telephone, fax, or electronic mail to:

Graduate Program Administrator
Department of Earth and Atmospheric Sciences
1-26 Earth Sciences Building, University of Alberta
Edmonton, Alberta T6G 2E3 Canada
Telephone: (780) 492-3329
Fax: (780) 492-2030
E-mail: ***EAS.Inquiries@ualberta.ca***

The Department of Earth and Atmospheric Sciences (EAS)

The Department of Earth and Atmospheric Sciences (EAS) at the University of Alberta has an international reputation for leading edge research and dynamic PhD, MSc, and MA programs. The Department was created in 1995 by the merger of the former departments of Geography (established in 1957) and Geology (established in 1912).

Research and degree programs include topics in geology, paleontology, human geography, atmospheric sciences, and environmental Earth sciences. With outstanding technical support staff, and laboratory and field research facilities, the Department offers wide opportunity for cross-disciplinary research.

There are currently 55 full-time faculty academic staff and 32 support staff in the Department, and 9 adjunct professors. The full-time academic staff members are funded by more than $2 million dollars in research grants and contracts annually. More than 135 hundred graduate students are enrolled in research degree programs leading to the PhD, MSc or MA. Approximately 40 per cent of these students are supported from major scholarships, and most of the rest from Teaching Assistantships.

The Executive of the Department includes the Chair, ***Dr. Robert Creaser (Acting Chair)***, and three Associate Chairs, ***Dr. Thomas Chacko,*** who has responsibility for graduate student affairs, ***Dr Murray Gingras***, for undergraduate student affairs, and ***Dr. Benoit Rivard***, who interacts with faculty and research units regarding funding opportunities and research programs. The Executive also includes an Assistant Chair (Administration), ***Mary-Jane Turnell***.

In addition to formal courses and programs, the Department has an active informal academic and social life. Faculty and students regularly take part in regional, national, and international conferences, and there is a weekly talk series featuring our own staff and graduate students as well as national and international visitors.

Areas of Research Specialization

Arctic environments
Atmosphere & ocean modelling
Biogeography
Economic geology
Engineering geology
Environmental geology
Experimental petrology
Fluvial geomorphology
Geochemistry
Geochronology
Geographic information systems
Geoprocessing
Geotectonics
Glacial geomorphology
Glaciology
Glacier hydrology
Human/environment interactions
Hydrogeology
Ichnology
Igneous, sedimentary, & metamorphic petrology
Invertebrate & vertebrate paleontology
Isotope geology
Location-allocation analysis
Marine icing
Medical geography
Meso-scale meteorology
Metalliferous mineral deposits
Microclimatology
Micrometeorology
Mineralogy
Periglacial geomorphology
Petroleum geology
Quaternary geology and geomorphology
Recreation & leisure studies
Remote sensing
Sedimentology (carbonate and clastic)
Stratigraphy
Structural geology

Academic Staff

All professors teach one or more courses related to their expertise. Fields of research in the Department are matched by those of the individual professors.

Many academic staff (including full-time professors, professor emeriti, adjunct professors, visiting professors, sessional lecturers, and research staff) have a number of related fields of interest and expertise. Graduate students are encouraged to interact with other academic staff members in addition to their immediate thesis supervisors.

The current full-time academic staff and their research interests are listed below. Additional detail about Earth and Atmospheric Sciences research interests can be found on our web page located at http://easweb.eas.ualberta.ca/page/62.

Graduate Program Administration

The Department oversees the supervision of graduate students enrolled in degree programs and serves as liaison with the Faculty of Graduate Studies and Research (FGSR). It is responsible for ensuring that the student receives proper guidance and support, and that all regulations and requirements of the FGSR are met.

The Department keeps the FGSR informed of progress and changes relating to the student's program, such as the appointment of a supervisor and supervisory committee, change of status after candidacy, course and program changes, scheduling of examination dates, etc.

Graduate-related issues in the Department of Earth and Atmospheric Sciences are administered by the Associate Chair (Graduate), Dr. Thomas Chacko (Thomas.chacko@ualberta.ca) with

assistance from the Graduate Program Administrator, René Gobeil (gobeil@ualberta.ca), the Assistant Chair, and the Graduate Program Committee.

Prospective applicants are encouraged to contact faculty whose research interest most coincides with their own to discuss a possible research project.

Academic Staff and Areas of Research

Agrawal, Sandeep	Land use planning and design, international planning, multiculturalism human rights and planning policy
Amrhein, Carl	Location decision theory, migration, economic geography, modelling, urban population health, Geographic Information Systems.
Bush, Andrew	Numerical modelling of atmospheres and oceans, paleoclimate modelling, glaciation simulation.
Caldwell, Michael	Evolutionary history, relationships and biogeography of fossil and living reptiles
Catuneanu, Octavian	Clastic sedimentology, facies analysis, interpretation of paleodepositional environments, sequence stratigraphic correlation and basin analysis.
Chacko, Thomas	Metamorphic petrology, granites, application of stable isotopes to petrology, experimental petrology
Collins, Damian	urban geography, suburbanization, health and risk, transport, Australasia
Creaser, Robert	Isotope geochemistry, precambrian geology, granite petrogenesis, crustal evolution
Deacon, Leith	Planning, environmental justice, environmental assessment and sustainability
Froese, Duane	Beringia, paleoclimatology, tephrochronology, history of permafrost in northwestern Northwestern North America, geomorphology and fluvial geomorphology, sedimentology.
Gamon, John	"breathing of the Earth," ecosystem processes, biodiversity, plant ecophysiology, disturbance and climate change, remote sensing, ecoinformatics and cyberinfrastructure
Garvin, Theresa	Environment and health; women and health; policy studies; social studies of science; qualitative research methods
Gingras, Murray	Ichnology, neoichnology, sedimentology, stratigraphy, facies models, petroleum geology, marginal marine, biology and environmental concerns

Gleeson, Sarah	Economic geology, hydrothermal geochemistry, water/rock interactions
Harris, Nicholas	Sedimentology and sedimentary geochemistry, Petroleum geology, Hydrocarbon Source Rocks, Tight gas sand reservoirs
Heaman, Larry	Isotope geology, geochronology, geochemistry, continental reconstructions
Herd, Christopher	Mineralogy, igneous and experimental petrology, petrogenesis of meteorites from Mars
Jones, Brian	Carbonate sedimentology, carbonate diagenesis, biostratigraphy, brachiopods, computer applications
Kavanaugh, Jeff	Glacier mechanics, mechanics of unconsolidated materials, subglacial and groundwater hydrology, permafrost and periglacial landscapes, environmental change, glacial response to changing climate, ice core paleoclimatology.
Konhauser, Kurt	Microbe-mineral interactions, bioweathering, acid mine drainage, radionuclide mobility, hydrothermal systems, evolution of life on the early Earth, origins of banded iron formations
Leighton, Lindsey	Marine invertebrate paleobiology and ecology, with special emphasis on biotic interactions (predation, competition), community dynamics, functional morphology & biomechanics, and extinction survivorship. Organisms of interest: Brachiopoda, Gastropoda, Bivalvia.
Luth, Robert	Igneous petrology, high pressure experimental geochemistry; composition, phase equilibria, and evolution of the mantle
Machel, Hans	Petroleum geology, diagenesis, sedimentary petrology and geochemistry
McGee, Tara	Public and stakeholder responses to hazards/risks; preparedness; social impacts; public participation; environmental values, attitudes and behaviors; qualitative research methods
Mendoza, Carl	Contaminant hydrogeology, numerical modelling of groundwater flow and transport processes, behavior of organic chemicals in the subsurface
Muehlenbachs, Karlis	Stable isotope geochemistry, oceans, water rock interaction, paleoclimates
Myers, Paul	Physical oceanography, ocean/climate modeling, paleoclimate modeling, numerical model development
Pearson, Graham	Origin of diamonds; genesis and evolution of cratonic mantle keels; the early Earth; radiogenic isotope geochemistry; platinum group element geochemistry and pharmacology
Pemberton, George	Ichnology, Cretaceous stratigraphy, facies analysis
Potter, David	Geophysics; petrophysics, formation evaluation, rock magnetism,

	palaeomagnetism, geophysical fluid dynamics, high pressure (shockwave) mineral physics
Reuter, Gerhard	Mesoscale meteorology, severe storms, cloud modelling, radar meteorology
Reyes, Alberto	Developing stratigraphic, geomorphic, and geochemical records of northern climate change and associated earth system impacts
Richards, Jeremy	Economic geology, origin of metalliferous mineral deposits
Rivard, Benoit	Geoprocessing; combined optical and radar airborne and satellite remote sensing for geologic mapping and environmental monitoring; infrared characterization of terrestrial materials
Rostron, Benjamin	Petroleum hydrogeology, regional groundwater flow, hydrocarbon migration, numerical modelling
Sanchez-Azofeifa, Arturo	Geographic information systems, remote sensing, ecology, biological land use change, hydrology/water resources
Sharp, Martin	Glaciology, glacial hydrology, glacier hydrochemistry; Canadian Arctic
Shirgaokar, Manish	Travel behaviour, auto mobility, land-use planning, developing countries, urban design
Stachel, Thomas	Diamonds (physical and chemical characteristics, syngenetic inclusions), calcanology, igneous and mantle petrology
Sutherland, Bruce	Experimental and theoretical atmosphere-ocean dynamics, internal gravity waves, gravity currents, plumes
Waldron, John	Structural geology, evolution of deformed sedimentary basins.
Wilson, John	Calculating winds (forests, windbreaks, hills) and particle trajectories in turbulent flow
Unsworth, Martyn	Geophysics: magnetotellurics, tectonics, environmental geophysics, continental dynamics
Zonneveld, John-Paul	Sedimentology, Cenozoic stratigraphy, Mesozoic stratigraphy, paleoecology, ichnology and petroleum geology.

Departmental Facilities

The Department houses a wide array of state-of-the-art laboratory, field, computing and other facilities for research. More than twenty technical and professional support personnel provide a wide range of services to faculty and graduate students.

Analytical equipment and facilities include a scanning electron microscope, electron microprobe,

powder X-ray diffraction analyzer, solid source-, gas source- and thermal ionization mass spectrometers, spectral and thermal reflectance portable spectrographs, ion chromatographs, X-ray Sedigraph, total organic carbon analyzer, high-pressure and high-temperature experimental apparatuses, and advanced rock cutting/thin section facilities.
There are two Class 100 Clean laboratories, and a cold room.

Environmental field equipment includes ground and ice penetrating radar systems, GPS and total station surveying systems, ice coring drill, borehole inclinometer, field portable gamma spectrometer and fluorometer, dataloggers and sensors for measurement of microclimatic, meteorological, hydrologica,l and hydrochemical data, and vibracoring/percussion systems for lake sediment coring.

Unix and PC-based computing systems, housed in 4 research and teaching laboratories, support ERDAS Imagine, PCI, and ENVI image processing software, and ARCINFO and ARCVIEW GIS software, along with large format facilities for scanning, digitizing, colour printing, and photogrammetry.

The Radiogenic Isotope Facility is comprised of three separate laboratories: an ultra clean lab for U-Pb geochronology studies, an ultra clean lab for tracer isotope studies (Sr, Nd, Pb, Os), as well as a mass spectrometry lab housing three thermal ionization mass spectrometers.

The CM Scarfe Laboratory of Experimental Petrology operates high temperature- and high pressure experimental apparatus to simulate conditions in Earth's lower crust and mantle.

The Earth Observation Systems Laboratory (EOSL) houses a 2,500 Gb image/GIS web server providing wide capacity for satellite image processing and analysis.

The Global Climate Modeling Laboratory operates a SGI Origin 2000 computer offering an effective memory throughway for large computations.

The De Beers Laboratory for Diamond Research houses an infrared spectrometer to analyze the composition and growth patterns of single diamonds.

Specialized library facilities are available in the William C. Wonders Map Collection and the Canadian Circumpolar Institute. Special specimen collections within the Department include the University of Alberta Meteorite Collection, the Biostratigraphic Reference Collection, the EAS Mineralogy Collection, the Lithostratigraphic Reference Collection, Modern Shell Collection, EAS Petrology Collection, Paleontological Museum and the University of Alberta Laboratory for Vertebrate Paleontology, Invertebrate Paleontology Collection, and the Teaching Collections for undergraduate training.

Graduate Degree Programs

The Department offers three graduate degree programs: MA, MSc, and PhD in Earth and Atmospheric Sciences.

The Master's Degree (MA and MSc)

A master's program allows a student to improve their knowledge of a specialized area of Earth or atmospheric science, and to complete a research project of restricted scope under supervision. The program provides experience in planning, performing, and reporting research at an advanced level.

MA and MSc Program Requirements (thesis)

A student is admitted into the master's program once a faculty member agrees to act as supervisor. The MA and MSc include course work and research leading to a single-authored, original thesis.

The amount of course work depends on the match between the student's undergraduate training and the master's degree research area. A minimum of three single-term (*3) University of Alberta courses are required. No more than two courses (*6) can be taken from the same instructor. Additional courses may be necessary if there is a change from the undergraduate discipline to the graduate program. Students may not take more than one 400-level course and one cross-listed graduate course, or two cross-listed graduate course toward their degree requirements. Exceptions are considered by the Associate Chair. Only one (*3) research or reading (directed study) course is counted towards the requirement, unless otherwise approved.

MSc (course-based Integrated Petroleum Geosciences)

Petroleum exploration and production is increasingly multi-disciplinary in nature. A collaborative approach among geophysicists, geologists and petroleum engineers is critical during exploration, field development and resource exploitation. This program is offered jointly by the Department of Earth and Atmospheric Sciences and the Department of Physics with the home department and administration in Earth and Atmospheric Sciences. The course-based MSc is a one full year program which has a start date in September of each year only. The Department does not guarantee financial support. This program has a limited amount of scholarships. You may not transfer to the thesis-based MSc or PhD without first completing the IPG program. Progression into the winter term is contingent on attainment of a satisfactory GPA (2.7 as defined by FGSR) at the end of the Fall term. Transfer credit will not be allowed for any course that has been credited towards another degree. Other requests will be considered on a case-by-case basis.

Students must take 8 (*3) core courses and 4 (*3) optional courses. The optional courses will be offered by the Department of Earth and Atmospheric Sciences and the Department of Physics. The optional courses will be decided by discussion between the applicant and the Director of the IPG program. The program requires a minimum of *36 (12 *3 single-term courses or equivalent), that includes the following: Eight core courses (*3) and four optional courses (*3). In addition, all students must complete the mandatory EAS Research Skills and Ethics training module.

The PhD Degree

A PhD program involves the independent planning, execution, and reporting of research at a professional level.

At least six single-term (*3) courses beyond the undergraduate level are required. At least three (total of *9 weight) must be taken at the University of Alberta. Not more than two (*6) may be taken from the same instructor. Not more than one 400-level course and two cross-listed graduate courses, or three cross-listed graduate courses are allowed. Except with the permission of the Department, only one (*3) research or reading course may be taken.

To ensure that a student has the necessary knowledge, background, and ability to complete a PhD thesis, a candidacy examination is taken within 20 months of admission (upgrades from a MSc degree may be allowed extra time with permission; up to 24 months).

Graduate Courses

Lecture and Seminar Courses

A complete list of graduate (500-level) Earth and Atmospheric Sciences courses appears below, together with a list of undergraduate (400-level) courses available for graduate credit. The Department cannot guarantee that a course will be offered in a given year. Every effort is made, however, to provide a comprehensive array of graduate courses each academic year.

Reading and Research Courses

As well as formal lecture and seminar courses, reading and research (individual study) courses are available to graduate students. A reading course provides the opportunity for extended reading and critical discussion in a specialized area. A research course provides the opportunity for directed library, laboratory, or field research on a limited topic or problem.

Application and Admissions

Application Fee

An application fee is required to apply ($100.00).

Entrance Requirements

The minimum admission GPA requirement for graduate studies is 3.0/4.0 in the last two years (or 60 credits) of undergraduate or graduate study at the University of Alberta, or an equivalent qualification from another institution (http://www.gradstudies.ualberta.ca/applyadmission/reqintlcountries.htm)

Evidence of proficiency in the English language is required where applicable (see below, "English Language Requirement").

Application Materials

A complete application consists of the following:

- Application form
- Official transcript(s); in English *and* the language of origin (if not English)
- Degree certificate(s); in English and the language of origin (if not English)
- Three letters of reference from professors
- A brief statement of your research interests if applying to the thesis programs and an outline of what you would like to study. Applicants are encouraged to contact individual professors ahead of time.
- Proof of proficiency in the English language (if required; see below)

On-Line Application Form

On-line application forms for Canadian and International applicants are available at http://www.gradstudies.ualberta.ca/apply/index.htm. The process will prompt you for payment (Visa or MasterCard accepted).

Evaluation of Applications

With the input of at least one potential supervisor, and one or two other professors in the applicant's field, applications are evaluated by the department's Graduate Program Committee (GPC) for admission and funding. Four main considerations guide the evaluation:

- Academic merit
- Departmental teaching assistantship needs
- Ability of the potential supervisor to fund the proposed project; and
- Distribution of assistantships among research areas within the Department.

Upon admission, students are assigned to a supervisor. An applicant will not be recommended for admission if there is no faculty member willing or available to supervise the proposed program.

Deadlines

The deadline for receiving Applications for Graduate Admission at the Faculty of Graduate Studies and Research for the Fall Term of an academic year is June 1**;** all applications received up to this date will be considered. Be advised, however, that applications submitted well before this deadline are the ones with the best chances of success, as the process is competitive: **December to February** is the prime period for making an application, *and early applicants are given first consideration*.

Students applying from outside Canada are advised to allow ample time for a student visa from the Canadian Government (Employment and Immigration Canada). An early application is also recommended if an assistantship is desired (TA). Applications received by **February 1** are given first consideration.

- The deadline for September admission is March 1
- The deadline for January admission is October 1

Financial Support and Graduate Assistantships

Fellowships, Scholarships and Bursaries

Fellowships, scholarships, and bursaries for full-time graduate students come from national, provincial, university, and other funding sources. Recipients of major awards may be given additional funding in the form of a one-half teaching assistantship during tenure of the award.

Major awards currently available are:

- NSERC scholarship (MSc and PhD)
- Province of Alberta Graduate Scholarship (MA and MSc)
- Andrew Stewart Memorial Graduate Prize (MSc and PhD)
- SSHRC scholarship (PhD)
- Province of Alberta Graduate Fellowship (PhD)
- Izaak Walton Killam Memorial Scholarship (PhD)
- Dissertation Fellowship (PhD)
- Vanier (PhD)

Most other fellowships, scholarships, and research grants are not "major awards" for the purpose of departmental funding entitlement. A number of additional awards are made each year in recognition of achievement in specific research areas or other criteria; students are nominated by their supervisor. The Associate Chair forwards the nomination to the appropriate university adjudication committee. Details and application forms are available from the Graduate Program Administrator.

Research Travel Grant

FGSR offers a grant to provide graduate students with the opportunity for travel, to expose their research results to peer review, test ideas with outside experts, etc. The grant supports attendance at a major national or international meeting where the student is presenting a paper or poster, or formally participating in a panel. The application is available on line from FGSR at http://gradfile.fgsro.ualberta.ca/awardsfunding/scholarships/uofaawards/index.htm.

TA and RA: Graduate Assistantships (Teaching and Research)

Purpose of assistantships

A graduate assistant is a registered student in a graduate program who is paid to carry out teaching or research duties. The purpose of assistantships is:

- To assist the Department in its teaching and research responsibilities; and
- To provide training to graduate students through experience in teaching or research.

A full teaching assistantship carries teaching-related duties of twelve hours per week for a 4-month term. TAs are normally held for the eight-month teaching year, September 1 to April 30.

The salary amounts are adjusted regularly following contract negotiations with the university's Graduate Students Association (GSA).

Please note that an offer of admission into a degree program does not automatically carry with it an offer of financial assistance. Decisions regarding the allocation of assistantships are based on the same criteria as admission decisions.

Third-Term (Research) Assistantships

Students admitted with an offer of a Graduate Teaching Assistantship will receive intersession (May-August) summer support as follows:

Master's Students: $4500 per summer for the first and second summer of their program.

Doctoral Students: $5000 per summer for the first through fourth summers of their program.

In the event that a student declines one or more summers of support (for instance to take paid employment), the Department will not extend the period of support beyond that outlined above.

Additional Assistance

Additional funds may be available from various agencies in connection with faculty research projects. Students should contact individual faculty members.

Students coming from countries outside North America should investigate funding sources in their home country; a number of national cultural exchange programs provide financial support to students. Contacts with the Canadian Embassy and your own Ministry or Department of Education can reveal potential sources of other financial support. Please be aware that many sources of financial aid are available only to students who have permanent resident status in Canada. .

Tuition and Fees

Detailed information about tuition and fees are available online:

Canadian Students:
http://www.gradstudies.ualberta.ca/regfees/fees/Fall%20Winter%20Fees/canadianThesisBased.aspx

International Students:
http://www.gradstudies.ualberta.ca/regfees/fees/Fall%20Winter%20Fees/internationalThesisBased.aspx

Please be aware that international students are assessed a 100% student differential fee.

English Language Requirement

Since English is the primary language of instruction and communication at the U of A, all applicants must be proficient in English prior to admission.

Note: Applicants from certain countries and international universities are exempt from the English language requirements. See our exemptions list.

Proficiency is demonstrated by:

- possession of a degree or its academic equivalent from an institution recognized by the University of Alberta and where the language of instruction is English. Proof that the instruction for the degree was in English will be required; or
- a satisfactory score on one of the following approved English language examinations

Test of English as a Foreign Language (TOEFL)	minimum score of 550 (paper-based), 213 (computer-based), or a total score of 88 with a score of at least 20 on each of the individual skill areas (internet-based)
Michigan English Language Assessment Battery (MELAB)	minimum score of 85
International English Language Testing System (IELTS)	minimum overall band score of 6.5, with at least 5 on each band
Canadian Academic English Language Assessment (CAEL)	overall minimum score of 60, with at least 60 on each subtest

Note: These are minimum scores required by the Faculty of Graduate Studies and Research. Some departments require higher scores.

If you need to complete one of these English language examinations, you should do so as soon as possible and arrange for the results to be sent to the department to which you are applying.

For more efficient response time, applicants should arrange for their English language test results to be sent directly to the Department of Earth and Atmospheric Sciences.

Information for International Students

International students who have been accepted by the Department are strongly advised to contact their nearest Canadian Consulate. This should be done as soon as possible following acceptance by the Department and no later than the end of May.

Detailed information for international students is available from the International Centre www.international.ualberta.ca .

Accommodation

Information about accommodation on campus is available from the University's Housing and Food Services web page at http://www.hfs.ualberta.ca/student/studenthousing.html and the Student's Union Web page **http://www.su.ualberta.ca/**

Keep in mind that although accommodation is available on campus, space goes quickly. Arrangements should be reserved in advance of your arrival on campus.

There are apartments for rent in HUB, an on-campus residence and retail complex close to the Department of Earth and Atmospheric Sciences. To obtain details of rates, facilities, and applications, write to: HUB General Office, 8909 - 112 Street, Edmonton, Alberta T6G 2C5.

For those who want to live off-campus, there are many options. Houses, apartments, basement suites and rooms near the university are all available for rent

Courses

Undergraduate Courses Available to Graduate Students

Earth and Atmospheric Sciences

EAS 421 Structural Geology and Tectonics
*3 *(fi 6)* (either term, 3-0-3). Geometric, kinematic, and dynamic analysis of structures produced by deformation. Stress and the origin of faults, joints, veins, folds, and tectonites. Brittle and ductile strain in rocks. Extensional, strike-slip, and compressional structural associations. Regional structure, orogens, and crustal tectonics. Lab exercises include structural interpretation for subsurface hydrocarbon and mineral exploration, stereographic techniques for structural analysis, and the study of rock fabrics. Prerequisites: EAS 233 and any 300-level EAS course. Not available to students with credit in EAS 321.

EAS 425 Contaminant Hydrogeology
*3 *(fi 6)* (either term, 3-0-3). An introduction to the principles of groundwater chemistry, the chemical evolution of natural groundwater flow systems, sources of contamination, and mass transport processes. Hydrogeologic aspects of waste disposal and groundwater remediation. Prerequisite: EAS 323.

EAS 430 Petroleum Geology
*3 *(fi 6)* (either term, 3-0-3). Origin, maturation, and degradation of petroleum; conventional and unconventional source rocks; principles of migration; reservoir rocks; traps. Exploration and development of hydrocarbon plays using seismic, core and wire line logging, thin section petrography, correlation, mapping, and geochemistry. Prerequisites: EAS 236 or 336.

EAS 432 Precambrian Geology
*3 *(fi 6)* (either term, 3-0-0). Precambrian geological evolution of Earth focusing on development of the continental lithosphere. Geochemical evolution of the crust and mantle as well as the atmosphere and hydrosphere. Special reference to the evolution, stratigraphy, petrology and geochronology of the Canadian Shield. Prerequisite: EAS 320 and 331

EAS 451 Digital Remote Sensing
*3 *(fi 6)* (either term, 3-0-3). This course introduces the interactions of electromagnetic radiation with terrestrial materials (rocks, soils, water, snow). These notions are fundamental for the interpretation of optical, thermal, and radar remote sensing imagery. Labs focus on image processing with emphasis on radiometric and geometric enhancements and image classification. The course covers existing and upcoming sensors and applications of the data to earth sciences including geologic and land use mapping and resource exploration. Prerequisite: EAS 221.

EAS 457 Global Change
*3 *(fi 6)* (either term, 3-0-0). Major processes of change in the contemporary environment, their history and their interrelationships (climate and sea level change, changes in atmospheric composition, deforestation, desertification, water resource depletion, soil erosion, atmospheric and aquatic pollution); global

biogeochemical cycles and their role in environmental change. Prerequisite: One of EAS 208, 225 or 250.

EAS 458 Cold Regions Geoscience
*3 *(fi 6)* (either term, 3-0-0). Environments and environmental change associated with high latitude and high elevation regions. Topics vary: see http://www.eas.ualberta.ca/eas458 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Arctic environments; (2) Alpine environments; (3) Antarctica. Prerequisite: EAS 225 or 250 or consent of the instructor.

EAS 460 Geobiology
*3 *(fi 6)* (either term, 3-0-3). The relationship between biology and geology. Ichnology, geomicrobiology, and microfossil content. The evolution of animal-rock relationships through time. Topics vary: see www.eas.ualberta.ca/eas460 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Ichnology; (2) Geomicrobiology; (3) Micropaleontology. Prerequisite: EAS 336.

EAS 462 Stratigraphy and Sedimentary Basins
*3 *(fi 6)* (either term, 3-0-3). The science of rock strata in a sequence stratigraphic gramework; sequence stratigraphic models; classification and evolution of sedimentary basins; applications of sequence stratigraphy to depositional systems and tectonic settings. Prerequisite EAS 336. Not available to students with credit in EAS 330.

EAS 464 Applied Hydrocarbon Geoscience
*3 *(fi 6)* (either term, 3-0-3). Advanced topics in the characterization of petroleum resources and the regional occurrence of hydrocarbons. Topics vary: see http://www.eas.ualberta.ca/eas464 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Regional and Petroleum Hydrogeology; (2) Petroleum Systems. Prerequisite: EAS 430 or consent of the instructor.

EAS 465 Sedimentology
*3 *(fi 6)* (either term, 3-0-0). The science of sedimentary rocks, focusing on the interpretation of sedimentary strata. Topics vary: see http://www.eas.ualberta.ca/eas465 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Carbonate Sedimentology and Diagenesis; (2) Clastic Sedimentology. Prerequisite: EAS 336.

EAS 466 Petrogenesis
*3 *(fi 6)* (either term, 3-0-3). Origin and formation of igneous and metamorphic rocks in the light of field, mineralogical, chemical and experimental evidence. Topics vary: see http://www.eas.ualberta.ca/eas466 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Cratons, Kimberlites and Diamonds; (2) Petrology of Subduction Processes. Prerequisites: EAS 331 and EAS 332, which may be taken concurrently with permission of the instructor.

EAS 467 Planetary Geology
*3 *(fi 6)* (either term, 3-0-3). The geologically evolving Earth and its context in an evolving solar system. Topics vary: see http://www.eas.ualberta.ca/eas467 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Planetary Systems; (2) Earth System Evolution (Not available to students with credit in EAS 435). Prerequisites: EAS 331 and EAS 332.

EAS 468 Geochemical Processes
*3 *(fi 6)* (either term, 3-0-3). Application of geochemistry to Earth materials and geological settings. Topics vary: see http://www.eas.ualberta.ca/eas468 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Geochemistry of Ore Deposits; (2) Environmental Geochemistry (Not available to students with credit in EAS 420). Prerequisite: EAS 320 or consent of instructor.

EAS 470 Clouds and Storms
*3 *(fi 6)* (either term, 3-0-0). Cloud properties; formation and growth of cloud droplets and ice crystals, rain and snow; weather radar; Doppler radar analysis; precipitation processes; severe convective storms, weather modification; numerical cloud models; Precipitation forecasting. Prerequisites: EAS 370 and 371.

EAS 471 Atmospheric Modelling
*3 *(fi 6)* (either term, 3-0-3). Dynamics and physics of general circulation models. Numerical Weather Prediction models, ocean models, limited area models. Finite difference methods; spectral methods, and numerical stability. Prerequisites: EAS 371, 373 and MATH 215.

EAS 475 Physical Oceanography
*3 *(fi 6)* (either term, 3-2s-0). Synoptic-scale processes; the general circulation; turbulence; oceanic mixing; wind-driven circulation; waves in the atmosphere and ocean; baroclinic instability; tides. Prerequisites: EAS 212 and 371 or consent of instructor.

Human Geography

HGP 443 Environment and Health
*3 (fi 6) (either term, 3-0-0). An examination of relations between human health and environmental issues, particularly those related to the natural, built, and social environments. Prerequisite: EAS 395 or HGP 343 or consent of Instructor. Not available to students with credit in EAS 494.

HGP 450 Resource Management and Environmental Policy
*3 (fi 6) (either term, 3-0-0). Roles of governmental and nongovernmental organizations, industry and private enterprise, and advocacy organizations in addressing issues of resource scarcity and environmental policy. Institutions, policies, and strategies for resource and environmental management at the provincial/state, national, and international levels. Prerequisites: EAS 294 or HGP 250. Not available to students with credit in EAS 491.

HGP 452 Human Dimensions of Environmental Change
*3 (fi 6) (either term, 3-0-0). Examination of the human dimensions of climate change. Topics include climate change politics, public perceptions and impacts, vulnerability and resilience, mitigation and adaptation. Classes concurrent with HGP 552. Prerequisite: Any 300-level EAS or HGP course or Consent of Instructor. Not available to students with credit in EAS 493.

HGP 470 Geographical Information Systems and Advanced Cartography for Social Science
*3 (fi 6) (either term, 2-0-1). The application of spatial analytic tools to social science topics. Assignments impart technical aspects through hands-on experience with commercial and in-house spatial analysis software. Prerequisite: EAS 221. Not available to students with credit in EAS 492.

HGP 481 Advanced Topics in Human Geography
*3 (fi 6) (either term, 3-0-0). Prerequisite: EAS 192 or HGP 100, and any one EAS 29X or HGP 2XX course. Topics vary; may be taken more than once for credit provided no topic is repeated. Students cannot repeat topics that have been taken previously in EAS 495.

HGP 485 Advanced Topics in Planning
*3 (fi 6) (either term, 3-0-0). Exploring planning theories in the context of contemporary events phenomena. Prerequisite: HGP 310. Variable content course which may be repeated if topics vary.

Paleontology

PALEO 412 Selected Topics in Paleontology
*3 (fi 6) (variable, 3-0-0). Covers specialized topics of current interest to advanced undergraduates in Biological Sciences and Earth and Atmospheric Sciences. Consult the Paleontology advisor for details about current offerings. Prerequisite: Consent of Instructor. Credit for this course may be obtained more than once.

PALEO 414 Paleontology
*3 *(fi 6)* (second term, 3-0-3). Morphology, paleoecology and evolution, with emphasis on both the theoretical aspects and practical techniques of paleontology. Concentration on invertebrate paleontology, but examples from vertebrate paleontology and paleobotany included. Prerequisite: EAS 230.

PALEO 418 Paleobiology of the Lower Vertebrates
*3 (fi 6) (first term, 3-0-3). Paleontology, evolution and paleoecology of early vertebrates, fishes, and amphibians, with emphasis on osteology, systematics, major adaptive shifts and subsequent radiations. Prerequisites: ZOOL 325 and any 300 level EAS or Biological Sciences course. Not available to students with credit in PALEO 318.

PALEO 419 Paleobiology of the Higher Vertebrates
*3 (fi 6) (second term, 3-0-3). Paleontology, evolution and paleoecology of Synapsida (e.g. therapsids and mammals) and Reptilia (e.g. snakes, lizards, dinosaurs, and birds) with emphasis on osteology, systematics, major adaptive shifts and subsequent radiations. Prerequisites: ZOOL 325 and any 300 level EAS or Biological Sciences course. Not available to students with credit in PALEO 319.

Graduate Courses

Note: Enrolment in graduate courses is subject to consent by the instructor.

Earth and Atmospheric Sciences Graduate Courses

EAS 520 Reading and Seminar Course
*3 (*fi 6*) (either term, 0-3s-0).

EAS 521 Advanced Structural Geology and Tectonics
*3 *(fi 6)* (either term, 3-0-0). Geometric, kinematic, and dynamic analysis of structures produced by deformation. Stress and the origin of faults, joints, veins, folds, and tectonites. Brittle and ductile strain in rocks. Extensional, strike-slip, and compressional structural associations. Regional structure, orogens, and crustal tectonics. Lab exercises include structural interpretation for subsurface hydrocarbon and mineral exploration, stereographic techniques for structural analysis, and the study of rock fabrics. Classes concurrent with EAS 421.

EAS 523 Advanced Topics in GIS: Dynamics of Land Use/Cover Change
*3 *(fi 6)* (either term, 3-0-0). Advanced treatment of methods and applications in earth observation science. Topics vary: see http://www.eas.ualberta.ca/eas523 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Multi and hyperspectral remote sensing; (2) Radar remote sensing; (3) Image processing and analysis; (4) Monitoring land use and land cover change with GIS.

EAS 524 Paleoecology and Taphonomy
*3 *(fi 6)* (either term, 3-0-0). Ideas and techniques that allow us to use the occurrences and manner of preservation of fossils in sediments to examine ancient environments these organisms lived in, and those that affected their remains after death. Offered in alternate years.

EAS 536 Mineralogy - Petrology - Geochemistry
*3 *(fi 6)* (either term, 3-0-0). Studies in geochemistry, petrology and mineralogy. Topics vary: see http://www.eas.ualberta.ca/eas536 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Seminar; (2) Thermodynamics; (3) Mantle Studies.

EAS 539 Isotope Geology: Radioactive Systems
*3 *(fi 6)* (either term, 3-0-0). Theory and systematics of radioactive decay, geochronology and isotopic tracing U-Pb, Rb-Sr, Sm-Nd, Re-Os and other radioisotope systems. Applications of natural radioactive isotope variation to a variety of problems spanning low and high temperature geologic processes. Offered in alternate years.

EAS 540 Isotope Geology: Stable Isotope
*3 *(fi 6)* (either term, 3-0-0). Theory of light-element isotope fractionation; isotope variations in the meteoric cycle, igneous, metamorphic, sedimentary rocks and ore deposits. Isotope techniques in paleothermometry and paleoclimate studies. Isotope biogeochemistry, oil and gas. Offered in alternate years

EAS 541 Topics in Structural Geology and Tectonics
*3 *(fi 6)* (either term, 3-0-0). Current topics in structural geology and tectonics, from mesoscopic strain and vorticity indicators to orogenic belts; terrain analysis and comparative tectonics, with emphasis on the contribution of North American Phanerozoic orogens to current theory; lectures by instructor, and student research and seminar presentations. Offered in alternate years

EAS 544 Hydrogeology
*3 *(fi 6)* (either term, 3-0-3). The storage and movement of water through Earth media. Topics vary: see http://www.eas.ualberta.ca/eas544 for details. May be taken more than once for credit provided no topic is repeated. Topics include: (1) Quantitative Hydrogeology; (2) Regional Groundwater Flow

EAS 547 Methods and Instrumentation in Geology
*3 *(fi 6)* (either term, 3-0-0). Course will cover analytical techniques such as probe, SEM, XRD, TIMS/gas source mass spectrometry, superpress, XRF, ICP-MS, TEM, NMR, SHRIMP and microthermometric techniques.

EAS 553 Ice Dynamics and Glacier Hydrology
*3 *(fi 6)* (either term, 3-0-0). Introduction to the mechanics and hydrology of ice masses with an emphasis on how they can be modelled and investigated in the field. The management of ice masses as sources of water and energy.

EAS 556 Topics in Geomorphology and Sedimentology
*3 *(fi 6)* (either term, 3-0-0). Selected, contemporary theories of landscape and sediment formation in glacial, glaciofluvial, alluvial, and periglacial environments.

EAS 560 Advanced Geobiology

*3 *(fi 6)* (either term, 3-0-3). The relationship between biology and geology. Ichnology, geomicrobiology, and microfossil content. The evolution of animal-rock relationships through time. Topics vary: see www.eas.ualberta.ca/eas560 for details. May be taken more than once for credit provided no topic in EAS 460 or 560 is repeated. Topics Include: (2) Ichnology; (2) Geomicrobiology; (3) Micropaleontology. Classes concurrent with EAS 460.

EAS 562 Advanced Stratigraphy and Sedimentary Basins

*3 *(fi 6)* (either term, 3-0-3). The science of rock strata in a sequence stratigraphic framework; sequence stratigraphic models; classification and evolution of sedimentary basins; applications of sequence stratigraphy to depositional systems and tectonic settings. Classes concurrent with EAS 462. Not available to students with credit in EAS 333 or 462.

EAS 564 Advanced Applied Hydrocarbon Geoscience

*3 *(fi 6)* (either term, 3-0-3). Advanced topics in the characterization of petroleum resources and the regional occurrence of hydrocarbons. Topics vary: see www.eas.ualberta.ca/eas564 for details. May be taken more than once for credit provided no topic in EAS 464 or 564 is repeated. Topics include: (1) Regional Petroleum Hydrogeology; (2) Petroleum Systems. Classes concurrent with EAS 464.

EAS 565 Advanced Sedimentology

*3 *(fi 6)* (either term, 3-0-0). The science of sedimentary rocks, focusing on the interpretation of sedimentary strata. Topics vary: see www.eas.ualberta.ca/eas565 for details. May be taken more than once for credit provided no topic in EAS 565 or EAS 465 is repeated. Topics include: (1) Carbonate Sedimentology and Diagenesis; (2) Clastic Sedimentology. Classes concurrent with EAS 465.

EAS 566 Advanced Petrogenesis

*3 *(fi 6)* (either term, 3-0-3). Origin and formation of igneous and metamorphic rocks in the light of field, mineralogical, chemical and experimental evidence. Topics vary: see www.eas.ualberta.ca/eas566 for details. May be taken more than once for credit provided no topic in EAS 466 or 566 is repeated. Topics include: (1) Cratons, Kimberlites and Diamonds; (2) Petrology of Subduction Processes. Classes concurrent with EAS 466.

EAS 567 Advanced Planetary Geology

*3 *(fi 6)* (either term, 3-0-3). The geologically evolving Earth and its context in an evolving solar system. Topics vary: see www.eas.ualberta.ca/eas567 for details. May be taken more than once for credit provided no topic in EAS 467 or EAS 567 is repeated. Topics include: (1) Planetary Systems; (2) Earth System Evolution (Not available to students with credit in EAS 435). Classes concurrent with EAS 467.

EAS 568 Advanced Geochemical Processes

*3 *(fi 6)* (either term, 3-0-3). Application of geochemistry to Earth materials and geological settings. Topics vary: see www.eas.ualberta.ca/eas568 for details. May be taken more than once for credit provided no topic in EAS 468 or 568 is repeated. Topics include: (1) Geochemistry of Ore Deposits (Not available to students with credit in EAS 434); (2) Environmental Geochemistry. Classes concurrent with EAS 468.

EAS 570 Advanced Climatology

*3 *(fi 6)* (either term, 3-0-0). A study of recent developments in climatology. Climate models and their use in examining past and future climates. Interactions between the atmosphere and terrestrial systems. Offered in alternate years.

EAS 572 The Atmospheric Boundary Layer
*3 *(fi 6)* (either term, 3-0-0). Dimensional analysis and similarity principles. Resolved ("mean") and unresolved ("fluctuating, turbulent") scales of motion, and the closure problem for the dynamical equations. Similarity theories for wind and turbulence over uniform terrain. Dynamics of disturbed wind flows (hills, forests, clearings, etc.). Turbulent transport and dispersion models. Offered in alternate years.

EAS 583 Advanced Contaminant Hydrogeology
*3 (fi 6) (either term, 3-0-3). An introduction to principles of groundwater chemistry, the chemical evolution of natural groundwater flow systems, sources of contamination, and mass transport processes. Hydrogeologic aspects of waste disposal and groundwater remediation. Research project. Classes concurrent with EAS 425. Not available to students with credit in EAS 425.

EAS 584 Advanced Clouds and Storms
*3 (fi 6) (either term, 3-0-0). Cloud properties; formation and growth of cloud droplets and ice crystals, rain and snow; weather radar; Doppler radar analysis; precipitation processes; severe convective storms; weather modification; numerical cloud models; precipitation forecasting. Research project. Classes concurrent with EAS 470. Not available to students with credit in EAS 470.

EAS 585 Advanced Digital Remote Sensing
*3 (fi 6) (either term, 3-0-3). Introduces the interactions of electromagnetic radiation with terrestrial materials (rocks, soils, water, snow). These notions are fundamental for the interpretation of optical, thermal, and radar remote sensing imagery. Labs focus on image processing with emphasis on radiometric and geometric enhancements and image classification. Covers existing and upcoming sensors and applications of the data to earth sciences including geologic and land use mapping and resource exploration. Prerequisites: EAS 220 and 221. Classes concurrent with EAS 451. Not available to students with credit in EAS 451

EAS 587 Advanced Physical Oceanography
*3 *(fi 6)* (either term, 3-2s-0). Synoptic-scale processes; the general circulation; turbulence; oceanic mixing; wind-driven circulation; waves in the atmosphere and ocean; baroclinic instability; tides. Class concurrent with EAS 475. Not available to students with credit in EAS 475.

Human Geography Graduate Courses

HGP 500 Topics in Human Geography
*3 (fi 6) (either term, 3-0-0). Theory and practice of geographic research at the graduate level. Discussion of major themes and research methods in contemporary human geography. Techniques for the development and enhancement of professional skills.

HGP 543 Advanced Environment and Health
*3 (fi 6) (either term, 3-0-0). An examination of relations between human health and environmental issues, particularly those related to the natural, built, and social environments. Prerequisite: Consent of Instructor. Research project. Classes concurrent with HGP 443. Not available to students with credit in EAS 494, 594 or HGP 443.

HGP 550 Advanced Resource Management and Environmental Policy
*3 (fi 6) (either term, 3-0-0). Roles of governmental and nongovernmental organizations, industry and private enterprise, and advocacy organizations in addressing issues of resource scarcity and environmental policy. Institutions, policies, and strategies for resource and environmental management at the provincial/state, national, and international levels. Prerequisite: Consent of Instructor. Research project. Classes concurrent with HGP 450. Not available to students with credit in EAS 491, 591 or HGP 450.

HGP 552 Advanced Human Dimensions of Global Change
*3 (fi 6) (either term, 3-0-0). Examination of the human dimensions of climate change. Topics include climate change politics, public perceptions and impacts, vulnerability and resilience, mitigation and adaptation. Research project. Classes concurrent with HGP 452. Not available to students with credit in EAS 493, 593 or HGP 452.

HGP 570 Advanced Geographical Information Systems for Social Science
*3 (fi 6) (either term, 2-0-1). Provides spatial analytic tools to social geographers and provides a social science perspective to geoprocessing students. Examples arise from marketing, operations research, sociology, and urban and economic geography. Assignments impart technical aspects through hands-on experience with commercial and in-house spatial analysis software. Prerequisite: Consent of Instructor. Research project. Classes concurrent with HGP 470. Not available to students with credit in EAS 492, 592 or HGP 470.

HGP 581 Advanced Issues in Human Geography
*3 (fi 6) (either term, 3-0-0). Topics vary; may be taken more than once for credit provided no topic is repeated. Classes concurrent with HGP 481.

HGP 599 Advanced Practical Study in Human Geography
*3 (fi 6) (variable, 10 - 15 days). Intensive field or practical study in Human Geography, typically as part of a team working off-campus. Details and areas of study may vary from year to year; consult the department about current offerings, fees and timing. Topics vary; may be taken more than once for credit provided no topic is repeated. Classes concurrent with HGP 499. This course may require the payment of additional fees. Refer to the Fees Payment Guide in the

Paleontology Graduate Courses

PALEO 512 Selected Topics in Paleontology
*****3 *(fi 6)* (either term, 4-2s-0).

PALEO 513 Advanced Paleontology
*3 *(fi 6)* (second term, 3-0-3). Morphology, paleoecology and evolution, with emphasis on both the theoretical aspects and practical techniques of paleontology. Concentration on invertebrate paleontology, but examples from vertebrate paleontology and paleobotany included. Prerequisite: EAS 230. Classes concurrent with PALEO 414. Not available to students with credit in PALEO 414

PALEO 520 Problems in Vertebrate Paleobiology
*3 *(fi 6)* (either term, 0-3s-0). Prerequisites: PALEO 318 and 319.