Clayton H. Riddell, O.C.

Clay Riddell received his B.Sc. Hons. in Geology from the University of Manitoba. He is a long-time supporter of the department and his name-sake faculty. Clay is the founder of Paramount Resources (Calgary) and has had a long and distinguished career in the petroleum industry. He is known as well for his volunteer contributions. In 2004, he received an Honorary D.Sc. from the University of Manitoba.

The Department of Geological Sciences is part of the Clayton H. Riddell Faculty of Environment, Earth, and Resources. The Riddell Faculty provides interdisciplinary and integrated approaches to understanding the Earth, its environment and resources. The Wallace Building, which houses the Department of Geological Sciences, also includes the Centre for Earth Observation Science, the Nellie Cournoyea Arctic Research Facility, and the administrative offices of the Riddell Faculty.

This brochure will introduce you to areas specific to Geological Sciences: our research programs, our staff, and our world-class research facilities. If you are considering graduate studies, you are encouraged to contact potential supervisors who have research programs matching your interests.

In addition to reviewing this brochure, all prospective students are expected to read the information on applicable web-sites:

Faculty of Graduate Studies:
http://umanitoba.ca/faculties/graduate_studies/
Department of Geological Sciences Graduate program pages:
http://umanitoba.ca/faculties/environment/departments/geo_sciences/GraduateProgram.html
Why choose UM Geological Sciences?

- multiple state of the art analytical labs
- all research labs are located in the Wallace Building
- dynamic learning community
- wide range of research possibilities
- recognized worldwide for its research
- provides research and scholarship support for graduate students without external sources of major funding

Wallace Building

- located on a large university campus with a full range of services
- located in Winnipeg, a culturally diverse city
- near the metal-rich Precambrian Shield (to the east)
- near the petroleum-producing Western Canada Sedimentary Basin (to the west)
- located near prime wilderness and recreation areas

Geological Sciences Grad Students 2015

Corydon Street, Winnipeg

Canadian Museum for Human Rights, The Forks
Over 100 years of history

As the oldest geosciences department in western Canada (est. 1910), the Department of Geological Sciences has produced outstanding graduates in industry, universities, and governments, and has developed an international reputation in a number of research areas.

The Department has maintained strong ties with its alumni, who can attest to a sense of identity and community that begins when a student enters the Geology or Geophysics undergraduate program or when a new graduate student steps through the door. The generosity and appreciation of our alumni is reflected in visible features like the Cretaceous Menagerie Museum and the Department’s History Wall (Centenary 2010), and scholarship and bursary support for our students.

A Vibrant Scientific Community

The Department fosters a culture that encourages community. We are large enough to have all the resources, but small enough to allow for personal interaction on a daily basis.

Graduate students are assigned a shared office in the Wallace Building in an area that includes a large lounge, wired and wireless internet and shared printer. Staff offices are a short walk down the hall. Research facilities are conveniently located within the building as well. Your thesis advisor will ensure that you have access to relevant research labs and receive training under the supervision of experienced technical staff.
Our graduate students have opportunities to apply for positions as lab instructors and markers, as teaching assistants at department field schools, and to participate as volunteers in our outreach programs to the general public. PhD students may be offered the opportunity to apply for sessional teaching positions to gain experience for careers in academia.

Field trips occur on a regular basis, organized by undergraduate or graduate student groups or by staff in the Department. Your thesis supervisor will generally provide funding for field work related to conducting your thesis research and will encourage you to attend and present at relevant conferences. In addition, your thesis advisor will normally cover the costs of expenses related to your thesis research.

Research Areas

With the expertise of faculty members and technical staff and instrumental facilities capable of producing seminal research on the physical, chemical and biological characteristics of Earth materials, the Department of Geological Sciences is contributing to the understanding of Earth history, current and past Earth processes, and environmental change. Our research is proving to have important applications in resource extraction and mineral processing and in addressing environmental issues.

The areas can be broadly broken into: Mineralogy and Crystallography; Environmental Mineralogy and Geochemistry; Sedimentary and Quaternary Studies; Invertebrate Paleontology; Crustal and Mantle Geophysics; Applied/Environmental Geophysics; Petrology and Tectonics; Mineral Deposits; Marine and Freshwater Systems.
Mineralogy and Crystallography

The University of Manitoba is widely recognized as a world centre for both theoretical and experimental Crystallography and Mineralogy.

Frank C. Hawthorne (O.C., F.R.S.C., Distinguished Professor), Elena Sokolova, and Anton Chakhmouradian work on a wide variety of topics in structural crystallography and mineralogy in collaboration with many scientists around the world.

Frank Hawthorne has a major focus on bond topology and its relation to energetics, mineral chemistry and paragenesis. He also works extensively on the structural behaviour of oxysalt minerals in general and sulfates and borates in particular. Together with recent students, he has worked on the crystal chemistry and growth of tourmaline-group minerals in granitic pegmatites, and has a long-term focus on the crystal chemistry of the amphiboles (with colleagues in Pavia and Rome, Italy).

Elena Sokolova works extensively on Ti-silicate minerals in collaboration with colleagues at the Fersman Mineralogical Museum and IGEM (the Institute of the Geology of Ore Deposits: Petrography, Mineralogy and Geochemistry), Moscow (Russia) and in Pavia (Italy), focusing on their structure and the relation between chemical composition and structural arrangement. She also leads a project on the characterization of silicate minerals from the Kola Superdeep Borehole in Russia in collaboration with colleagues at IGEM.

Anton Chakhmouradian (below) is currently focused on rare-earth and niobium mineralization in carbonatites, and other industrially important aspects of the petrology and mineralogy of mantle-derived alkaline and carbonate rocks. This work involves field studies around the world, including the four newly discovered carbonatite occurrences in Manitoba, and is aimed at developing a detailed understanding of the processes that led to the formation of these unusual rocks and concentrations of rare metals. Anton collaborates with the Manitoba Geological Survey and various industrial partners.

All mineralogical work is supported by an extensive array of instrumentation and overseen by expert technical staff.
Environmental Mineralogy and Geochemistry

Building on work by Petr Cerný on the mineralogy and geochemistry of the TANCO pegmatite in the 1980s, this area of research has grown over the years. Norman Halden has demonstrated a strong synergic interaction between mineralogy, geochemistry and the environment. Important thrusts are emerging in non-linear dynamic processes, environmental mineralogy, microbial-mineral interactions and biomineralization. With such interactions occurring on a very small scale, microbeam analysis and crystal chemistry in these areas is paramount. With the local availability of expertise, the department’s research in mineralogy and geochemistry is cutting edge. The interdisciplinary microbeam work on otoliths (fish ears) developed by Norm Halden provoked great interest from the fish biology community because otoliths record finely resolved details of environmental change.

Mostafa Fayek (Tier II CRC Research Chair) brought another dimension to this research area and secured the addition of a Secondary Ion Mass Spectrometer. Mostafa is expanding on existing research by studying fluid-solid interactions at the atomic level and the linkages between specific isotopic signals and the mechanistic signatures and textures in environmental contaminations and nuclear waste disposal. His strong interest in geoarchaeology focuses on sourcing and dating techniques for archeological artifacts throughout the southwestern United States and Mesoamerica.

What’s in a name?
The following minerals were named for faculty members or alumni of our Department: Bobfergusonite, Burnsite, Cernyite, Ercitite, Frankhawthorneite, Gaitite, Griceite, Groaitite, Harrisonite, Markcooperite, Nuffieldite, Sabinaite, Sokolovaite, Trembathite, Wicksite

Teller Peak in Antarctica is named for Jim Teller

N. Halden - first you have to catch the fish!
Inset: SEM image of a fish otolith

Mostafa Fayek (centre) and students examine uranium tailings.
Inset: SIMS
Giants among us!

Bob Elias and Graham Young (Adjunct Professor at the U of Manitoba and Geology and Paleontology Curator with The Manitoba Museum) led a project that resulted in the discovery in northern Manitoba of the world’s largest trilobite. The fossil is on display in The Manitoba Museum and a replica may also be viewed in the Cretaceous Menagerie, Wallace Building, University of Manitoba.

Sedimentology and Quaternary Studies

Nancy Chow in the Canning Basin, Australia

Nancy Chow is interested in all aspects of the sedimentology of Paleozoic carbonate rocks in western Canada. Her research focuses on Devonian carbonate platforms in Alberta and Manitoba and has taken her as far afield as northeastern Thailand and the Canning Basin of northwestern Australia. Her work has contributed to the understanding of environmental changes and tectonic events controlling reef growth and diagenesis.

Bill Last (Senior Scholar) has conducted applied sedimentological research on the Mesozoic reservoirs and source rocks of the Williston Basin. His research on evaporate sedimentology helped define the modern and past geochemical system of lakes across a large part of western Canada.

Bill Last and Jim Teller (Professor Emeritus) are known for pioneering research on the sedimentology and paleolimnology of Quaternary lacustrine deposits in western, central, and northern Canada, and in semi-arid regions of Australia, the Middle East, South America, Africa and Asia. This research often focused on climatic and hydrologic change, and their environmental impact. Jim Teller’s outstanding research on glacial Lake Agassiz and its overflow to the oceans has been widely recognized and is used internationally to model future climate change.

Invertebrate Paleontology

Robert Elias is an internationally recognized expert on early Paleozoic corals. His research focuses on coral faunas and environmental changes during some of the most significant events in Earth history: the great Ordovician bio-diversification, the end-Ordovician mass extinction, and the Early Silurian biotic recovery. Fundamental studies on all aspects and applications of corals are being integrated with analyses of the patterns and processes involved in these events.
Crustal and Mantle Geophysics

Andrew Frederiksen’s primary focus is on the extraction of high resolution 3-dimensional Earth structure from large seismic data sets derived from earthquakes. His special interests include mantle fabric and associated seismic anisotropy, inversion of receiver functions, scattered wave imaging using teleseismic earthquakes, and tomography of the North American lithosphere. Current projects include detailed imaging of the lithosphere in the Grenville Province, and the relationship between crustal and mantle features; the large scale structure of the mantle root beneath the Superior Province and associated mantle fabric; and the on-going development of a tomographic inversion technique for scattered teleseismic waves at the sparse station arrays. Ian Ferguson is conducting large-scale studies of the crust and upper mantle in Canada and Australia. Analysis of the data resulting from his participation in the Canadian LITHOPROBE transects in the Proterozoic Trans Hudson Orogen and Archean Superior Province and the SNORCLE transect in the Northwest Territories and Yukon is on-going. Ian has also participated in the Canadian POLARIS project and electromagnetic studies in the Grenville Province of Ontario and the Slave Province of the Northwest Territories. The aim is to arrive at a better understanding of the tectonic history and structure of these regions. The information obtained on the resistivity structure of the crust and mantle is also used to refine the modeling of geomagnetic hazards such as the currents induced on power-lines during magnetic storms.

Applied and Environmental Geophysics

Ian Ferguson (at left) conducts geophysical studies of environmental, economic, and near-surface targets. Projects include defining the magnetic and electrical properties of a gold deposit in eastern Manitoba, delineating saline contamination from petroleum production, delineating kaolinite deposits and palaeokarst features, imaging of snake dens, investigating mine tailings, and mapping the radiometric and magnetic properties of an igneous intrusive complex.
Petrology and Tectonics

The Precambrian geology of Manitoba has long been a prime research interest in the Department. **Norman Halden** continues to work on the tectonic and magmatic evolution of the Superior Boundary Zone (encompassing both the Thompson Nickel Belt and the Fox River Belt) as well as layered igneous intrusions.

**Anton Chakhmouradian**’s expertise in alkaline igneous rocks is being brought to bear on the Eden Lake Complex.

**Alfredo Camacho** (at left) is using theoretical and practical geochronology to constrain cooling histories and the rates of tectonic processes. Looking at spatial and temporal relations among shearing and fluid flow in subducting zones where rapid burial advects cold material into the mantle, he seeks answers to the following: what are the characteristics and origin of the fluids; can phase transformations occur under dry conditions or is a fluid always required; what are the durations heat by fluids or shear heating; and are exhumation histories diagnostic of the burial processes. He is also interested in addressing the fundamental processes that affect isotopic ages, including geological conditions that influence the mobility of isotopes, chemical factors that control the retentivity of minerals, diffusion mechanisms, and partitioning of isotopes between minerals.

Mineral Deposits

**Mostafa Fayek, Anton Chakhmouradian, Alfredo Camacho** and others have research projects in areas relevant to mineral deposits, including studies of uranium, gold, kimberlite, rare earth, and massive sulphide deposits. **Mostafa Fayek**, for example, holds collaborative research grants with industrial partners aimed at understanding the mechanisms for uranium deposit formation in the Athabasca Basin and elsewhere.
Marine and Freshwater Systems

An evolving area of research involves marine systems in the Arctic and the hydrology of freshwater systems.

Soeren Rysgaard (below) focuses on sea ice and sediments in the Arctic. A central interest is to understand how, where, and when organic matter is produced and degraded in the Arctic marine environment. The work includes oxygen consumption pathways, the cycling of redox elements, and biogeochemical processes. It involves in situ techniques for quantifying sea ice algal primary productivity, microbial activity and biogeochemical processes. Special attention is directed to the chemical reactions in sea ice brine, including the carbonate system and minerals such as calcium carbonates.

Zou Zou Kuzyk (at right) studies the biogeochemical cycles of carbon and other elements in Arctic coastal and continental shelf areas, with an emphasis on how carbon cycling in these areas is impacted by environmental change, including changes on the land (e.g., river runoff and coastal erosion) and in the marine environment (e.g., sea ice cover and ocean currents). She uses marine sediment cores, together with a variety of geochemical tracers, including radioisotopes, stable isotopes, redox-sensitive elements and organic proxies (e.g., lignin) for much of her work. She is also interested in tracing freshwater distribution using oxygen isotopes. She has worked on projects within ArcticNet (an Arctic Network of Centres of Excellence) and the Canadian International Polar Year (IPY) program, both in the Arctic Ocean and Hudson Bay.
Genevieve Ali (at right) is focused on watershed hydrology and hydro-biogeochemistry. She seeks to understand how water, nutrients and pollutants move through watersheds. She focuses on water transport and storage mechanisms and aims to better predict how watershed systems will react in case of enhanced flooding, diffuse pollution or climate change. Presently she addresses water quality issues in Lake Winnipeg Basin by studying how water and nutrients are distributed between plants, shallow soil layers and deep aquifers in Prairie landscapes. Her research relies on a strong field component but also makes use of extensive GIS data and innovative mathematical models in order to identify priority areas for water protection.

Professors Emeriti and Senior Scholars

The retired staff members listed in this section are active in the Department in a variety of ways: supervising undergraduate theses and reports, outreach activities, and active research. They may be involved in graduate student supervision or advising (e.g., as a member of a thesis committee) but this is the exception rather than the norm.

William Last (left), Senior Scholar, Ph.D. Manitoba

Research interests: Non-marine evaporite and carbonate sedimentology; clastic sedimentology and diagenesis; petrography, sedimentology and geochemistry of Mississippian and Jurassic sediments; sedimentology, stratigraphy, geochemistry of saline lakes (W. Canada and northern U.S.) and of organic rich rocks, western Manitoba; Quaternary paleolimnology of saline lakes in Australia

Wooil Moon (right), Prof. Emeritus, Ph.D. UBC

Research interests: Satellite global geodynamics; microwave remote sensing theory and applications; satellite radar altimetry; geophysical application of synthetic aperture radar (SAR) and polarimetric SAR; geological and geophysical information fusion; GIS and spatial reasoning; global tectonics and geodynamics
Jim Teller (left), Professor Emeritus, Ph.D. Cincinnati

Research interests: Quaternary geology; paleohydrology and climatic impact of North American proglacial lakes and rivers; reconstruction and re-evaluation of shorelines and outlets in the glacial lake Agassiz basin; sedimentology and history of valley fills leading to glacial Lake Agassiz

William C. Brisbin, Prof. Emeritus, Ph.D. California

Research interests: Structural geology, Precambrian tectonic styles, gravimetry, engineering geology

George S. Clark, Sr. Scholar, Ph.D. Columbia

Research interests: Isotope geology, geochronology

Allan C. Turnock, Sr. Scholar, Ph.D. Johns Hopkins

Research interests: Mineral synthesis and stability; metamorphic petrology

Most Cited Geoscientist

Named in Thomson Scientific as “the World’s most cited Geoscientist of the Decade 1997-2006”, Frank Hawthorne has garnered many honours. Among them: Officer of the Order of Canada (2006), the Carnegie Medal (2009), the Killam Prize in Natural Sciences (2008), and the Mineralogical Society of America’s Roebling Medal (2013).
Instructors

Instructors are not available for supervising graduate programs or serving on a thesis committee. However, they teach a number of advanced level undergraduate courses that may be available to graduate students and have frequently been involved in organizing and running field trips that include graduate student participation.

Karen Ferreira (left) Instructor II, M.Sc. Manitoba
E-mail: karen.ferreira@umanitoba.ca
Research interests: Mineral exploration and technical communications

Russel Hiebert (left),
Instructor I, M.Sc. Acadia
E-mail: Russell.hiebert@umanitoba.ca
Research interests: Mineral deposits, igneous petrology, layered igneous intrusions, geochemistry

Jeff Young, (left) Senior Instructor, M.Sc. Manitoba
E-mail: jeff.young@umanitoba.ca
Research interests: Structural geology
Potential Supervisors of Graduate Students

**Mostafa Fayek**

- Applications of Secondary Ion Mass Spectrometry (SIMS)
- Fluid-solid interactions at the atomic level including the mass transport of chemicals, elements and nutrients near the Earth’s surface
- Environmental contamination and disposal of nuclear waste
- Sourcing and dating techniques of archeological artifacts
- Uranium and gold exploration

Professor and Head
Canada Research Chair
Ph.D. University of Saskatchewan
E-mail: Mostafa.fayek@umanitoba.ca

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**Genevieve Ali**

- Surface and subsurface runoff processes
- Isotope hydrology
- GIS-based conceptualization of watershed dynamics
- Hydrological modeling
- Watershed classification

Assistant Professor and Junior Chair in Watershed Systems Research
Ph.D. Université de Montréal
E-mail: genevieve.ali@umanitoba.ca

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**Alfredo Camacho**

- Heat distribution in the crust during orogenesis
- Genetic relationship between basin formation and orogenic activity
- Understanding earthquake activity in continental interiors and subduction settings
- Geochronology and diffusion rates of minerals: applying principles of diffusion to study geological processes and unravel thermal (T-t) histories of geological terranes

Associate Professor
Ph.D. Australian National University
Web-site: [http://home.cc.umanitoba.ca/~camacho/](http://home.cc.umanitoba.ca/~camacho/)
E-mail: alfredo.camacho@umanitoba.ca
Anton Chakhmouradian

- Economic REE, Nb and 3r deposits
- Igneous alkaline and carbonatitic rocks
- Magmatic and subsolidus processes in carbonatites and kimberlites
- Crystal chemistry of phosphates, titanates and titanosilicates
- Ti, Zr, Nb, and REE minerals in kimberlites, carbonatites, and alkaline igneous rocks

Professor
Ph.D. St. Petersburg State University
E-mail: Anton.chakhmouradian@umanitoba.ca

Nancy Chow

- Carbonate sedimentology
- Petroleum Geology
- Stratigraphy and sedimentology of Paleozoic carbonates in the outcrop belt and subsurface Manitoba
- Sedimentology of Devonian carbonates in the Alberta Basin and Canning Basin of Australia

Professor
Ph.D. Memorial University
Web-site: http://www.umanitoba.ca/faculties/science/geological_sciences/people/faculty/chow/chow.html
E-mail: nancy.chow@umanitoba.ca

Robert Elias

- Coral faunas and environmental change during the great Ordovician biodiversification, end-Ordovician mass extinction, and Early Silurian recovery
- Paleobiology and biometrics of Ordovician corals
- Paleoenvironmental reconstruction of Ordovician and Silurian units in Manitoba

Professor
Ph.D. University of Cincinnati
E-mail: Robert.elias@umanitoba.ca
Ian Ferguson

- Application of electromagnetic (EM) methods to investigate the Earth’s crust and upper mantle
- Application of magnetotelluric (MT) methods to define the resistivity and tectonic structure of the lithosphere in Canada, especially in Precambrian terranes
- MT surveys to aid the modeling of GICs, electric currents induced on powerlines and pipelines during geomagnetic storms
- EM and other near-surface techniques to investigate a variety of mineral, environmental and groundwater targets

Professor
Ph.D. Australian National University
E-mail: ian.ferguson@umanitoba.ca

Andrew Frederiksen

- Seismic imaging and methods
- Geophysical computation and inverse theory
- Applications of inverse theory to seismic imaging and tomography
- Lithospheric tectonics and continental roots
- Anisotropic fabric in the crust and mantle

Associate Professor
Ph.D. University of British Columbia
Web-site: [http://home.cc.umanitoba.ca/~frederik/](http://home.cc.umanitoba.ca/~frederik/)
E-mail: Andrew.frederiksen@umanitoba.ca

Norman Halden

- Geochemistry and petrology of magmatic systems
- Chemical zoning in Earth materials
- Analysis of trace element partitioning between minerals and trace element distribution within minerals
- Non-linear modeling of trace element zoning patterns
- Image analysis of mineral textures and rock fabrics
- Otolith microchemistry

Professor and Dean, C.H. Riddell Faculty of Environment, Earth, and Resources
Ph.D. University of Glasgow
Web-site: [http://home.cc.umanitoba.ca/~halden/halden.html](http://home.cc.umanitoba.ca/~halden/halden.html)
E-mail: norman.halden@umanitoba.ca
Frank Hawthorne

- Crystallography and mineralogy
- Architecture of crystal structures
- Structural crystallography, particularly the solution of crystal structures of minerals, development of hierarchical schemes of structure architecture, application of crystal-structure refinement, mineral spectroscopy and microprobe analysis to problems in crystal chemistry
- Bond topology and crystal structures

Distinguished Professor
Ph.D. McMaster University
E-mail: frank.hawthorne@umanitoba.ca

Zou Zou Kuzyk

- Impacts of environmental change on Arctic coastal and continental shelf areas
- Terrigenous organic matter in marine sediments: sources, pathways and sinks
- Sedimentation processes in Arctic coastal and shelf environments
- Diagenesis of redox-sensitive elements
- Freshwater sources and pathways in the coastal ocean
- Land-ocean interactions and the marine nutrient cycle
- Pathways and fate of contaminants in the Arctic Ocean

Assistant Professor
Ph.D. University of Manitoba
Web-site: http://umanitoba.ca/faculties/environment/departments/ceos/people/zkuzyk.html
E-mail: ZouZou.Kuzyk@umanitoba.ca

Soeren Rysgaard

- Marine microbiology and biogeochemistry
- Benthic pelagic coupling
- Carbon and nutrient cycling in Arctic waters
- Structure and function of Arctic marine ecosystems
- Sea ice processes
- Glacier-fjord-ocean interactions
- Global change

Professor and Canada Excellence Research Chair
Ph.D. University of Aarhus
Web-site: http://umanitoba.ca/faculties/environment/departments/ceos/people/srysgaard.html
E-mail: Soeren.Rysgaard@umanitoba.ca
Elena Sokolova

- Crystallography and crystal physics
- Mineralogy of alkaline rocks
- Crystal chemistry with emphasis on the silicate minerals
- Isomorphism and topology of crystal structures
- X-ray diffraction of new minerals and synthetic compounds

Professor
Ph.D. Moscow State University
D.Sc. Moscow State University
E-mail: Elena.sokolova@umanitoba.ca

Churchill River, northern Manitoba.
Photo: Graham Young, Adjunct Professor
Adjunct Professors

Adjunct professors are actively engaged in research activities, often working collaboratively with full-time faculty members. They can serve as co-supervisors of graduate students or on thesis committees.

Scott Anderson, Ph.D. Dalhousie University
Dr. Anderson is a Mineral Deposits Geologist with the Manitoba Geological Survey. His interests include structural geology, mineral deposits and Precambrian geology. His investigations with the Manitoba Geological Survey range from detailed to regional-scale projects. A recently initiated project focuses on the Au metallogeny in the Jeep property, Manitoba.

Andrey Bekker, Ph.D. Virginia Polytechnic
Dr. Bekker is an Assistant Professor at the University of California, Riverside. Andrey’s research includes: climate changes in the deep past; chemical composition of the atmosphere and ocean and the link with global tectonics; ocean redox state in the Precambrian, C, S, and Fe cycles; first appearance of marine sulfate evaporates; sedimentary mineral deposits; stable isotope geochemistry. Andrey is a former Associate Professor in Geological Sciences, University of Manitoba.

Christian Böhm, Ph.D. ETH Zurich
Dr. Böhm is Chief Geologist, Precambrian Mapping Section, Manitoba Geological Survey. His expertise is in the field of Precambrian geology, isotope geology, geochronology, and their applications in geological studies. He has also been involved with diamond and uranium support in his position with the Manitoba Geological Survey. His career has spanned work in industry, government and academia.

William Buhay Ph.D. University of Waterloo
Currently an Associate Professor in the Department of Geography at the University of Winnipeg, Dr. Buhay’s expertise is in the fields of Quaternary geology, hydrology, and isotope geology. His work on the use of stable isotopes as environmental indicators, on climate change, and on geoarcheology overlaps the research interests of W. Last, N. Halden, M. Fayek, J. Teller, Z.Z. Kuzyk and A. Becker. In addition, new opportunities will exist for collaboration with Genevieve Ali in Watershed Systems Research.

James Craven, M.Sc. University of Toronto
Jim Craven is a Physical Scientist with Natural Resources Canada (Geological Survey of Canada) with extensive experience in the application of MT in a number of geological settings in Canada covering project direction, and electromagnetic data acquisition, analysis, and interpretation. His electromagnetic work has included innovations like the application of 3-D MT surveys in exploration. One of his more recent projects involves seismic interferometry at Snow Lake, Manitoba.
Ryan (R.J.) Galley, Ph.D. University of Manitoba

Dr. Galley studies the physical properties and processes that occur in Arctic sea ice and snow, with the view to their role in modifying the exchange of climatically active gases between the ocean and atmosphere in polar oceans. In particular, his research program focuses on methodological development for the purpose of improving the characterization of sea ice crystallography, as well as the morphology and change in the liquid and gaseous inclusions in sea ice. The evolution of brine in sea ice and snow, both in time and space, in the context of the physical controls on its presence and movement is of critical interest. This work is completed in laboratory microcosms, at the University of Manitoba’s Sea ice Experimental Research Facility (SERF) and in the Arctic of Canada and Greenland under the auspices of the Arctic Science Partnership (asp-net.org). He is a Network Investigator in ArcticNet (phase IV, 2015-2018) and holds an NSERC Discovery Grant (2015-2020).

Michel Houlé, Ph.D. University of Ottawa

Dr. Houlé is a research geoscientist with the Geological Survey of Canada. He specializes in the petrology, volcanology, and geochemistry of mafic to ultramafic igneous rocks and in economic geology. His particular areas of expertise are magmatic sulphide deposits (komatiite-associated Ni-Cu-PGE deposits and Cr-PGE layered intrusions). Prior to joining the Geological Survey of Canada, he was a senior geoscientist with the Ontario Geological Survey/Ministry of Northern Development and Mines.

Vince Palace, Ph.D. University of Manitoba

Dr. Palace is currently a research scientist with Stantec Consulting (formerly with the Department of Fisheries and Oceans, Government of Canada). His research has advanced the knowledge of factors affecting the productivity and health of fish and fish habitat, with emphasis on the biochemistry, histology, and physiology measures of fish health and the impact of environmental contaminants. He is collaborating with Norman Halden, analyzing Cu, Pb, Zn, Se, and Hg distributions in fish otoliths.

James Reist, Ph.D. University of Toronto

Dr. Reist is a Research Scientist with the Department of Fisheries and Oceans, Government of Canada. He has collaborated with Norman Halden on the analysis of Arctic Char otolith microchemistry for about fifteen years. His research focuses on anthropogenic impacts (e.g., climate change, industrialization) on Arctic fishes and their habitats and ecosystems. He has managed and provided direction for major projects like IPY Canada Arctic Char and climate change, Species at Risk, and Sensitive Freshwater Fishes.

Christopher Spence, Ph.D. McMaster University

Dr. Spence is a Research Scientist with Environment Canada, National Hydrology Research Centre, in Saskatchewan. His expertise is in the hydrology and hydrometeorology of Canada’s cold regions, especially the subarctic Canadian Shield, as well as hydrological processes in the Prairie Pothole region of Saskatchewan. He has also conducted research in the Experimental Lakes area of northern Ontario on the manipulation of headwater hydrology.

Bradley Van Gosen, M.Sc., Colorado School of Mines

Brad Van Gosen, a Research Geologist with the U.S. Geological Survey (Denver), has made significant contributions to USGS programs such as critical metal deposits, minerals and health, and nuclear resources, and he has an extensive publications record. His expertise is sought internationally. He is currently serving as the U.S. delegate for the International Atomic Energy Commission and is the Vice-Chair for the United Nations Economic Commission Expert Group on Resource Classification.
Graham Young, Ph.D. University of New Brunswick

Dr. Young is the Curator of Geology and Paleontology at The Manitoba Museum and is actively involved in the department as a co-supervisor of graduate theses and as a contributor to and collaborator in research. His research interests involve: invertebrate paleontology, systematic, biogeography and paleoecology of fossil corals and associated organisms, modeling of colony growth.

Research Facilities

The Department is uniquely equipped with analytical facilities that support the research of faculty members and graduate students. Access to these facilities is coordinated through the student’s thesis advisor.

Ar-Ar Laboratory

- ARGUS VI gas mass spectrometer with five faraday cups and one electron multiplier
- Noble gas preparation system for purification of complex gas mixtures
- Analyte.193 ultra short pulse excimer laser ablation system
- CO₂ laser system for total fusion analysis
- Ultra-high vacuum sample cell for geochronology

Secondary Ion Mass Spectrometer (SIMS)

- CAMECA MS 7f SIMS for trace element determination, isotopic measurements and depth profiles
- Resistive Anode Encoder (RAE) for elemental mapping
- Capabilities:
  o Qualitative analyses on selected material based on the availability of standards
  o Stable isotopes H, C, O, S, Cu
  o U-Th-Pb geochronology-U minerals
  o Depth profiling
  o Ion imaging
  o Archeology, provenance studies, hydration dating

Kevin Jones, MSc student, in the SIMS Lab

Ryan Sharpe, Manager, SIMS Lab
The Microbeam Facility in Geological Sciences is set up as a regional facility to serve the needs of universities, industry and government institutions with an electron microprobe and LAM-HR-ICP-mass spectrometer, and a scanning electron microscope and image analysis system, and includes the following equipment:

- CAMECA SX100 electron microprobe with PGT EDS and 5WDS spectrometers equipped with windows based operating system
- Thermo-Finnigan Element 2 HR-ICP-MS with New Wave UP213 nanosecond and Quantronix Integra-C femtosecond laser ablation systems.
- Cambridge Stereoscan 120 Scanning Electron Microscope with back scattered electron detector, energy dispersive X-ray detector, and digital image store facility
- Relion cathodoluminescence imaging system
- Fluid inclusion stage

Spectroscopy Laboratories

- Jobin-Yvon Horiba LabRam Aramis Raman microspectrometer: This instrument utilizes inelastic scattering of monochromatic light to obtain structural information about solid, liquid and gaseous materials. Its versatile design allows for a wide range of samples to be analyzed, including minerals, gemstones, glasses, fluid inclusions, archeological artifacts, solutions, and tissue samples. The microspectrometer is fully confocal, equipped with three lasers and a motorized stage, and is capable of measuring Raman spectra with a spectral resolution better than 1 cm⁻¹ at a lateral spatial resolution better than 1 micron. The instrument is used routinely in geological research for material fingerprinting (rapid identification), quantitative characterization of minerals containing Raman-active molecular species, and inclusion studies.
- Bruker Tensor 27 FTIR with Hyperion 2000 IR Microscope including IR polarizers, horizontal ATR attachment, low-pressure diamond anvil cell for single-xtl IR and a Spex X-Press 35 ton hydraulic pellet press
X-Ray Diffraction Laboratories

- Bruker Apex II Ultra TXS single-crystal diffractometer with a 6kW rotating anode (Mo) x-ray generator, HELIOS Mo x-ray optics, SMART APEX II CCD area detector, low pressure diamond anvil cell and both high- and low-temperature attachments
- Bruker P4 four-circle single crystal diffractometer on a 3kW sealed-tube (Mo) x-ray generator with SMART APEX CCD area detector
- Bruker D8 Discover TXS micro-powder diffractometer with a 6kW rotating anode (Cu) X-Ray generator, extremely fine beam collimation optics, an X-Y-Z sample stage with attached phi-rotation stage, laser/video sample alignment and a Hi-Star 2D area detector
- Siemens/Bruker D5000 powder diffractometer with rotating sample holder, graphite monochromator, scintillation detector and a 3kW sealed-tube (Cu) x-ray generator
- A broad assortment of crystallographic and mineralogical software (eg. MDI JADE+, SHELXTL, ATOMS, SHAPE, MIN-IDENT, etc.) as well as licensed databases (eg. ICDD PDF-4, ICSD, etc.) and including molecular mechanics and molecular dynamics software
- Single-crystal optics setup consisting of a Nikon E-600 POL polarizing microscope with photo capability, assorted bandpass filters, Supper spindle stage and Cargill refractive index oils ranging from 1.400 – 1.800
- Full sample preparation facilities including Nikon binocular microscopes, Leitz optical microscope, precision balances, Buehler Isomet Low speed saw, Buehler Isomet 1000 Precision saw, Buehler MetaServ 2000 Grinder/polisher, Buehler HandiMet II Roll grinder, Mitutoyo precision thickness measuring device, etc.

Invertebrate Paleontology Laboratory

- Stereoscopic and petrographic microscopes
- Cameras and accessories for photomicrography and macrophotography
- Computers, scanners, printers
- Sample preparation room with saws, grinders, and a thin section machine.

Sedimentological, Petroleum Geology, and Quaternary Studies Laboratories

- Automated size analyzers (Sedigraph and Galai PSA Laser 2010)
- RoTap sieve shaker, Soil-Test sieve shaker
- Drying ovens, muffle furnaces
- Nikon epi-fluorescence microscope
- Mettler analytical balances
- Fisher Accumet pH-Eh meters
- Carbonate analyzer, centrifuges, water chemistry field analytical kits, conductivity meters, specific ion electrodes
- Galai Image Analysis system (IAS) with colour and monochrome monitors, video camera, digitizing tablet, and statistical and GIS software
Watershed Research Facilities and Equipment

- Field work facilities and equipment: weather stations, river flow recording instrument, groundwater fluctuation recording instruments, automatic water samplers.
- Wet chemistry lab for water quality analysis

Geochemistry Laboratory

- Wet chemical laboratory fully equipped for sediment, rock and mineral analyses
- Mitsubishi CA-06 moisture meter with a VA-21 high temperature furnace
- Leco induction furnace sulphur analyzer
- Accumet 950 specific ion analyzer

Stable Isotope Mass Spectrometry Facilities

- Thermo Finnigan Delta V Plus IRMS coupled to GasBench II (with PAL system and heating block), Costech ECS 4010 EA (with Zero-Blank autosampler: mainly for C and N analysis) and Thermo Finnigan TC/EA (with Zero-Blank autosampler)
- Thermo Finnigan Delta V Plus IRMS coupled to Costech ECS 4010 EA
- Thermo Finnigan ConFlo III and Conflo IV open-split interfaces
- Sartorius CP2P microbalance
- New Wave Micromill Sampling System
- Sample preparation facilities including water saws, grinders, polishers, pulverizers, furnaces, ovens, and pipettes
- Extensive rock collection of Precambrian carbonates, black shales, and iron formations

Geophysical Laboratories

- Larger-scale research geophysical instrumentation includes a 7-instrument broad-band portable seismograph facility, a 3-component down-hole seismic system, and a Geonics PROTEM47 time-domain EM system
- Smaller-scale equipment including Geonics EM31 and EM34 instruments, Bison DC-resistivity system, Scintrex magnetometer-VLF system, Scintrex magnetic susceptibility meter, Exploranium gamma-ray spectrometer, Worden gravimeter, and Bison hammer seismograph
- Computing facilities including GEOTOOLS and WinGLink magnetotelluric software, VISTA 2D seismic processing software, earthquake data processing software, and a high resolution colour graphics imaging system supporting satellite and multispectral geophysical imaging
- Seismograph station with 3-component long-period and 3-component short-period seismometers, amplifier system, and helicorder display

The University of Manitoba is a founding member of the Canadian POLARIS university-government-industry consortium which has geophysical equipment including satellite telemetred broad-band seismographs, broad-band magnetotelluric, and long-period magnetotelluric instruments.
Departmental Field Station and Museums

Star Lake Field Station

The Geological Sciences Star Lake Field Station is approximately 170 km southeast of Winnipeg in the Precambrian Shield. The facility:

- is the base for undergraduate Geology and Geophysics field courses.
- has kitchen facilities, classroom buildings, bunkhouses.
- is available as a base for research projects via a graduate student’s faculty advisor.

Ed Leith Cretaceous Menagerie

Opened in 2003, the Menagerie is a spectacular gathering place for students and visitors to the Wallace Building. Located in the main foyer of the building, the Menagerie contains four spectacular skeletal replicas of gigantic creatures of the Cretaceous Period as well as several interpretative panels. The gallery is dedicated to Ed Leith who taught in the Department from 1935 to 1971 and who continued to contribute to outreach, archival collections, and paleontological research during his long tenure as an Emeritus Professor.
Robert B. Ferguson Museum of Mineralogy

The museum contains more than 7500 mineral samples donated to or purchased by the Department of Geological Sciences over the last hundred years. A large number of the specimens are exhibited in cabinets in the Cretaceous Menagerie with the remaining samples displayed in cabinets lining the corridor of the main floor of the Wallace Building. The facility is named for Professor Emeritus Robert Ferguson who was instrumental in establishing the museum and who led the mineralogical and crystallographic research in the Department through three decades of rapid growth to its present level of international excellence.

Below: Some recent donations to the Mineralogy Museum (From left: Cuprite, Mesolite, Beryl)

Program Requirements

M.Sc. Program
- Minimum of 4 courses (12 credit hours) of which at least 2 courses (6 credit hours) must be at the graduate (7000-) level
- Completion of GEOL 7760 Seminar in the Geological Sciences (3 credit hours)
- Completion of an acceptable research project and thesis
- Projected time to completion based on full-time study: 2 years

Ph.D. Program
- Minimum of 4 courses (12 credit hours) beyond the M.Sc.
- Completion of GEOL 7760 Seminar in the Geological Sciences (3 credit hours)
- Completion of an acceptable research program and thesis
- Successful completion of the Candidacy Examination
- Projected time to completion (based on full-time study): 4 years
Program Fees and Useful Links

Fee information:
Registrar’s Office: http://umanitoba.ca/student/records/fees/988.htm

Note that international students pay a differential fee of 100% calculated on the total tuition fee. The Faculty of Graduate studies has International Graduate Student Entrance Scholarships (for students coming into the first year of graduate studies), as well as Graduate Student Scholarships (for returning Ph.D. students who are proceeding to their second year). These scholarships effectively eliminate the fee differential for qualified students.
Information on these scholarships and minimum academic background to be eligible: http://umanitoba.ca/faculties/graduate_studies/funding/international.html

Health and Dental Plan:
Students who are not covered by an external plan, must enroll in the UMSU Health and Dental Plan: http://umanitoba.ca/student/bannatyne/umsu-health-dental.html

Relocating to Winnipeg:
International Centre for Students, University of Manitoba: http://umanitoba.ca/faculties/graduate_studies/admissions/international.html

Housing and Student Life: http://www.umanitoba.ca/student/housing/

Living in Winnipeg: http://www.tourismwinnipeg.com/things-to-do

UM Graduate Students Association: http://www.umgsa.org/
Thinking of Applying to our Graduate Program?

The most up-to-date information on requirements for admission and on application procedures is available from the Faculty of Graduate Studies web-pages: [http://umanitoba.ca/faculties/graduate_studies/](http://umanitoba.ca/faculties/graduate_studies/)

**Minimum Academic Background**

**M.Sc. Program**
Generally, you should hold a four-year Bachelor of Science in geology or geophysics or a closely related field. Students with honours degrees in related disciplines (such as Geography, Soil Science, Biology, Chemistry, Environmental Science, Physics, Mathematics, Engineering Physics, and Geological, Civil and Electrical Engineering) may be accepted by the Graduate Admissions Committee providing their planned degree program involves studies in the geological sciences. The majority of the required courses taken by the student should normally be from the Department of Geological Sciences. The research should also be in the geological sciences.

Minimum grade requirements are noted in the Faculty of Graduate Studies web-pages under “Admission Information”.

**Ph.D. Program**
Successful completion of an approved M.Sc. program in a related discipline. In certain circumstances, students registered in a M.Sc. program may be allowed to transfer to a Ph.D. program without completing the M.Sc. degree. Minimum grade requirements are noted in the Faculty of Graduate Studies web-pages under “Admission Information”.

**IMPORTANT:** When applying to a graduate program, keep in mind that a position must be available in a research project and the prospective faculty supervisor must have funding to support the student and the research. There are often a number of highly qualified applicants wanting to work with a particular supervisor or in a particular area of research. Therefore, the application process is competitive and meeting minimum standards for admission does not guarantee a successful application.

Students who have contacted a prospective supervisor and who have received an encouraging response increase their chances of a successful application. Ensure that your inquiries are clear and well-written, that you have demonstrated a knowledge of the supervisor’s research, and that you include salient points (e.g. academic qualifications, relevant work experience and publications). If a particular supervisor has been recommended to you by a faculty member at another institution, mention this early in the e-mail. Keep in mind that we receive hundreds of inquiries annually. If, after several attempts, you do not receive a response, it is a good indication that the prospective supervisor is not interested in accepting another graduate student at this time.
Application Process and Required Documentation (ALL Applicants)

Apply on-line to the Faculty of Graduate Studies, using the UM GradConnect system:
http://umanitoba.ca/faculties/graduate_studies/admissions/index.html

Documentation requirements are noted here:
http://umanitoba.ca/faculties/graduate_studies/admissions/required_docs.html

Your application will be reviewed by the Department of Geological Sciences Graduate Admissions Committee as soon as the following are received:

- A completed application form and remittance of the application fee.
- Three (3) Letters of Reference are required by the Department of Geological Sciences. Your referees may load the letters directly to the GradConnect system.
- Unofficial transcripts (uploaded by the applicant) are sufficient for the review process. However, all students accepted to the graduate program will be required to submit official transcripts from all colleges and/or universities previously attended, prior to registration in the graduate program. Specific instructions on what constitutes an “official” transcript may be viewed on the web-site noted above. If the document is in a language other than English, the applicant must arrange for official translations.
- A short summary of research interests (approx. 500 words) is required of applicants to Geological Sciences.
- A brief statement to indicate that you have a major external grant or scholarship support, OR, that you require departmental financial assistance.

Additional Documentation Specific to International Applicants

- If your first language is not English, proficiency in English must be demonstrated prior to admission. Applicants must present an acceptable English language proficiency test score, e.g. TOEFL, CanTEST. Further information is available from the Faculty of Graduate Studies web-page: http://umanitoba.ca/faculties/graduate_studies/admissions/139.html

- The Department of Geological Sciences requires submission of a Graduate Record Examination (GRE) General score. Graduates of U.S. institutions are exempt. Further information on the GRE: http://www.ets.org/gre/
  NOTE: If you cannot arrange to sit for the GRE prior to an application deadline, the Department will conduct a review of your file based on instructions for “ALL Applicants” on the previous page and an acceptable English language proficiency test score (if applicable). If your file is reviewed favorably, you may be contacted to advise you that a GRE score is required prior to a final recommendation to accept or reject.
FAQ’s and problems with on-line application:
http://umanitoba.ca/faculties/graduate_studies/admissions/admissions_faq.html

Still searching for an answer?

If you’ve “done your homework” and still have a question:

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